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"Prevention and risk analysis, work organization, system engineering, health protection"

ORAL PRESENTATION

Knowledge evaluation test as a tool for the accident prevention in livestock housing

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Abstract

Several investigations on the accident causes in animal housing have revealed that the risk reduction is strongly related not only to the objective conditions of the operational means (buildings, machines and plants) but even more to the subjective modes adopted in using such means by workers. To face this problem an interactive tool for training has been realized, capable of producing a personalized evaluation of the farm operators about the level of knowledge on accident prevention, with specific reference to the working procedures.

Such a tool has been promoted by the INAIL (Italian Institute for Workers Accident Insurance) that granted the realization and diffusion of a CD-ROM aimed at promoting the knowledge of the proper accident-preventive procedures among the subjects operating with various roles in animal farms.

The main and innovative part of this product is consisting of an automated evaluation test based on various lists of questions, with multiple fixed answers among which the user has to choose those (not necessarily just one) that he considers correct. At the end a score is given determining a level of sufficiency (or not) with respect to a predetermined minimum standard and the wrong answers are put into evidence.

Keywords: livestock housing, safety, knowledge, evaluation test.

Introduction

Though the number of work accidents in agriculture is decreasing in Italy year by year the rate per worker is still increasing due to the continuous decrease of the working people. In particular the number of the heavier injuries is decreasing slower than the total.

A survey on the cases occurred in the nineties revealed that the incidence of the activities connected to the animal breeding is about 25% of the total of the accidents in agriculture.

A research carried out in the northern regions (Brugnoli, 2000) showed that the main "risk factors" are: the geographic altitude, the rate of mechanization, the type of production, the age of the workers, the incidence of family farms and of animal breeding. On the contrary, one of the main "protection factors" is the professional knowledge of the workers. Which includes, obviously, the knowledge about the safe working procedures.

Various surveys carried out by ourselves in animal farms have revealed that the possibility of reducing the risk of accidents is depending not only on the "objective" farming conditions (building, plant, machines) but even more on the way the workers do in practice their job.

Whilst the first aspect can be easily ascertained by experts following specific check lists, the second aspect can be only evaluated by examining the working procedures in a direct relationship with the workers. Furthermore when the satisfaction of the objective inadequacies of the operational means can be easily verified with on farm inspections, the improvement in the knowledge or care of workers about safety needs a specific and interactive instrument.

The relevance of an action aimed at evaluating the lack of practical advice and promoting the awareness about safety among workers in a direct individual relationship has become more and more evident in recent years. In particular various interactive training procedures to be executed in automatic way by means of dedicated software have been produced in various countries (Federal Government of Manitoba, Canada; University of Minnesota USA; Unionsafe by the Australian Ministry of Work; Michigan State University (USA)).

For these considerations we turned our attention to create means aimed at implementing the knowledge of people employed in animal housing (cattle, pig and poultry breeding) about the safe working procedures. To this purpose we deemed it useful to create a training interactive procedure capable of automatically measuring the degree of knowledge of the farm operators and favouring the fulfilment of the lacks individually ascertained.

This lead us to ask the INAIL (National Institute for Insurance of Work Accidents) to support the realization of a CD ROM containing an educational system for the evaluation and improvement of the workers attitude towards the proper working procedures in animal housing.

Material and Methods

The main and most innovative part of the CD ROM consists of an evaluation test, being carried out in autonomous or guided way, based on various lists of questions, with multiple fixed answers, among which the user has to choose those (not necessarily just one) that he considers correct. The test is arranged in four different versions addressed to the different farm operators involved in safety (Workers, Workers Representatives, Employers,

Figure 1. The opening page of the CD ROM

Agents of the protection and prevention service) and is organized in blocks according to three thematic sections: machines, buildings and plants, farm organization.

At the end a score is given and a judgement of sufficiency (or not) with respect to a predetermined minimum standard is pointed out.

Figure 1 shows the various options that can be chosen by the users at the introduction of the CD with the respective contents.

Figure 2 shows the different versions of the self evaluation test to be selected in order to accomplish it.

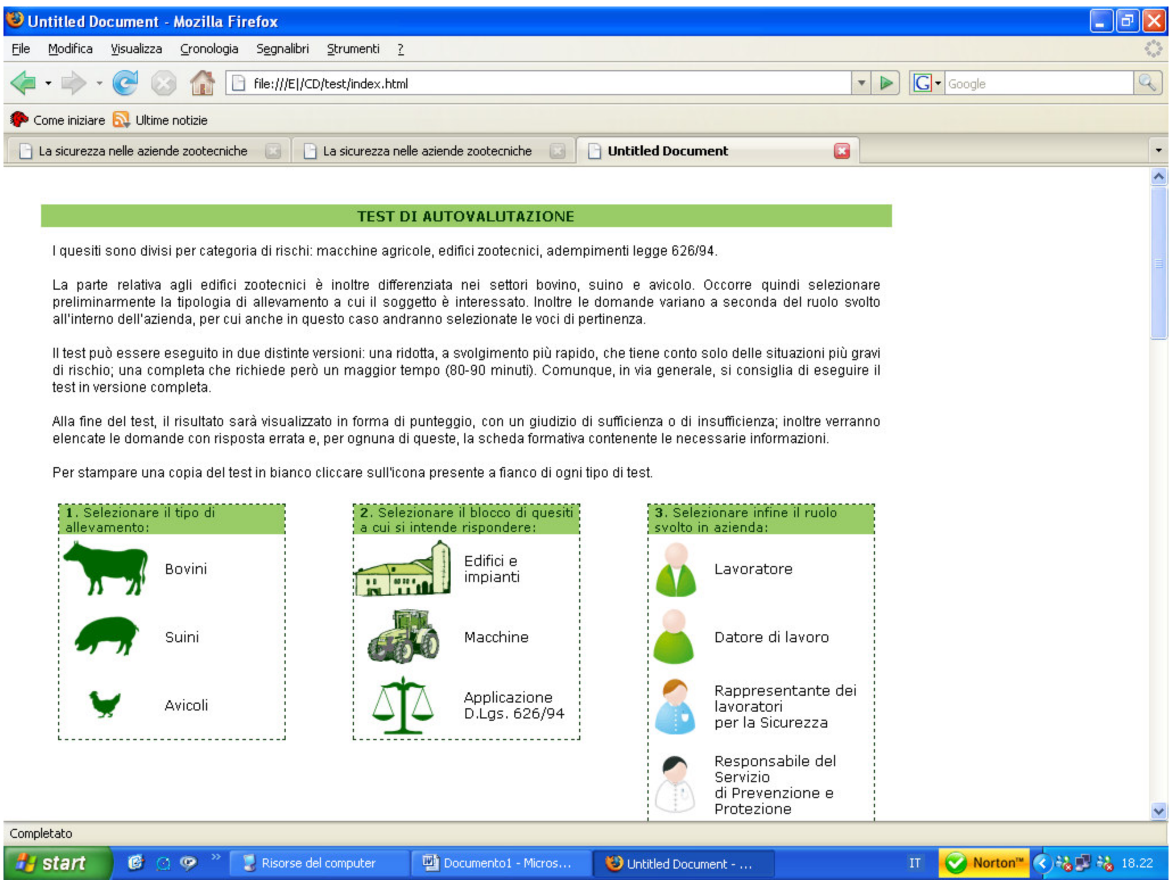

Figure 2. The various alternative blocks of test questions

The calculation of the final score of the test (per block) and the determination on the level of knowledge (sufficient or not) is quite a complex process (see an example in Fig. 3).

Every question has assigned a level of gravity (1, 2, 3) and presents more possible answers some of which are right when selected and some when not selected. Every answer has a specific score based on its relevance which is standardized in order that the answer "don't know" has a score of 1; then a score is obtained by multiplying the standardized score by the gravity assigned to the respective question.

The fulfilment of the test for each block of questions is measured by subtracting from the sum of the scores of all the answers the scores of the wrong ones (i.e. those not selected if they should have or vice versa). The result, expressed in percent, is considered satisfying if at least the 70% of the maximum theoretical score is achieved.

Furthermore the wrong answers are put into evidence and a specific training form is addressed where the user can read useful information about that subject filling his lacunae. Afterwards he can repeat the test obtaining a new score; or else simply have a look to the right answers.

The test can be performed in two ways: a simpler and faster version, comprising only the more relevant aspects, and a longer and more complete one (requiring about 80-90 min.).

The test can also be printed in a paper version to be used in a traditional way.

The CD ROM contains, in addition to the test and the respective training forms, a check list for inspections of farm inadequacies.

N°	Severity	QUESTION	Score of the selected questions	Score of the not selected questions	Standardized Score (P.S)	Total Score P.S * Severity'
1	*3*	**Before every intervention on moving components of the machine which action should be done?**				
		☑ **stop the engine of the tractor**	▪	2	0,80	2,40
		☑ **extract the key from the dashboard**	▪	1	0,40	1,20
		☑ **insert the brake**	▪	2	0,80	2,40
		❑ **lubrication of the components to be operated**	3		1,20	3,60
		❑ **don't know**	2,5		1,00	3,00
2	*2*	**When driving in a public street is it allowed to pull an equipment by linking the lower arms of the three point linkage and the drawbar? ?**				
		❑ **yes**	2		2,00	4,00
		☑ **not**	0		0,00	0,00
		❑ **don't know**	1		1,00	2,00
3	*1*	**If the stamping that you can read on a drawbar eye is 14tV2, what means the number 14?**				
		☑ **the maximum pulling force(tons)**	0		0,00	0,00
		❑ **the maximum vertical load (tons)**	2		2,00	2,00
		❑ **dont'know**	1		1,00	1,00
		If the stamping that you can read on a drawbar eye is 14tV2, what means the number 2 ?				
		❑ **the maximum pulling force (tons)**	2		2,00	2,00
		☑ **the maximum vertical load (tons)**	0		0,00	0,00
		❑ **dont'know**	1		1,00	1,00
4	*2*	**Driving in a public road with the pneumatics filled of water is it allowed ?**				
		❑ **yes**	2		2,00	4,00
		☑ **not**	0		0,00	0,00
		❑ **yes in some cases (when indicated in the circulation certificate)**	2		2,00	4,00
		❑ **dont'know**	1		1,00	2,00

Figure 3. The evaluation scores of the test questions

This product has been distributed to about one thousand institutions concerned with work safety in agriculture all over Italy.

A website was also set up to allow the download of the test, the exchange of information and the acquisition of updating.

Conclusion

A final balance of this experience is far to be accomplished. Certainly this initiative found some interest among the farm advisors as it could be deduced by the requests of CD copies. However the use of the website as an instrument of continuous feedback for acquisition of results and check of the test feasibility and appreciation was much below the expectation. Probably more education and practice with computerized procedures should be still promoted among farm operators to achieve the maximum potential of computer and Internet opportunities.

Acknowledgement

Thanks to the INAIL (Italian Institute for Workers Accident Insurance) for funding the realization and the diffusion of the CD-ROM.

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User-centric information modeling

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Abstract

Agriculture and farmers faces a great challenge in effectively manage information both internally and externally in order to improve the economic and operational efficiency of operations, reduce environmental impact and comply with various documentation requirements. In order to meet this challenge, the flow of information between decision processes must be analysed and modelled as a prerequisite for the subsequent design, construction and implementation of situated information systems.

This paper presents an attempt to use system engineering principles for the identification of decision processes and information flows within specific agricultural domains as a framework and guidance for the design of the physical information system.. The information flow configuration is centred around the farmer as the principal decision maker.

The new information management concepts and designs mean that farmers have to be ready to adopt new working habits and perhaps also undergo further training. Farmers can utilise different services more efficiently and they are able to outsource some of the tasks they had previously performed themselves. Farmers have better knowledge of their production processes and are able to evaluate the performance of the chosen technology. This should lead to better process control in farms. Farmers can also utilise the collected farm data to show the quality of farming *e.g.* traceability, to markets and administration. The system concept also allows the farmers to access and utilise better scientific research and technological developments by providing fresh real process data and the ability to update the systems according to the latest knowledge.

Keywords: system analysis, decision processes, information flows.

Introduction

Agriculture and farmers faces a great challenge in effectively manage information both internally and externally in order to improve the economic and operational efficiency of operations, reduce environmental impact and comply with various documentation requirements. In order to meet this challenge, the flow of information between decision processes must be analysed and modelled as a prerequisite for the subsequent design, construction and implementation of situated information systems.

The required information modelling can be fulfilled through concentrated efforts aimed at extracting domain knowledge and deriving information flows at various planning and process levels. This effort demand considerable research and development and that is specifically the case in terms of incorporating user preferences and requirements. The tendency to use a more user-centric approach in developing new technologies has gained considerable appeal (e.g. Akao & Mazur, 2003; Norros *et al.,* 2004). The development and design of innovative technologies, like dedicated information systems, has often lacked user acceptance when users or stakeholders are not sufficiently involved in the requirements elicitation and engineering (Kujala *et al.*, 2005). A user-centric approach assumes that the users' ideas and requirements reactions concerning the specific characteristics of the designed technology are integrated in the subsequent design.

This paper presents an attempt to use system engineering principles for the identification of decision processes and information flows within specific agricultural domains as a framework and guidance for the design of the physical information system. The information flow configuration is centred around the farmer as the principal decision maker indicating that the information flow is primarily seen in the view of the farmer and in terms of how he/she uses and produces information. Specifically, interface requirements and demands on time critical availability and amount of information are important aspects to be considered. The essential task of the information system is to be able to capture the Core-Task of the farming operation by developing a precise understanding of how the farmer experience the Core-Task and associated decision processes (Nurkka *et al.* 2007). The orientation of the farmer (concept of work) and the way of working (how the work is carried out) are important elements to include in the information model.

Information management in farming

Farming in general, which comprises many different production processes, can be compared with management of any process. The management duties include controlling and monitoring the farming process, collecting and analysing statistics on the process and using the collected information in decision-making and strategic planning. Challenges in management increase as the farmer needs to confront changes for which his experience provides limited guidance. These challenges include the introduction of new farming techniques, since the main aims of agricultural production to date are not only profitability in terms of economic efficiency, but also the maintenance of a healthy environment.

The focus of agricultural production is changing from quantity to quality and sustainability (Jensen *et al*., 2000). Precision Agriculture (PA) aims to achieve these goals. By generic definition, PA refers to agricultural techniques that increase the number of (correct) decisions per unit area of land per unit of time, with associated net benefits (McBratney *et al*., 2005). When practising PA, a farmer manages crop production inputs (seed, fertiliser, lime, pesticides, *etc*.) on a site-specific basis to increase profits and crop quality, but also to reduce waste and maintain environmental quality. In order to make precise decisions in different phases of the farming process, he/she therefore needs to analyse information from different vast and sporadically located information sources. Management of the information and decision-making is the core issue for the farmer in successful PA, not the data acquisition process. A range of Decision Support Systems (DSS) and Farm Management Information Systems (FMIS) are available to farmers, but the adoption of those systems and of PA has been disappointingly low (Rosskopf *et al*., 2003; McBratney *et al*., 2005; Parker, 2005). DSS and FMIS tools have a number of applications in farming, the most important being to support strategic and operational decisions and to enable better identification and shared analysis of problems (Loevinsohn *et al*., 2002) by permitting access to and manipulation of information.

In order to analyse the information flow on high-tech farms, both science-based and practice-based modelling of the core-task is needed in order to extract the requirements for facilitated decision-making. The human-centred design process aims to design a new information management concept that supports the farmer's core task. It is divided into two parts; research and design. The research part handles the problem at a general level, focusing on the core task of farming, the farmer's orientation to his/her work. The core task and associated information management are defined on both a scientific and practical basis. The science-based core-task model postulates the core task according to scientific and physical facts as a matrix where successive work processes form one dimension and the move from general to specific the other dimension. The practice-based core task is modelled after the farmer's understanding of his/her work.

The integrated information modelling phase changes the focus from general to specific, in this case from information management in farm production processes to information management in field task operations. In this phase results and demands from the research part are taken into account, data flow models of field task operations are created, available relevant technology for design is inventoried and specifications for a novel system concept are defined.

Integrated information modelling approach

In this phase, scientific information and practical information and experience are gathered together, and new ideas and technologies are brought in as material for a creative designing process. The work starts by defining a functional description of the needed system. Then, inventory of available technologies is made. Finally, specifications for a new concept for information management system in automated plant production are defined.

A detailed structuring and formalisation of physical entities and the information, which surrounds the planning and control of efficient mobile working units is a decisive prerequisite for the development of comprehensive and effective ICT-system for task management on the farm. The basic idea is to model all the activities and decisions, which take place in a targeted production section and combine this modelling with all the relevant data. The formal description includes **entity definition** (*in this case mobile work units*), a **process model** (*activities and decision processes*) and a **data model** (*data relating to the processes*). The defined processes in the process model and the entities and attributes in the data model provide the basis for developing compatible information systems – see Figure 1.

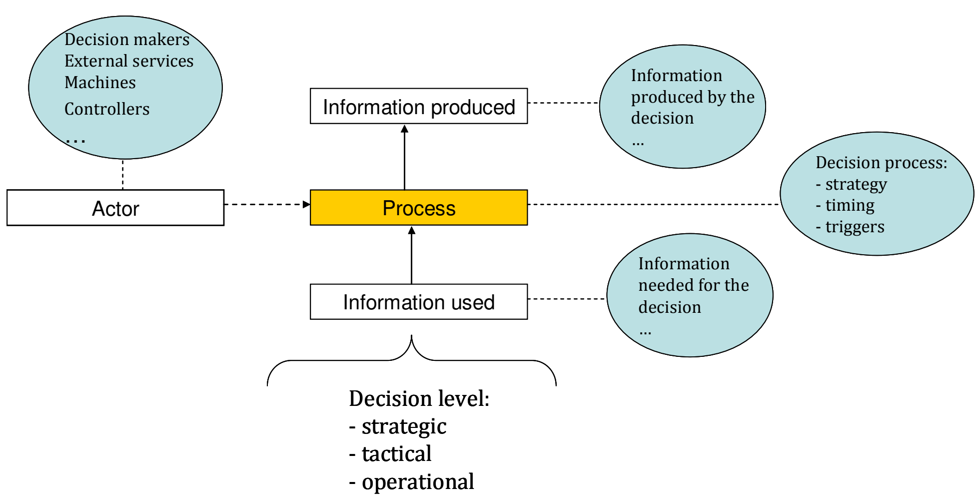

Figure 1. Employed information modelling approach

Information modelling of the core task of field work

In a new situation where a novel information management system concept is utilised, the description of the core task will change. As part of modelling the novel system concept, the information flow model for the case of fertilisation was run according to the new system concept and design. Figure 2 shows the scope of the information modelling the fertiliser case in terms of identified actors to be included in the system. These actors include external entities outside the farm, the farmer as the prime decision maker and the mobile unit entities involving in actual carrying out the planned tasks.

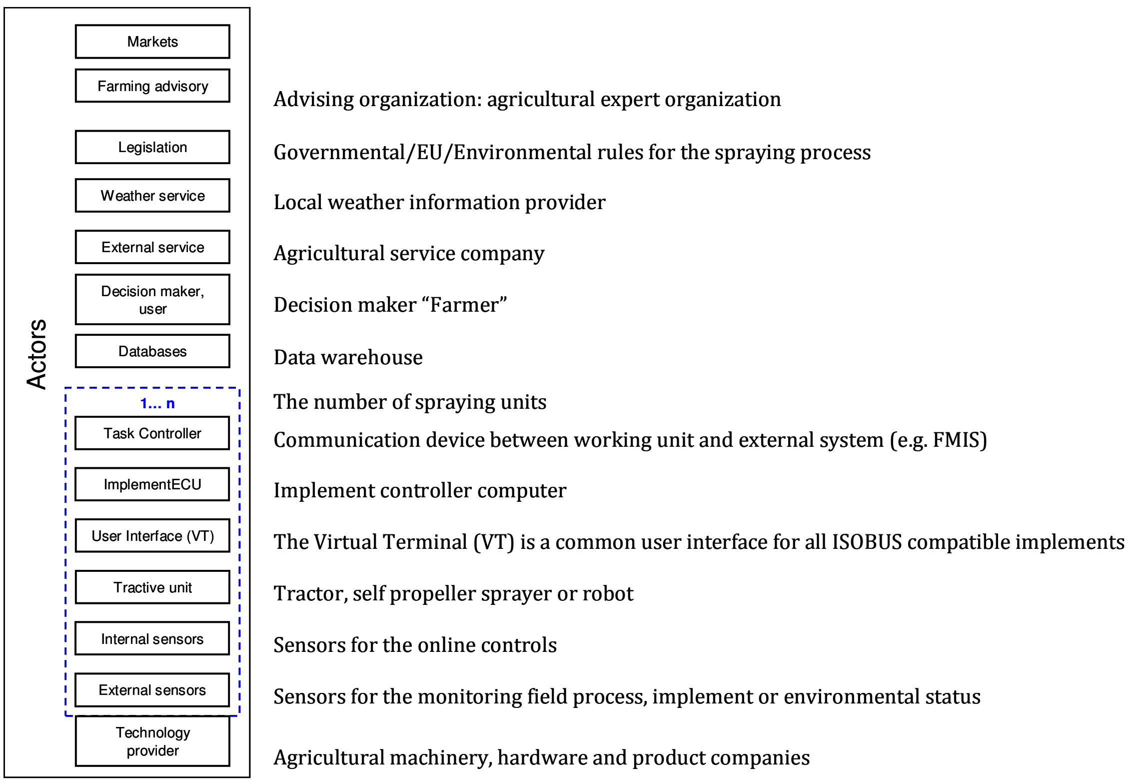

Figure 2. Identification of actors in the information system

The decomposition of information processes is based on the management functions ranging from strategical to operational planning, execution control and evaluation, and a number of underlying processes and sub-processes. Figure 3 gives an example of the information modelling for the tactical planning of a fertilising operation involving the seasonal planning.

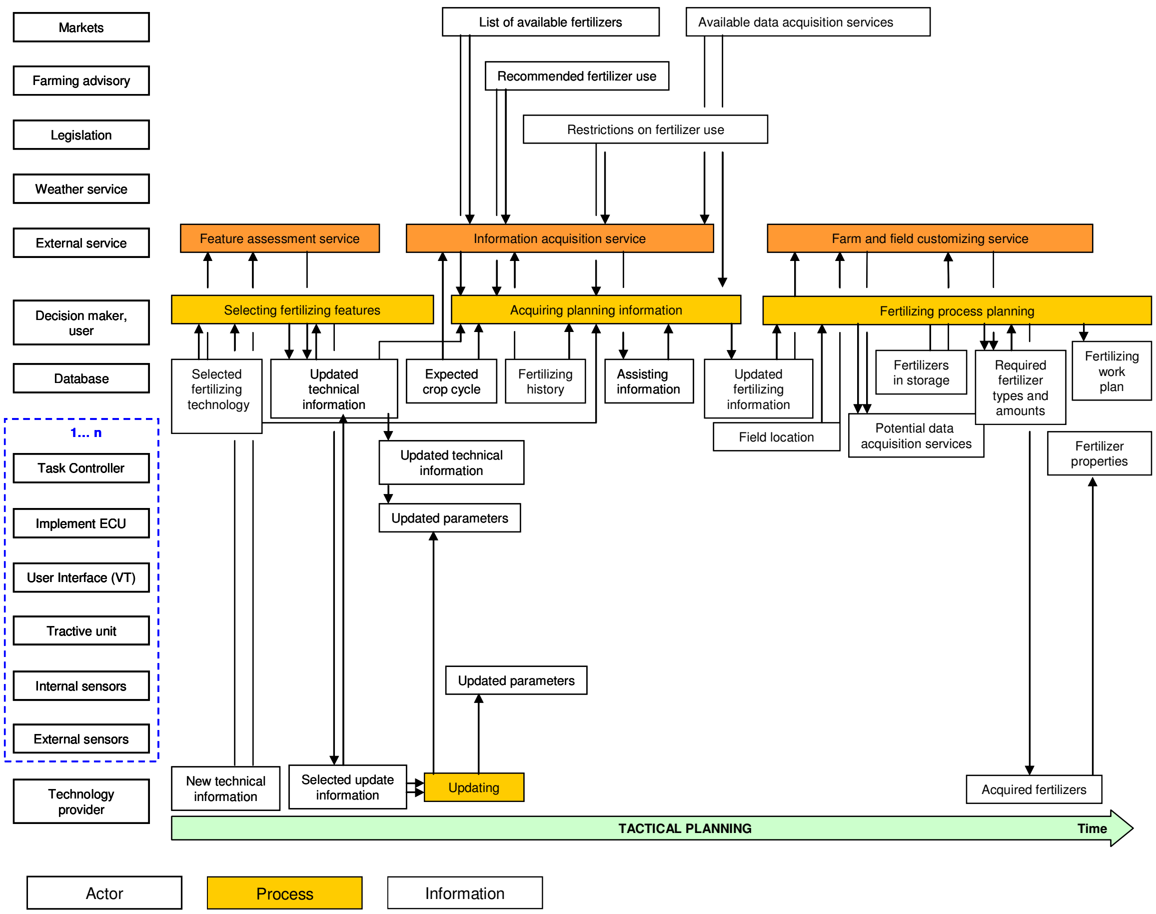

Figure 3. Information flow model for execution of field fertilisation operations. The elements include actors (physical entities), processes (information users and producers) and information (information flow)

Based on the identified information flows associated with the management functions and controlling of the spraying operation, the data entities and attributes inherent in the information flows is identified. Table 1 shows selected data entities for the execution phase in Figure 3.

Table 1: Selected data entities for the execution phase

Entity	Definition	Attributes/data
Field information	Description of needed field information	- field ID - location - area - crop type
Actual crop condition	Current status of the growth	- field ID - current growth status - type of observation
Selected TASK-file	The selected TASK-file for execution	- field ID - type of setting (fertliser 1… n, nominal dosage, mixture rates, driving speed, documented parameters, variable rate application (VRA) map) - control settings value for the specified types of settings

Conclusions

New information management concepts and designs mean that farmers have to be ready to adopt new working habits and perhaps also undergo further training. Farmers can utilise different services more efficiently and they are able to outsource some of the tasks they had previously performed themselves. Farmers have better knowledge of their production processes and are able to evaluate the performance of the chosen technology. This should lead to better process control in farms. Farmers can also utilise the collected farm data to show the quality of farming *e.g.* traceability, to markets and administration. The system concept also allows the farmers to access and utilise better scientific research and technological developments by providing fresh real process data and the ability to update the systems according to the latest knowledge. The results are in accordance with the policy recommendations to *implementation strategies* proposed by Ahlqvist *et.al* (2007) in the summary report "Nordic ICT Foresight: Futures of the ICT environments and applications on the Nordic level".

Important enhancement includes:

- Recording and storing of implement status/work documentation into farm database. This also means increased usage of numerical / formative data.
- Farm database has a central role in both human and machine decision making.
- Active use of external services increases.
- Increased use of automation.
- Smart assisting system features to support work are common, used information management technology shifts towards knowledge management technology

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Safety of *"part-time and not professional"* operators in agriculture: the Tuscany regional law n°30/2007 and reference in the national law 81/2008

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Abstract

Authors report on a new legislative approach due to the high number of accidents that each year occur to hobbyists, part time and not professional agricultural operators.
Only in Tuscany farms managed by hobbyists, part-time and not professional operators represent 80% of the total amount. Working day per year are less than 40 but with turns over 10 hour a day. Entrepreneurial mindset is very low.
These operators have hold a not reliable machinery in almost all cases and an average of 15 mortal and more with permanent handicap accident occur each year caused by capture in the rotating mechanical parts or by crushing due to loss of control of small farm tractors or capsizing of machinery.
The Tuscany Regional Administration faces up to these problems by the regional law n°30 of May 25, 2007 that promotes actions to inform and train these increasing sector of agriculture. But now the D.Lgs. 81/2008 expands this action to the whole nation.
A specific project has been implemented in Tuscany in which AUSL 3 Pistoia and DIAF have the aim to analyse and diffuse technical note for a safer use of machinery.
A large extention training is in progress by easy access manuals, multimedia tools and meetings.

Keywords: safety, risk management, non professional agricultural workers.

Introduction

INAIL (National Institute of Assurance against Injuries on Labour) data related to accidents on agricultural operations in Tuscany (Italy) reveal a general decrease in the last years. 4881 cases are reported in 2006. But mortal accidents are increasing with 76 dead a year. Most of these accidents occur to operators who drive occasionally agricultural machinery.

The current agricultural productive system is more and more characterized by new figures of operators who are not professional. Hobbyists, part-time, familiar and occasional workers are undoubtedly replacing professional operators in small farms. This is particularly evident in the sub-urban areas. The phenomenon also called "new-urbanization" or "new-ruralisation" is strongly increasing for many reasons: many people prefer living in rural areas, and an expanding urbanization along main roads close to the city is in progress.

A survey conducted in 2005 by the Department of Agricultural Economy of the University of Florence (Rocchi B., Stefani G., 2005) highlights that in the Region of Tuscany an amount of 80% farms are conducted by not professional workers that mainly produce food for own family need. The entrepreneurship level is very low, the operations are concentrated in short periods, the use of machinery is occasional, and the turn of daily work is often higher than 10 hours.
All these factors represent a further risk in the machinery use.

The occasional use of machine and the hard conditions of work are the main cause of accidents for the category of hobbyists and part-time farmers whose main income derives from other activities. As a consequence very often they have not the necessary competences to manage in safe way mechanical operations in field.

Another specific aspect of risk related to hobbyists and part-time workers in agriculture it's due to the use of old machinery no more corresponding to law's criteria and characterized by a low price, which are still and more used by these categories of operators. Dangerous machines are therefore often used occasionally with a low training level (Vieri M., 2007).

All surveys confirm that bad behaviours and human error are the causes statistically more frequent.

Each worker influence farm risk index with his behaviour. It derives from own experience, personal skills, health and emotional status.

Risk level is increased by many factors: low information on machine or plant works; use of material, machine and process unsuitable for the specific work or situation; low training on the correct drive and behaviour in the specific situation; lack of correct procedures in agricultural machine use; fixing machine components; lack of correct maintenance; being careless, tired, in a hurry, having too much confidence with machines . (Figure 1)

Figure 1. Accidents and risks in agricultural machinery use have always been well known as represented in the (*ex voto*) exposed all over in Shrines. But this know-how is no longer owned by the new farmers who work occasionally without experience and with often old and not reliable machinery

In the case of hobbyists and not professional operators these risks are accentuated by the absence of institutional controls on the machinery.

But suitable training, correct maintenance and periodical controls are fundamental in these cases. (Vieri, 2007 [2])

To control risks in these particular situations of agriculture scenery Tuscan Regional Administration issues Law 30 on may 25, 2007 "*Norms on safe and health of agricultural workers*". This law involves all situations and operators not mentioned by the Law by Decree 626/94. All persons who use agricultural machinery also for personal use are penalty responsible of accidents caused by these.

Besides just now has been issued the Law by Decree 81/2008 that introduces new measures similar to these, which are already provided by Regional Law 30/2007. The main innovation in comparison to measures provided by Law 626/94 consists in the enlargement of application range: Law 81/2008 takes into account all sectors and all people, and there are no distinction between ordinary and occasionally workers.

As application of the tasks expected by the Regional Law 30/2007 a specific project called "*Safety culture promotion in use of agricultural machinery*" has been designed by DIAF (*Dept. of Agricultural and Forestry Engineering - University of Florence*) and Agency USL (*Prevention Departments of Sanitary* 3 Pistoia (Italy). The project has the aim to realize information and training tools address to unprofessional and hobbyist agricultural operators.

It's articulated in four main steps: preparation of informative and formative multimedia tools; realization of specific courses; their diffusion in the whole regional area; survey on safety appropriate conditions of tractors and their use on the Tuscany regional territory.

Methods

The steps of action done by Agency USL 3 Pistoia and DIAF involve:

- ✓ friendly manual with basic informations on accidents, risks, needed maintenance of machinery, operative behaviour and procedures;
- ✓ multimedia clips on conventional and possible cases of accidents with 2 wheel, 4 wheel and track tractors in operative situation and in reparation moments;
- ✓ proposal of a new active protection device for 2 wheel tractor. For the third goal it has been realized a device that hold disconnected clutch.

The project "Safety culture promotion in use of agricultural machinery" has to be applied to the whole regional areas and involve subjects focalized by Law 30/2007. The aim is to provide informative and training tools for unprofessional and hobbyists agricultural workers with particular reference to safety and eco-compatibility.

Technical extension is in progress with easy comprehensive tools. Impressive language has been adopted to fix attention of operators.

Diffusion of these materials has been realized by meeting carried out on the whole Tuscany areas and with the cooperation of the Agricultural Operators Organizations.

Results

In the first step of the project it has been realized an extension technical handbook titled "*Ten rules for safe use of agricultural machine*". In this handbook are analyzed the main causes of accidents and injuries. Real events reported in the daily news are focused.

Particular attention is assigned to risks in use of small four well drive tractors and two well drive tractors that represent the most dangerous machines. Each accident is analyzed to focus either human errors and either machine malfunction, to point out a check list of controls, maintenance and behaviour at work that could prevent risks of accidents.

General behaviour in machine use are described in the handbook and the last chapter is dedicated to the check lists control applicable to the different equipment use and the related legislative norms.

Many video clips have been produced in which are shown typical cases of risks in the use of unconformable and old agricultural machinery.

Have been developed many screenplays about: small tractors, 4WD and 2WD tractors with different equipment applications, rotary hoes, chain saws, hand mowers.

Figure 2. Old tractor without ROPS (*Rollover Protective Structure*) are cause of mortal accident. Inefficient brake system and lack of assisted-aid systems characterize these machines

Figure 3. Accidents with conformed tractors equipped with ROPS and retention belt don't have heavy injuries for operators in almost all cases

In the specific case of small tractors have been taken into account the following risk cases: limbs capture or crushing, tractor rollover caused by heavy carried equipment, overload in pulling, extreme transversal slope, transversal skid, uncontrolled kynematisms between tractor and equipment, unexpected release of gear, unexpected autonomous start of machinery, immoderate forward speed or fast manoeuvre.

Risks related to Motor Hoes and Two Wheel Drive Tractors are examined in the cases of: capture of clothes or limbs, accident due to slicing of operator, crushing between tractor and obstacles.

In the case of mower use it has been focused risk derived from the rotary blade that can cut limbs (hand, arm, or foot) if: the operator has not enough attention, motor is running during maintenance. Stones or other objects can be thrown during weed cutting.

The use of chain saws has been examined too.

Figure 4. Oversights could have funny results but at the same time very dangerous

All this informative multimedia supports are illustrated and delivered during meeting carried out on the whole Tuscany areas.

The program of these meetings is organized as follows: accidents analysis in agriculture with particular attention to Tuscany activities, risk cases analysis, controls and procedure to mitigate risks in agricultural activities, legislative approach, norms, responsibilities and actors.

Figure 5. 4WD small tractor: typical case of capture *(see the shoelace)* and case of tractor rear up pulling something

All actions are arranged with the Agriculture Professional Organizations who have the task of wide extension service. The technicians of these organizations have cooperated in the project with the task of survey on farms machine conditions.

The survey has been done following a check list of analysis applied to a representative sample of the typical regional farms.

All the multimedia products are presented on a specific web site of the Regional Administration and on local television networks.

Different professional figures are implicated: agronomists, technicians, agricultural machine constructors , agricultural equipment dealers, local administration officials.

Dealers of agricultural equipment have great responsibility in training operators for safe use of machinery for their opportunity to meet frequently the farmers.

Figure 6. Motor hoe tractors provoke usually heavy and permanent injuries

Tests on safety devices for 2 wheel tractors are still in progress, and it has been proved that these devices can be use with old machinery too.

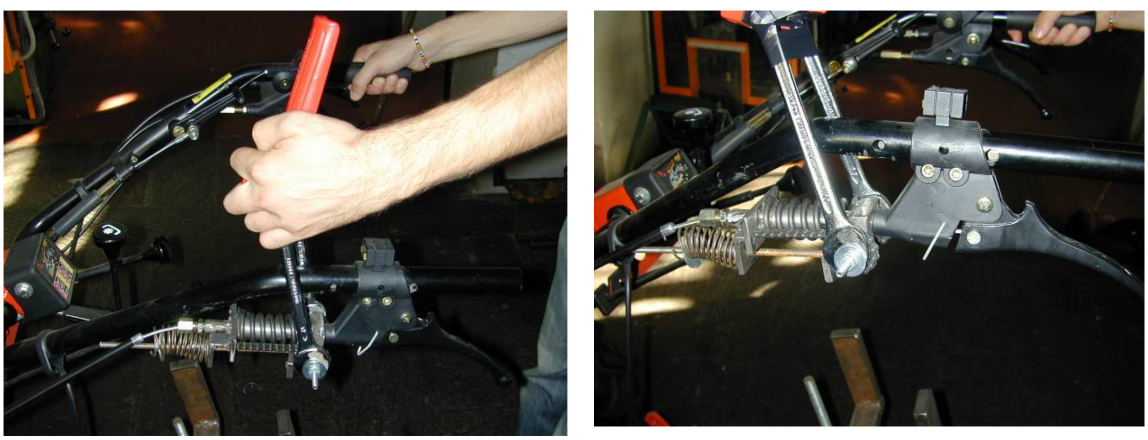

Figure 7. Prototype of fit device to control automatically the immediate clutch disconnection on 2WD mechanical gear tractors. Belt gear systems are easier to control as connection is usually due to a kept action

Conclusions

The Tuscany Regional Law 30 on may 25, 2007 "*Norms on safe and health of agricultural workers*" is aimed to reduce risks in agriculture and in particular when the operators are hobbyists, unprofessional or occasional. It reaches now national acknowledgement on Law 81/2008 that takes into account all sectors and all people with no distinction between ordinary and independent workers.

As application of the task expected by the Regional Law 30/2007, and probably by the national law 81/2008, a specific program called "*Safety culture promotion in use of agricultural machinery*" is in progress and it has the aim to realize information and training tools addressed to unprofessional and hobbyist agricultural operators.

Very important is the participation of all categories involved in the scenery: agronomists, technicians, agricultural machine constructors , agricultural equipment dealers, local administration officials.

Because of their opportunity to meet frequently the farmers, dealers of agricultural equipment have great responsibility in training operators for safe use of machinery.

Impressive movies and pictures together with a detailed analysis of the accident are very effective on unprofessional agricultural operators who often don't know in detail the evident and potential risks.

This information and training process is extremely important in this evolution time in which hobbyists, part-time, familiar and occasional workers are undoubtedly replacing professional operators in small farms. As already highlighted this is particularly evident in the sub-urban areas where the phenomenon also called "new-urbanization" or "new-ruralisation" is strongly increasing.

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Evaluation of Tractor Safety Frames Structural Deterioration with Age

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Keywords : used tractor, ROPS, reliability, corrosion

Objectives
An investigation was undertaken to determine the structural severity and practical implications of tractor safety frames (ROPS) structural deterioration with age in Italy.
The research aimed in particular to verify if this kind of ROPS can maintain the minimum security level required by the standards currently in force.

Methods
A detailed survey of frames deterioration level fitted on a significant amount of used tractors, manufactured over a wide time period (between 1965 and 2000) was carried out in some Italian northern regions.
A statistical analysis of the Italian used tractors fleet was primarily provided, followed by a field analysis, carried out through the creation and the implementation of a structured questionnaire, then applied of about 150 used tractors equipped with safety frames differently aged.
A strength test was finally carried out on a sample of a 4-pillar safety frame, able to adequately represent the situation of the surveyed fleet, ascertained in the previous study step.

Results
The results of the approval tests carried out more than 30 years ago were essentially confirmed, and therefore reasonably confirming the minimum safety requirement defined in the standards currently in force.
The fairly positive results recorded in the strength test do not therefore underestimate what highlighted in the field investigation, where critical ROPS conditions were frequently found, due to time and above all corrosion wearing, incongruous repairing, interventions and accidental damages.
These troubles always change (inevitably for the worse) the strength of the ROPS.

Study of workers' exposures to vibrations produced by portable shakers[1]

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Abstract

Herein note focussed the attention on the vibration levels issued by two portable shakers models build in different and subsequent times by the same building company, which present different design and constructive solutions for both the handles.

The two tools were used, during tests, by a single operator, expert in the use of this typology of tools due to his job activity during the olives harvesting campaigns; the measurements were carried out respecting the indications contained in the provisions UNI EN ISO 5349.

A different dynamic behaviour of the two tools emerged from the tests. Has been highlighted, also, the importance of the evaluation of the vibrations produced by portable shakers with the purposes to carry out studies that aim to the research of technical solutions which allow the reduction of vibrations transmission through the handles and through the shoulder support device of the tool.

Keywords: olive harvesting, safety, transmitted vibration.

Introduction

The exposure of human body to mechanical vibrations can, as it is well known, be source of pathologies of different nature and entity, even if the levels (intensity, spectrum content, daily and total exposition duration) which determine the above-mentioned injures are not exactly known (ENAMA 2005, ISPESL 2001, UNI 1999).

The whole problems connected to the transmission of the vibrations to man can be divided according to two essential typologies: - vibrations of the whole body; - vibrations of the hand-arm system, meaning, with the first, a stress of oscillatory nature which involves the whole human organism; with the second, instead, a mechanical stimulation, also of oscillatory origin, which propagates through the hands and the arms and that gradually decrease.

The transmission of the vibrations through the hand-arm system is consequent to the use of tools equipped with handles through which the operator makes the job; it is a rather complex phenomenon because involves other factors which interact with the intensity of the vibration and its way of introduction and propagation in the organism (UNI 2004). Has to be remembered that, in most cases, the handles represent the support device of such tools which are equipped with an internal combustion or electric engine that transmits the motion to the working utensil (Monarca *et al.*, 2003).

Through the handles the operator reacts to strengths and moments which spring between utensil and piece during the manufacturing. At least, the entity of the vibrations transmitted through the hand-arm system and the consequent effects are affected strongly by the

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[1] Research developed within the 2005 MIUR project (2005070324) "Methods of planning and systemic-integrated verification of the safety of work, food and environment in the agroindustrial sector - ISPROject (Integrated Safety Project)", Principal Investigator Prof. G.Zoppello.

Each of the authors contributed in equal parts to this work.

prehensile and/or pressing strength of the operator which, obviously, changes in function of the hands and wrists position during the manufacturing, in function of the finish level requested by the manufacturing itself and in function of the simultaneous use of the two hands.

Herein note focussed the attention on the vibration levels issued by the portable shakers which are always more used in the Apulia region olives production for the harvesting operations of the olives by the trees first of all for the greater investment and exercise economy with respect to the traditional taken or self-moved shakers.

In particular, the results of the tests on two portable shakers models build in different and subsequent times by the same building company, which presents different design and constructive solutions for both the handles are reported.

Materials and Methods

The experimental tests have been carried out in an olives tree field located nearby the Agricultural Research Council (CRA-ISMA) in Monterotondo (Rome) and have been made on two brand new and actually produced models of portable shakers, both equipped with an internal combustion engine produced by TEKNA s.r.l. in Ostuni (BR): Vibrotek TK 650 e Vibrotek TK 5000 (Table 1).

Table 1. Technical characteristics of the tested portable shakers

Model	Engine	Fuel tank capacity l	Vibration system	Reduction	Rod stroke mm	Frequency vibration stroke/min	Weight machine kg
Vibrotek TK 650	52 cc single-cylinder 2 stroke engine	1,7	Cam-rod system	Helical gears	60	till 1900	14,4
Vibrotek TK 5000					50		11

The choice fell on these models because, even though they are constructively similar, they present a substantial diversity in the arrangement and structuring of the handles.

In the Vibrotek TK 650 model, the command handle is mounted on an articulate quadrilateral support, in which torsion spring connected to the extremities to the two connecting rods, reacting to the vibrating stress recalls the system in the initial position. Instead, the auxiliary handle, runs, winning the recall spring's reaction, on a metal board mounted in the same direction of the vibrating rod (Fig. 1).

In the Vibrotek TK 5000 model both the handles are mounted on the same axis which is itself connected to the tool by an articulate parallelogram system, with the recall springs located in the anchoring points of the axis with the two connecting rods (Fig. 2).

Besides, both the tools, presents, downstream of the flywheel, a centrifugal clutch which, at the minimum regime, does not transmit the motion to the conic couple connected to the rod-lever mechanism which produces the alternative motion of the working rod.

The two machinery were used, during tests, by a single operator, expert in the use of this typology of tools due to his job activity during the olives harvesting campaigns.

The measurements were carried out respecting the indications contained in the provisions UNI EN ISO 5349 equipping both the shakes with two aluminium rods of different length: 325 cm (long rod); 225 cm (short rod).

Figure 1. Vibrotek TK 650: *a* – control hand-grip (*1* – connecting rod, *2* – spiral spring); *b* – auxiliary hand-grip

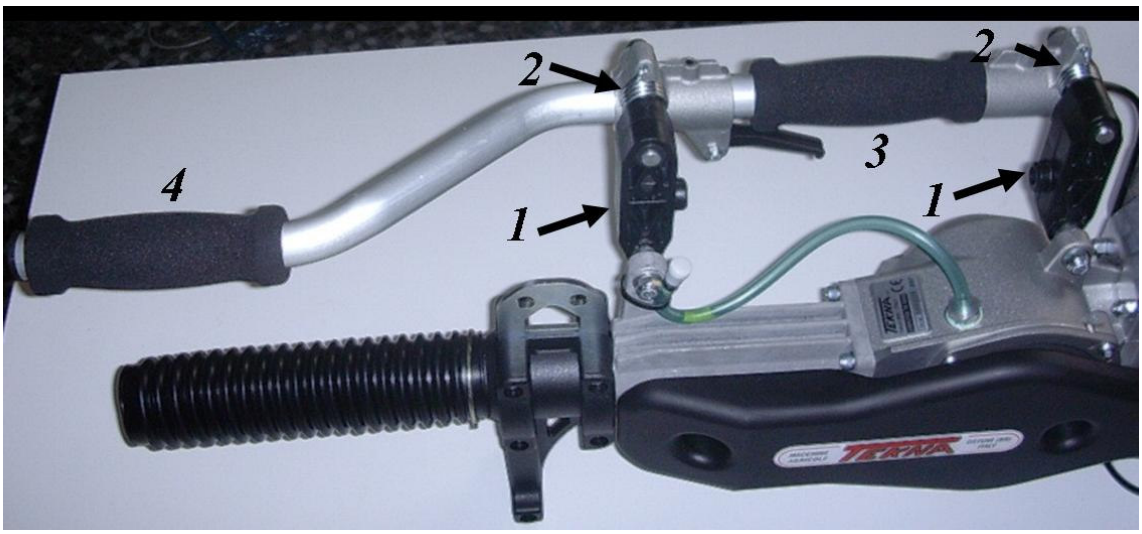

Figure 2. Vibrotek TK 5000: *1* – connecting rod, *2* – spiral spring, *3* – control hand-grip, *4* – auxiliary hand-grip

The instruments and tools used were:

- Brüel & Kjær 4326 tri-axial accelerometer, with 0,320 mV/(m/s^2) sensitivity; 10 g mass; frequency response from 0,1 Hz to 13,3 kHz for x axis, from 0,1 Hz to 10 kHz for y axis and from 0,1 Hz to 16,6 kHz for z axis (linear response with a precision<10%);
- PCB SEN020 tri-axial accelerometer, with 0,100 mV/(m/s^2) sensitivity; 10 g mass; frequency response between 0,5Hz and 5 kHz, resonance frequency >25 kHz;
- Brüel & Kjær 2647 converter, used only for the B&K tri-axial accelerometer, used to convert the charge signals into continuous electrical signals;
- "SoundBook" data acquisition system made by a PC and a multi-analysis real-time interface (8 measurements channels);
- SoundBook™ "SAMURAI" operating system, used to configure acquisition system, to real-time monitor the measurements and to elaborate and present the obtained data;
- PCB 394C06 calibrator, characterized by a test signal of 9,835 m/s^2 (RMS), at the frequency of 159,2 Hz;
- aluminium supports, having 12 g of mass, used to fix the accelerometers to the handles of the shakers; these supports have been fixed with two plastic strip in order to ensure a perfect connection between accelerometers and tested machinery.

Particular attention was used during the fixing process of the accelerometers on the auxiliary and command handles, in order to have each axis oriented in the directions imposed by the provisions UNI EN ISO 5349-1 (basicentric coordinate system): y_h axis parallel to the axis of the handle; x_h perpendicular to the axis of the handle oriented by the back towards the palm of the hand and, at last, the z_h axis perpendicular to the plan formed by the two previous axis (Fig. 3)

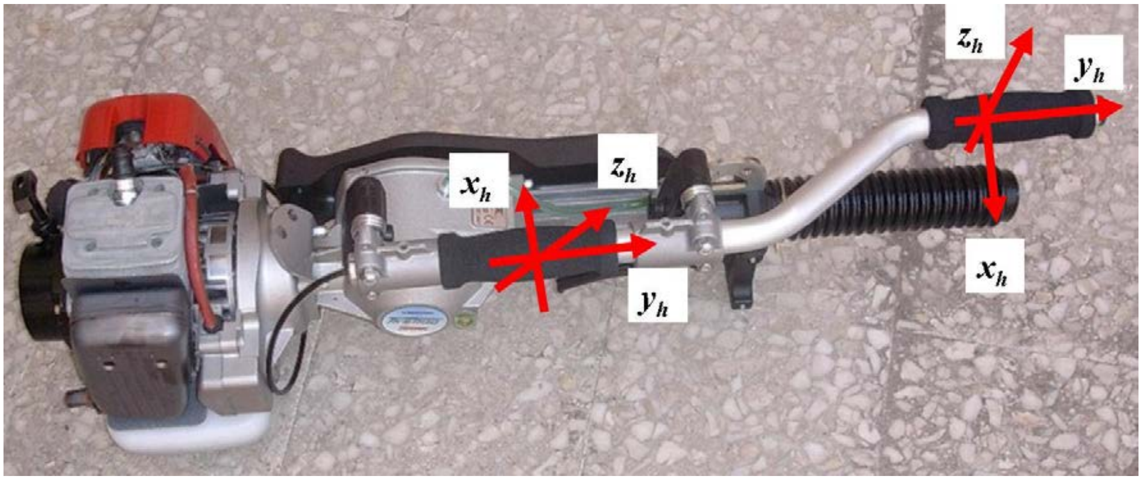

Figure 3. Basicentric coordinate system adopted for measurements

The measure was set up using the optional software SoundBook HVMA which having, so, a class 1 testing instrument for the measure of the human exposure to the vibrations in conformity to the ISO 8041-1990 and ISO/DIS 8041-2003 and with digital direct weighing filters on the incoming signal. The analysed frequency spectrum, correspondingly to the actual provisions related to the hand-arm vibrations, was considered between 6,3Hz and 1250 Hz.

The equivalent accelerations weighed up in frequency on the single axis (a_{wx},a_{wy},a_{wz}) and total (a_{hv},), acquired simultaneously, were measured for the following modes of working of the tested shakers:

- at the minimum engine regime, that's to say ~2100 rpm (*idle speed*) with a measurement time of 20 s;
- during shaking work (*full load*) with a measurement time of 300 s;
- at the maximum engine regime, that's to say ~9000 rpm (*top speed*) with a measurement time of 4 s.

The measurements at *idle speed* (working rod stopped) and at *top speed* have been carried out with measurement times of 20 s e 4 s respectively, holding the shakers with both hands in a normal working position (working rod at ~60° on the horizontal plane); these tests were carried out only on the shakers with the long working rod mounted.

The *full load* working mode was made of several working phases: a) "hooking" of the branch with the engine to the minimum regime; b) operation of the accelerator, in order to open to the maximum value the valve of the carburettor; c) shaking of the branch exercising a constant strength on the handles; d) release of the accelerator, in order to take back the engine to the minimum regime; e) "unhooking" of the branch. The *full load* measurements were carried out with the shakers equipped with long working rod (*full load -- long rod*) and with the short one (*full load – short rod*)

The tests in each operating condition were repeated five times.

To monitor the data during the tests has been set up the real-time visualization of frequency analysis of the two accelerometers, of global value of the spectrum (axis x,y,z) and of a video capture using a web cam (Fig.4).

Before each test series and at the end of the series a calibration of the measurements instruments was carried out.

Figure 4. Signal analyses coming from the accelerometers displayed in real time

Results and discussion

In the Tables 2 and 3, have been represented, respectively for the Vibrotek TK 650 and for the Vibrotek TK 5000, the frequency weighted accelerations along the axis and the total accelerations a_{hv}. The values a_{wx}, a_{wy} and a_{wz} are obtained, the prevision contained in UNI EN ISO 5349, as arithmetical average of the ones measured on the same axis (x, y and z) during the five repetitions made for each working mode of the shakers (*idle speed*, *top speed*, *full load - long rod*, *full load – short rod*); the total equivalent accelerations were calculated, how the same rule states vectorially adding the mean values concerning the three cartesian axis.

The most significant values are obviously the ones measured during the harvesting tests (*full load*), as they represent the real use of the shakers; in these condition of usage the "intrinsic" characteristics of each shaker (rigidity, mass, rotating inertia of the individuals component and total), that define in an univocal way the natural frequencies and the ways of vibrating of the shaker, modify themselves at the moment in which the hook of the rod hooks the branch. This last one presents its intrinsic characteristics (rigidities, mass, etc.), moreover very much variables in function of its dimensions (length, diameter, etc.), that interacts with those of the shaker originating a quivering system, established by the branch-shaker system, of which it is difficult to foresee the dynamic behaviour. In this regard, it's useful to observe that the total weighted acceleration a_{hv}, and the corresponding vibration emission, concerning the *top speed* mode, dependent just from the characteristics of the shaker, is different from that *full load* mode related, instead, to the characteristics of the branch-shaker system.

Table 2. Vibrotek TK 650. Average values of the frequency-weighted vibrations (values in m/s^2)

hand - grip	Test condition	a_{wx}		a_{wy}		a_{wz}		a_{hv}	
		average	St.dev	average	St.dev	average	St.dev	average	St.dev
control	*idle speed*	2,0	0,20	1,5	0,23	2,4	0,11	3,5	0,20
	top speed	12,9	1,2	14,1	3,2	19,2	2,20	27,2	2,7
	full load - long rod	9,7	1,1	10,4	0.9	4,0	0,4	19,5	2,0
	full load -short rod	10,6	0,9	14,5	1,6	3,1	0,4	18,2	1,9
auxiliary	*idle speed*	4,1	0,48	0,6	0,05	3,6	0,5	5,5	0,3
	top speed	15,2	3,6	27,5	9,1	17,42	3,16	36,1	9,6
	full load-long rod	12,2	1,4	11,8	2,0	11,3	1,8	20,4	2,5
	full load-short rod	13,3	1,7	12,4	1,8	14,5	2,1	23,2	3,0

For the Vibrotek TK 650 shaker, the usage of the long working rod or of the short working rod produce on both the handles weighted total acceleration values a_{hv} of the same magnitude (average 20,3 m/s^2). This tendency is the same for the *x* and *y* axis, while, on the *z* axis, the accelerations on the command handle are very much smaller (average 3,5 m/s^2); this behaviour is probably due to the constructive characteristics of this handle which evidently is more rigid in the *z* direction.

Table 3. Vibrotek TK 5000. Average values of the frequency-weighted vibrations (values in m/s^2)

hand - grip	Test condition	a_{wx}		a_{wy}		a_{wz}		a_{hv}	
		average	St.dev	average	St.dev	average	St.dev	average	St.dev
control	*idle speed*	4,5	0,1	1,3	0,1	3,3	0,1	5,7	0,1
	top speed	9,3	1,1	9,4	0,6	7,7	0,6	15,3	1,2
	full load - long rod	8,4	1,0	7,6	1.2	8,3	1,2	13,1	2,0
	full load -short rod	8,5	1,1	9,2	1,5	9,0	1,3	15,4	2,1
auxiliary	*idle speed*	6,8	1,0	0,9	0,1	2,6	1,2	7,4	1,4
	top speed	5,9	0,8	12,1	0,8	17,0	1,1	21,7	1,4
	full load - long rod	16,1	1,9	6,3	1,2	12,4	2,0	21,3	2,7
	full load -short rod	6,5	1,1	1,7	0,9	9,6	2,0	11,7	2,2

With regards to the Vibrotek TK 5000 shaker, the assembly of the two handles on a single axis, integral part of an articulate parallelogram system, has modified the dynamic behaviour of the shaker itself with respect to the other tested shaker. On the command handle the total weighed acceleration a_{hv} is reduced of 33% with the long working rod and of 15% with the short working rod with respect to the same value measured for the Vibrotek TK 650 shaker; on the auxiliary handle, considering the working condition with the short working rod, the a_{hv} value is reduced of 50%. On this handle, besides, the acceleration values are comparable between the two shakers only when they are both equipped with the long working rod.

In the Figures 5 and 6, are represented in the shape of bar diagrams, the frequency analyses for 1/3 octave bandwidth of the vibrations measured, respectively on the Vibrotek TK 650 and the Vibrotek TK 5000 shaker, during the mode *full load -- long rod*. These figures were obtained considering the vectorial sum of the linear accelerations measured on the three axes. From these figures the different dynamic behaviour of the two tools emerges in a clear way and, above all it is possible to notice the values meanly smaller of the accelerations measured on both the handles of the Vibrotek TK 5000 shaker. As we are dealing with the *full load* working mode, the regime of the engine is changed in a continuative way between 2100 and 9000 rpm, exciting the vibrating system in the correspondent range between 35 Hz and 150 Hz; to that has to be added the pulsating strength connected to the alternative movement of the working rod.

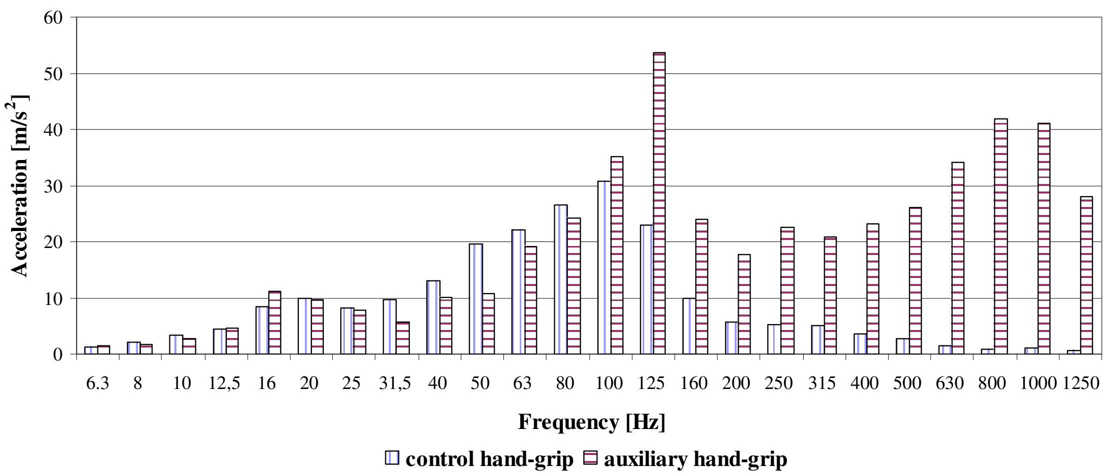

Figure 5. Vibrotek TK 650 equipped with long working rod. Average frequency spectrum of vibrations

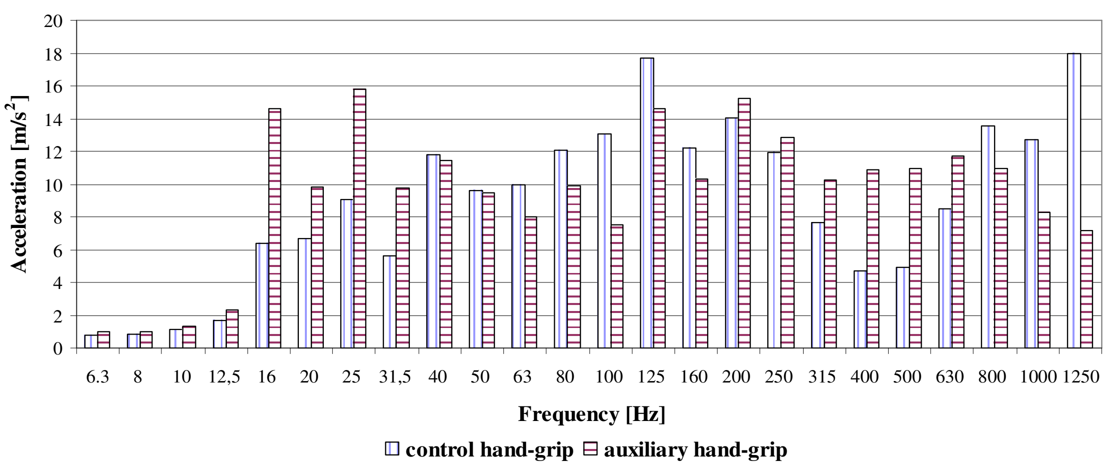

Figure 6. Vibrotek TK 5000 equipped with long working rod. Average frequency spectrum of vibrations

Conclusions

The results of the carried outs tests, point out, in a particular way, the importance of the evaluation of the vibrations produced by portable shakers with the purposes to carry out studies that aim to the research of technical solutions which allow the reduction of vibrations transmission through the handles and through the shoulder support device of the tool.

Moreover is important to pay attention also to the weight of the tools so that can be avoided heavy physiological and muscular efforts.

The different dynamic behaviour of two devices which are structurally different only in the typology and disposition of the handles emerged from the tests; in purpose it is useful to remember that the limitation of the vibrations in design phase is one of the indication suggested by the current technical provisions [UNI 2007] to the tools manufacturers in order to increase the safety levels of the workers; in design phase, in fact, the in-depth study of some technical aspects allows an effective reduction of the effects of the exposure to damaging vibrations.

Acknowledgements

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Analysis of anthropometric compatibility of several tractor cabin guide

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Abstract

Anthropometry is a part of ergonomy responsible for measuring human body in its totality and components. The design of every handmade good concerning working sphere (but not only), needs the information supplied by this science.

In the agriculture sector, anthropometry has a remarkable relevance above all in designing and realization of tractor's cabin guide. This is due to the fact that many agricultural workers spend the most part of day driving tractors. A tractor with an uncomfortable cabin guide represents a risk for the driver. A space too narrow is extremely dangerous in case of overturning, collision with the inner side of the cabin, unintentional use of a control and consequent accidental movement of the tractor. The present paper is focused on experimental analysis of the inner dimension of tractor's cabin guide. The main goal is to verify the respect of "the least overall dimensions" of the driver and, according to UNI EN ISO 3411 standard, is calculated on big size drivers; it corresponds to the inner surface of the cabin with no visible deformation [4].

The experimentation has been realized on 15 tractors of different dimensions and year of production. The results have been then compared to verify the least overall dimensions inside the cabin guide. On the basis of the results, the analysis shows that all the tractors don't respect some parameters of the standard.

Keywords: ergonomics, anthropometry, S.I.P. (Seat Index Point), cabin guide, tractors.

Introduction

The UNI EN ISO 7250:2000 "*Basic human body measurements for technological design*" gives a description of anthropometric measurement that can be used as a reference for comparison of groups of people. The ergonomics can use this norm to define groups of population and to apply their knowledge to project the geometries of the working and living places of people. The project needs to consider the anthropometric variability existing in the population used for a reference allowing in some cases sufficient space for the maximum value (e.g. cabin height), in others, foreseeing the possibility of adjustment depending on the size and specification of the subject. Generally the liveable internal space is projected considering the percentile distribution of the anthropometric dimension of a population. The percentile represents the percentage of subjects which have the same or inferior dimensions than the assigned ones. In a symmetric distribution, the 50th percentile represents the medium value of the considered distribution: for example, in the distribution of height of a population the 50th percentile equals the average height of that population. Generally the dimensions of a working place are projected based on the population dimensions between the 2,5 and 97,5 percentile, which means that the same ambience is able to adapt itself to 95% of people [5].

With tractors and moving agricultural equipment, particular care needs to be taken of the seat, on which an operator can spend a whole working day. In their most comfortable versions the driver's seats have:

- base large enough and horizontal on the resting points of the ischium (the lower pelvis bone) with a light descending gradient and a length inferior to the thigh (femoral arteries are not compressed and the leg can move freely);
- lower back support adjustable in height and convexity to anatomically support the lower vertebrae (subject to discopathy);
- adjustable inclination of the back for a better support of the trunk;
- arm rests for a better support of the arms;
- a 20º rotation angle in both directions to facilitate entry and exit and observation of rear machinery;
- regulation in height and position (back/forward) to adapt the distance from the commands to the typical dimensions of the subject and to facilitate a comfortable position for both feet on the cabin floor;
- vertical suspension to reduce vibrations made by the machinery and adjustable to the weight of the individual;
- horizontal suspension to reduce horizontal impulses, felt as blows to the back (can generally be turned on or off on command);
- upholstery that allows for perspiration.

On tractors, vertically and longitudinally adjustable seats with parallelogram springs and suspension based on the driver's weight are usually available. Bases, backs and arm rests are anatomically shaped (and often adjustable) to contain the operator well even on strong gradients. On tractors with cabins the upholstery is made of suiting (cloth) to reduce perspiration problems.

Anthropometrics regulates also the disposition of the commands (figure 1) that once again has to be rationally studied based on:

- the anthropometric working radius (arms and legs);
- the possibility of easy usage based on the easiest movements with the hands or the feet;
- easy visibility based on sight angle and easy movement of the head;
- the easy recognition of all the commands to use the machine [4].

Figure 1. A tractor cabin guide and details of the joystick for traction command

The quantity of handles and commands in the driver's seat of a tractor can be numerous (figure 1). Essential for the easy and secure use of the commands is their maximum recognition, which can be improved with a characteristic shape and colour. Some handle commands, for example hydraulic distributors, in which the position of the handle is proportionate to a certain effect, should have the possibility of a resting point for the hand, for a fine and safe control. Regarding the commands for movement of the machine (accelerator, clutch, lower and higher gears), they usually are all the same colour, easily recognizable from the other commands. For this reason the coding for the different luminous signals (shape, colour and symbol) need to be carefully studied and in some cases is based on international standards. In some cases, acoustic signals, like the luminous ones, are particularly useful to inform the driver of serious malfunctions or dangerous situations. Particularly quoted, in the field of the information theory, is the said "law of the magic number seven". An average person, subjected to visual stimulations, will not remember and process more than seven, with variations from five to nine. Particularly important signals for the driver therefore will have to be visualized in a clear and simple and heavily reduced way, to give only the most important information, necessary to make the quickest and most effective counter-measure [3].

The driver's seat of a tractor, finally, needs to allow for maximum external visibility, without blind spots and above all visibility of the rear and front machinery. Exactly these needs call for a cabin nearly completely made out of glass and a so called tractor with clear or improved sight of the front (with a lowered engine compartment) for a better sight of the machinery carried at the front [2].

Material and methods

Tests have been conducted on 15 tractors of different brands, models, power engine and production years. Power vary from 65 to 200 kW and the tested tractors have been produced between 1983 and 2007. For the purpose of this research the measurements have been made with the help of a wooden instrument, constructed by a specialized joinery using numeric controlled machinery to obtain the finest of precisions and to respect the construction directive of the UNI EN ISO 5353 standard (figure 2).

This instrument has been used to individualize the Seat Index Point (S.I.P.) of the seat, from which all the measurements take place.

Figure 2. Wooden instrument for determination of the SIP

The instrument has been constructed of various types of wood to obtain maximum resistance even though the wooden part of the instrument has a mass of only 2,98 kg which, together with four iron pedestals, comes to a total mass of 6 kg as cited in the above described standard. The four iron pedestals are used to support weights added to arrive to the desired final mass (figure 3).

Figure 3. Instrument for the determination of the SIP complete with iron pedestals to support the weight

The numeric controlled machinery that has been used to construct the instrument has allowed to cut hundreds of wedges that later have been joined together and glued with a particular mechanic press. The instrument consists of two parts: 1. horizontal base which conforms to the analyzed seat, with curve angles following the standard UNI EN ISO 5353; 2. vertical back, also with curve angles following the same standard, and conforming to the analyzed seat [4].

The base and the back have been joined by a wedge which at both ends has a 45º angle so that base and back will result perpendicular.

The Seat Index Point (S.I.P.) is defined by the intersection of the horizontal straight line passing through the two holes on the upper part of the instrument with the vertical straight line passing through the hole situated in the centre of the lower part of the instrument (figure 4 and 5).

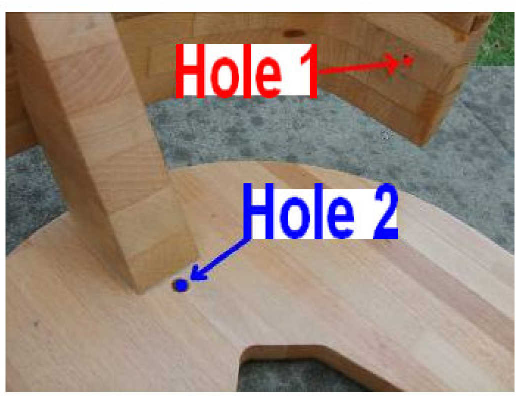

Figure 4. Holes situated on the upper part of the instrument (hole1) and hole situated on the lower part of the instrument (hole 2)

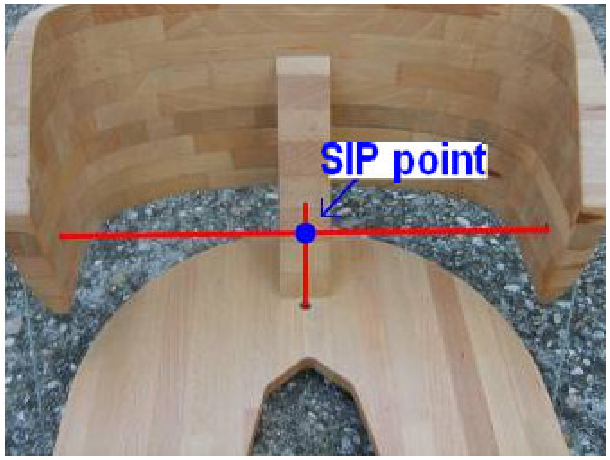

Figure 5. Determination of the S.I.P. point

In addition to the instrument described above to do measurements were used measuring tape, spring rule, folding meter, bubble level, adhesive tape, paper, and metal tiles with a mass of 10 kg to come to the final desired mass.

Form for the transcription of measurements

For the transcription of the measurements in the field, a form especially conceived to summarize the measurements to be analyzed has been used as per UNI EN ISO 3411 standard. The form shows all the maximum and minimum dimensions to respect the norm, the cells to be filled with the measurement taken and, at the bottom of the page, three images to facilitate the interpretation of the relative measurements

The method described in detail in the UNI EN ISO 5353 standard, cited in chapter 5, paragraph 5.3 has been followed.

Additional to what has been reported above, other measurements have been made adding small modifications to the measurement methodology wherever it was impossible to follow the standard because of obstacles in the way of the position of the metal tiles on the four iron pedestals. To make the S.I.P. more accessible to the measurements a method has been studied that permits, after the S.I.P. has been located, to remove the instrument and therefore allow an easy and immediate measurement. Following the UNI EN ISO 5353 standard, once the instrument is positioned on the seat, a thread is passed through the two holes on the vertical back (the upper part) of the instrument, then stretched and attached in the internal side of the cabin, with adhesive tape, thus carefully forming a horizontal straight line using bubble levels. On the opposite side the thread is stretched and the point where the thread should be attached is marked. The thread is then pulled out of the instrument, while still being attached to the side of the cabin and the instrument is removed. Once the instrument is removed the thread is stretched again to the marked point and by doing so the precise coordinates of the SIP are obtained without particular obstacles for the measurement. The minimum overall dimension of the operator is the internal dimension of the driver's position.

The recommended overall dimension in the driver's position (cabin) of a fully dressed operator refers to the S.I.P. defined in the **ISO 5353:2000** "*Earth-moving machinery, and tractors and machinery for agriculture and forestry - Seat index point*".

The minimum overall dimension of the operator is based on the dimensions of bigger sized operators. This is measured on the internal surface of the driver's position, without visible superficial deformations, and can be smaller than the one specified by the UNI EN ISO 3411 standard if it can be proved that such reduced overall dimension of the operator, in particular types of machines, allows the operator to do his work adequately.
The parameters (as described in the UNI EN ISO 3411 standard) that have been measured are:
δ1: distance between the cabin and the commands in their closest position to the cabin itself. The minimum limit value of this distance imposed by the norm is 50 mm.
R1: distance between the S.I.P. and the cabin ceiling in the transverse plane. The minimum limit value of this distance imposed by the norm is 1050 mm for tractors with more than 150 kW, 1000 mm for tractors between 30 and 150 kW and 920 mm for those with less than 30 kW.
R2: radius at intersection between the internal walls of the cabin and intersection of the internal walls of the cabin with its ceiling. The maximum limit value is 250 mm.
R3: distance from the rear wall. The gathered measurement needs to be at least b+400 mm, where b equals half of the seat's horizontal adjustment dimension.
h1: vertical distance between the SIP and the lower extremities of the upper side walls of the cabin. The standard establishes a maximum value of 150 mm.
h2: vertical distance between the SIP and the lower extremities of the upper rear wall of the cabin. The gathered measurement needs to be equal to the vertical distance between the SIP and the upper part of the seat in its lowest adjusted position.
l1: length inside leg space. The standard establishes a minimum space of 560 mm.
L1: distance for the forearm inside the upper lateral zones of the cabin. This distance needs to be at least 500 mm.
L2: distance between the cabin and the arctic shoes of the operator which operates a pedal or pedal command in any position. The minimum limit value imposed by the norm is 50 mm.

Results

TRACTORS	**Power HP**	**Power kW**	**δ1**	**R1**	**R2**	**R3**	**h1**	**h2**	**l1**	**L1**	**L2**
Case MX 270	270	188,5	☺	☺	☺	☺	☹	☹	☺	☺	☺
Case CS 110	110	80,9	☹	☺	☺	☺	☹	☹	☺	☺	☹
Case 1255 XL International	125	91,9	☺	☺	☺	☺	☺	☺	☺	☺	☺
Fendt Farmer 309 C	107	78,6	☺	☺	☺	☺	☺	☹	☺	☺	☺
Ford Tw 30	190	139,7	☺	☺	☺	☺	☺	☹	☺	☺	☺
Hurlimann Sx 1500	155	113,9	☺	☺	☹	☺	☺	☹	☺	☺	☺
John Deere 5615 F	90	66,1	☺	☺	☺	☺	☺	☹	☺	☺	☹

John Deere 6330 Premium	118	86,7	☺	☹	☺	☺	☺	☹	☺	☺	☺
John Deere 7730	220	161,7	☹	☹	☺	☺	☹	☹	☺	☺	☺
Landini Globus Top 80	58,8	43,25	☹	☹	☺	☺	☹	☹	☺	☺	☺
Landini Legend Tecno	106,6	145	☹	☹	☺	☺	☺	☹	☺	☺	☺
Same Galaxi Turbo	170	122,3	☹	☺	☺	☹	☹	☹	☺	☺	☺
Same Hercules 160 V	160	117,6	☹	☺	☺	☹	☺	☹	☺	☺	☺
Same Iron 200	200	147	☺	☹	☺	☹	☺	☹	☺	☺	☹
Steyr 9083	88	64,7	☹	☹	☺	☹	☺	☹	☺	☺	☹

Table 1. Summarized table of the respected dimensional characteristics of the analyzed tractors.

Conclusions

In table 1 the gathered results are summarized; parameters not respected on each tractor are indicated by the red un-smiling little face.

Considering that the UNI EN ISO 3411 is a "norm" and not a "directive", constructors and manufactures of agricultural machinery, and in this case agricultural tractors, are not held completely to respect the limits indicated by the standard itself. However they have the obligation to motivate and justify an eventual choice in construction which does not respect the norm's limits [1].

Resulting from the anthropometric analysis conducted in this research, all the analyzed machines, regardless of size and age, have a percentage of parameters that do not respect the norm.

Starting with the "h2" measurement (vertical distance between the SIP and the lower extremities of the upper rear wall of the cabin), 14 analyzed tractors result to be below the standard value. This depends on the fact that the agricultural tractors often use machinery attached to the back on a three point attachment or towed.

For this reason, the lower extremity of the rear window is generally lower than the standard dictates, to have a bigger sight angle towards the ground. In fact it needs to be underlined that the applied norm refers to ground moving machinery (a similar European norm does not exist for agricultural tractors).

Another parameter which is often not respected is "δ1" (distance between the cabin and the commands in their closest position to the cabin itself).

Regarding this parameter, 7 tractors out of 15 result to violate the minimum safety distance.

Based on the standard, the distance between the cabin and the commands should have a minimum of 50 mm to avoid that the operator gets crushed or hits the cabin using this command.

Usually constructors place rarely used commands in the close vicinity of the cabin.

This does not take away the fact that using these kinds of commands the operator encounters the risk of crushing his fingers. Other parameters that result to be violated are "R1" (violated in 6 tractors out of 15) and "h1", (violated in 5 tractors out of 15) respectively the distance between the SIP and the cabin ceiling in the transverse plane and the vertical distance between the SIP and the lower extremities of the upper side walls of the cabin.

Regarding the "R1", in some tractors, space is occupied to allow the insertion of ventilation purposes.

Some constructors justify the violation of "h1" with the insertion of a lateral control panel and the use of the most commonly used controls inserted into the arm rest (this type of disposition is nowadays present in all medium and large sized tractors of the last generation).

A parameter violated only in 4 tractors out of 15 is "L2" (distance between the cabin and the arctic shoes of the operator which operates a pedal or pedal command in any position).

This distance has a minimum limit of 30 mm and is not respected by those tractors that have a too long pedal travel. In all the found cases this pedal results to be clutch pedal.

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The contribution to the programming and executing of this research must be equally divided by the authors.

Transmission of vibrations from portable agricultural machinery to the Hand-Arm System (HAV): risk assessment and definition of exposure time for daily action and exposure limits

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Abstract

Every day agro-forestry workers are exposed to health and safety risks, due to work environment and the machineries they use.
Some of these risks, vibrations for example, are usually underestimated by workers as well, because vibrations do not represent an immediate risk for the health.
The vibrations can cause some professional diseases whose symptoms can appear after many years too. This is not a good reason to ignore the problem; in fact the consequences of a long exposure time can be very serious.
A deeper knowledge of diseases caused by vibrations, laws, the best precautions and safety systems can represent a start to limit the phenomenon.
The research about agro-forestry machineries can represent a stimulus to use ergonomic instruments in order to guarantee the health and the safety of the workers.
The present research aims to highlight the importance of the exposure to vibrations in agro-forestry sector and its consequences on human health, above all the risks for the hand-arm system during the working day.
Every machine has been directly analyzed to establish the level of vibrations produced according to the laws in force and the most recent ISO norms.
With the collected data it was possible to establish the maximum exposure times for every instrument in order to respect the European Directive 2002/44/CE of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations).

Keywords: health at work, hand harm vibrations, portable instruments.

Introduction

Agro-forestry workers are exposed to many types of risks. Some of these risks, like vibrations, are underestimated by workers as well since they do not represent an immediate damage for the health. Indeed, disease symptoms can appear several years afterwards. However, this is not a reason to ignore the problem as the consequences of being exposed to extended vibrations can be rather serious. To this day, all the possible implications related to the exposure of human body to vibrations are still not totally clear. In order to formulate biomechanical models operative for the definition of appropriate criteria of risk assessment , it is necessary to understand the influence between the physical parameters of the vibrations and the physiological ones of the exposed organism.

The research on agro-forestry machineries may encourage operators and constructors to adopt ergonomic instruments to guarantee high work performances, as well as workers health and safety. The aim of this paper is to give a contribution to vibration risk assessment deriving from the utilization of portable equipment, which is largely used in this sector. More specifically, we refer to the assessment of the risk for the hand-arm system at which operators are exposed during the working phases. The assessment has been done trough direct measurement, using the adequate equipment to record the vibrometric levels of each analyzed machine. Above all, six models of shoulder portable blowers, four brush-cutters, one chainsaw and one hedge cutter have been analyzed. The procedure has been carried out following all legal provisions and the most recent ISO standards. The data elaboration deriving from this survey has permitted to check if the models respect the requirements of the European Directive 2002/44/CE.

Material and methods

Legal framework

The European Directive 2002/44/CE on the minimum health and safety requirements regarding the exposure of workers to the risks arising from vibrations is characterized by a set of basic and fundamental obligations to preserve the safety of workers exposed to mechanical vibrations. These obligations are consolidated by the European legislation also for other risk factors. More specifically, two exposition indicators for the vibrations transmitted to the hand-arm system have been identified: the action value and the exposure limit value (table 1). The overcoming of these two values lead to a set of obligations. The daily exposure action value on the hand-arm system, standardised to an eight hour reference period, A(8) shall be 2,5 m/s^2 r.m.s., while the daily exposure limit value, standardised to an eight-hour reference period, shall be 5 m/s^2 r.m.s.

Table 1. Daily action and exposure limit values transmitted to the hand-arm system standardised to an eight hour reference period

VIBRATIONS TRANSMITTED TO THE HAND-ARM SYSTEM	
Level of daily exposure action value A(8) = 2,5 m/s^2	Daily exposure limit value A(8) = 5 m/s^2

The action value represents that value of daily exposure from which specific measures for the protection of exposed workers must be implemented (e.g. training about the specific risk, intervention aiming at risk reduction, periodic health control for exposed workers), while the limit value represents the level of exposure that cannot be exceed (because it involves an inacceptable risk for an individual exposed to vibrations without the adequate protections). In relation to the exposure to vibrations transmitted to the hand-arm system, the European Directive fixes as prevention reference levels (action and exposure limit values) the same values indicated by the specialized technical literature, and therefore it defines:

- limited risk situations (A(8) < 2,5 m/s^2); exposures for which maintaining the general attention is enough (for instance, the medical control of workers that declare problems related to vibration exposure transmitted to the hand-arm system or the purchasing of specific equipment able to transmit lower values of vibrations, etc.);
- intermediate situations between the level of action and the exposure limit values (that is 2,5 m/s^2 < A(8) < 5,0 m/s^2), which determine the need of intervention, the editing of a bonification programme and the health monitoring;
- high risk situations (A(8) > 5,0 m/s^2) that determine an immediate intervention through the introduction of intervals of the exposed workers or the utilization of appropriate IPD (individual protection devices), while waiting for the implementation of technical interventions in order to bring the exposure conditions to values lower than A(8) = 5,0 m/s^2.

Reference ISO standards for vibrations transmitted to the hand-arm system

The assessment of the vibration exposure level transmitted to the hand-arm system is mainly based on the determination of the value of daily exposure standardised to an eighthour reference period, A(8) (m/s^2), estimated on the base of the root of the sum of the squares ($A_{(W)sum}$) of the root mean square value of the frequency-weighted accelerations, calculated on the three orthogonal axes *x*, *y*, *z*, in agreement with the ISO 5349 – 1 (2001) standard [3]. The equation to calculate A(8) is the following:

$$A(8) = A_{(w)sum}\ (Te/8)^{1/2} \qquad (1)$$

where:

Te : total daily vibration exposure (hours);

$A_{(w)sum}$: $(a^2_{wx} + a^2_{wy} + a^2_{wz})^{1/2}$;

a_{wx} a_{wy} a_{wz}: r.m.s. values of frequency-weighted acceleration (m/s^2) on the *x*, *y*, *z* axes.

The EN ISO 5349 standard "Mechanical vibration. Measurement and evaluation of human exposure to hand-transmitted vibration" is divided in two parts: the EN ISO 5349 – 1 and the EN ISO 5349 – 2. The EN ISO 5349 – 1 "Part 1: General requirements" specifies the general requirements for the measurement and the record of the exposure to mechanical vibrations transmitted to the hand on the three orthogonal axes (*x*, *y*, *z*). It defines the weighting frequency and the band filters in order to obtain a uniform and standardized comparison of the measurements. The obtained values can be utilized to calculate the negative effects of the vibrations transmitted to the hand for the octave band 8Hz-1.000 Hz frequency interval. Furthermore, as it is shown in figure 1, the normative defines the Cartesian axes system. The orthogonal reference system starts at the head of the third metacarpal segment, being the *z* axis parallel to the hand axis, the *y* axis perpendicular to the plan delimited by the *x* and *z* axes with a right-left orientation.

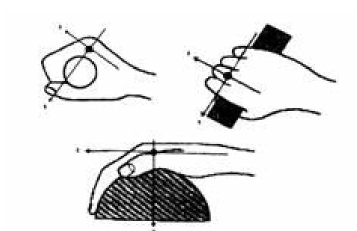

Figure 1. Definition of the measurement axes (ISO 5349)

The EN ISO 5349 standard – "Part 2: Practical guidance for measurement at the workplace" describes the cautions to be adopted in order to obtain representative measurements of vibrations and to determine the daily exposure to each operation with the aim of calculating the total value of vibration standardised to an eight hour reference period, A(8), according to the principle of the equal energy (daily exposure to vibration). In addition, the normative gives the means to determine all the relevant operations that should be taken into account when evaluating vibration exposure. The normative is valid for all situations in which persons are exposed to vibrations transmitted to the hand-arm system from portable machinery, manual guiding machines, vibrating tools or control devices of mobile or stationary machinery [4].

Data collection equipment

To measure the hand-arm system vibrations, instruments of different constructors have been used. More specifically, to detect the accelerations on the 6 models of blowers it has been used the Brüel & Kjǽr measuring chain, which consists in a 4506 Deltatron® 3 axes accelerometer and in a 1700 model 3 channels interface for human vibrations that has the function to amplify and transmit the signal to the measuring device made of a 2260 Investigator integrating sound level meter. All the other measurements have been done utilizing the Larson Davis SEN020 3 axes ICP accelerator connected to the 3 axes HVM-100 vibration measuring equipment. This instrument is more manageable than the previous one because it is smaller and lighter; furthermore, it can measure at the same time the vibrations on the three axes *x*, *y* and *z* and the relative vector sum. The utilized analysers have the rating certificate and satisfy all requirements the instrumentation type 1 stated by the CEI EN 61672-1-2 (former IEC 804). Before doing the measurements, all instruments have been rated using generators of sinusoidal vibration that provide a known pick acceleration (10 m/s^2 r.m.s.) at a given frequency (159,2 Hz). During each set of measurements, a stimulating calibrator has been applied to the accelerometer in order to verify the calibration of the entire measuring system on the three axes (*x*, *y*, and *z*) of the accelerometer. The utilized accelerometers have been firmly fixed on the handle of the machine, close to the hands of the operator, but not affecting the normal course of action. To fix the accelerometers on the machines, specific adaptors with two plastic bands have been utilized; while the accelerometer cables, in order to avoid distortions in the measured signal or eventual damages, have been fixed near the transducer with adhesive tape.

Characteristics and place of measurement

During the experimental phase of this survey, the sums of squares ($A_{(W)sum}$) of the root mean square value of the frequency-weighted accelerations have been measured with the appropriate instrument. These values, as is shown in the formula (1), calculated for an exposure time of Te = 8 hours correspond to the daily exposure values standardised to an eight-hour reference period A(8). However, since we have noticed that in the chosen farms, due to refuelling and interruptions, it is rare to reach eight working hours per day with the machines always on, it is more correct to consider a total vibration exposure time of seven hours (Te = 7 hours). Thus, in order to test a more realistic level of exposure for the operators, the respective A(8) referred to 7 hours of exposure have been calculated. Therefore, the formula (1) becomes:

$$A(8) = A_{(w)sum} \; (7/8)^{1/2} \qquad (2)$$

To make the measurements repeatable, it has been necessary to equalize the maintenance conditions of the machines. Before the experimental tests, all air and fuel filters have been cleaned and the spark plugs have been checked. Furthermore, all machines have been refuelled with the same kind and amount of fuel. The measurement of the vibrations given off by the shoulder portable blowers has been carried out during the hazelnut harvest in some farms located in the Monti Cimini area (central Italy). The acceleration values of the other portable equipment have been gained at the Faculty of Agriculture of Tuscia University, and more specifically at the botanical garden and the corporate didactic trial. The tests have been carried out during the regular working activity. In all machines, in correspondence with each measurement point and for each axes, the values of three samples have been first recorded and then averaged to obtained a single level of acceleration for each axes *x*, *y* and *z*. The EN ISO 8041:2005 standard, which defines the metrological method for the vibration measurement equipment, states that in order to reduce the error, it is proper to record a sample of at least 20 seconds [5].

Results

In table 2, all the accelerations related to the hand-arm system and measured directly are shown. For each column are respectively indicated the A(8) values referred to a seven hours exposure period and $A_{(w)sum}$ .For those machines held with both hands are indicated the values related to each limb, while for the blowers the measurements refer only to the right hand because the left one is not used. In any case, the calculation of the daily exposure level has been done considering the higher value.

Table 2. Hand-arm system vibration's values

Hand-arm system HAV					
Model		Operative conditions	$A_{(w)SUM}$ (m/s^2)		A (8) ref. T_e = 7 h (m/s^2)
			L	R	
1	**Blower Echo PB 6000**	working load	**N.R.**	**2,57**	2,40
2	**Blower Zenoah Komatsu EB 7000**	working load	**N.R.**	**2,60**	2,43
3	**Blower Shindaiwa EB 630**	working load	**N.R.**	1,27	1,19
4	**Blower Shindaiwa EB 8510**	working load	**N.R.**	1,99	1,86
5	**Blower Shibaura KB 60**	working load	**N.R.**	**4,22**	**3,95**
6	**Blower Efco SA 2062**	working load	**N.R.**	**4,71**	**4,41**
7	**Chainsaw Stihl Ms 250**	working load	**6,07**	**4,13**	**5,68**
8	**Hedge cutter Stihl Hs 85**	working load	**6,17**	**4,23**	**5,77**
9	**Brush cutter Efco SA 2062**	working load	**4,84**	**4,01**	4,53
10	**Brush cutter Echo srm-4605;**	working load	**4,62**	**3,83**	4,32
11	**Brush cutter Stihl Fs 250**	working load	**4,22**	**3,38**	**3,95**
12	**Brush cutter Shindaiwa Sk 45 F**	working load	**4,38**	**3,85**	**4,10**

As it is notable from the table, the machines indicated with the numbers 1, 2, 3 and 4 give off an acceptable hygienic level of vibrations. Indeed, the A(8) values referred to T_e = 7 h do not exceed the prevention values defined by the 2002/44/EC directive. More specifically, the Echo PB 6000 blower has a level of 2,40 m/s^2, Zenoah Komatsu EB 7000 of 2,43 m/s^2, Shindaiwa EB 630 of 1,19 m/s^2 and Shindaiwa EB 8510 of 1,86 m/s^2. The first two models are slightly under the limit of 2,5 m/s^2 fixed by the normative. Anyhow, these two machines have a $A_{(w)sum}$ level that correspond to the A(8) referred to 8 hours of exposure, just above the action level. In addition, it is important to notice that the A(8) values calculated for the Shindaiwa blowers do not reach any action limit and therefore, even for those working activities that take height hours, the Shindaiwa model guarantees the not overcoming of the limits imposed by law. The models 5, 6, 9, 10, 11 and 12, even if not overcoming the limit values of daily exposure and thus not representing a high risk situation, expose the operators to vibration levels higher than the action value. More specifically, the Efco SA 2062 blower with 4,41 m/s^2, the Efco SA 2062 brush cutter with 4,53 m/s^2 and the Echo srm-4605 brush cutter with 4,32 m/s^2 have high values that concerning prevention and health at work should be taken into consideration. The vibrations given off by the machines number 7 and 8 (Stihl Ms 250 chainsaw with 5,68 m/s^2 and Stihl Hs 85 hedge cutter with 5,77 m/s^2) correspond to A(8) values greater than the daily exposure limit value. Thus, being a high risk situation the employer must take immediate measures to lower the exposure, individuating the causes of the overcoming and taking the protection and prevention measures to avoid a new overcoming [1 - 2].

Daily duration of exposure

To make the employers able to organize adequate work schemes, respecting the health of the worker, the maximum daily duration of exposure for each machine has been calculated (table 3). To be more precise, the time needed to reach the limits defined by the 2002/44/EC directive in one day by a single worker it has been evaluated as follow:

- the daily duration of exposure to the action value (Ta), that is the time that a worker needs to reach the action threshold (A(8) = 2,5 m/s^2 HAV): $Ta = [A(8)^2/a_{hw}^2] \cdot 8$;
- the daily duration of exposure to the limit value (Te), that is the time that a worker needs to reach the limit value of exposure (A(8) = 5 m/s^2 HAV): $Te = [A(8)^2/a_{hw}^2] \cdot 8$.

Table 3. Exposure time to the action value and the daily limit

Model		a_{hw} [1] (m/s^2)	Daily duration of exposure to the action value (h)	Daily duration of exposure to the limit value (h)
1	Blower Echo PB 6000	2,57	7,57	24,00
2	Blower Zenoah Komatsu EB 7000	2,60	7,40	24,00
3	Blower Shindaiwa EB 630	1,27	24,00	24,00
4	Blower Shindaiwa EB 8510	1,99	12,63	24,00
5	Blower Shibaura KB 60	4,22	2,81	11,23
6	Blower Efco SA 2062	4,71	2,25	9,02
7	Chainsaw Stihl Ms 250	6,07	1,36	5,43
8	Hedge cutter Stihl Hs 85	6,17	1,31	5,25
9	Brush cutter Efco SA 2062	4,84	2,13	8,54
10	Brush cutter Echo srm-4605;	4,62	2,34	9,37
11	Brush cutter Stihl Fs 250	4,22	2,81	11,23
12	Brush cutter Shindaiwa Sk 45 F	4,38	2,61	10,43

The limit daily duration of exposure, so that the machines can be utilized without overcoming the A(8) limit value are shown in figure 2. It is evident that these durations plenty overcome the seven hours working period, which is the usual working period for an operator. Only in two cases the operators could reasonably reach the limit value defined by law: with the Stihl Ms 250 chainsaw (n.7) if the worker would be exposed more than 5,43 hours and with the Stihl Hs 85 hedge cutter (n.8) in case of duration of exposure greater than 5,25 hours.

[1] The ahw values correspond to the $A_{(W)SUM}$ acceleration values.

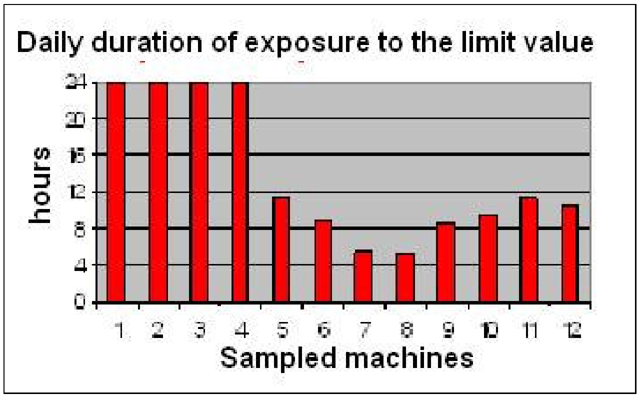

Figure 2. Limits of daily duration of exposure

On the other hand, the remarks on the daily duration of exposure to the action limit (figure 3) are quite different. Indeed, only for the Echo PB 6000 (n.1), the Zenoah Komatsu EB 7000 (n. 2), the Shindaiwa EB 630 (n. 3) and the Shindaiwa EB 8510 (n. 4) blowers there are no risks of reaching the action value in the seven hours working period, since their limit duration at action are 7,57, 7,40, 24,00 and 12,63 hours respectively. For all the other models, the action level is reached within the working day. The action times of the Shibaura KB 60 (n. 5) and the Efco SA 2062 (n. 6) blowers (2,81 and 2,25 hours respectively) are very similar to those of the four brush cutters (n. 9-10-11-12). For the other two remaining models, the chainsaw (n. 7) and the hedge cutter (n. 8), the caution level is rapidly reached: for the first machine after 1,36 hours and for the second one after only 1,31 hours.

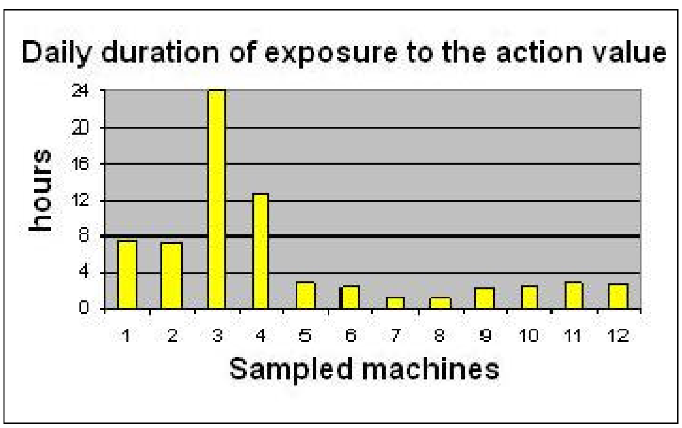

Figure 3. Daily duration to the limit action value

Conclusions

The present research, evaluating the risk to the hand-arm system due to vibrations, has given an overview of the risks to which operators are exposed when using these machines. In order to make a correct assessment, all the laws and the standard normative about this issue have been taken into account. More specifically, we referred to the 2002/44/EC directive, which defines all the specific requirements regarding the exposure of workers to the risks arising from mechanical vibrations, and to the ISO 5349 standard that gives details for the hand-arm system. All the acceleration levels standardised to an eight hour reference period but referring to a seven hour exposure period (A(8) ref. 7h Te) have been recorded. In order to verify if the sampled models respond to the safety requirements, the obtained data have been compared with the prevention values fixed by the normative. The vibration levels given off by the machines and measured during the real working conditions, in some cases do not respect the actual normative. Still, significant differences can be noticed among the models. The best machines from an hygienic point of view are the Shindaiwa EB 7000 and the Shindaiwa EB 630 blowers, for which has been recorded a A(8) ref. 7h value lower than the action limits. The Echo PB 6000 and the Zenoah Komatsu 7000 models expose the workers to low action values, but if we consider a working day of 8 hours the action limit is overcame reaching 2,57 and 2,60 m/s^2. The Shibaura KB 60 and the Efco SA 2062 blowers, as well as the four brush cutters, expose the workers to levels greater than the action ones. In any case, the worst result from a hygienic point of view comes from the chainsaw and the hedge cutter. Indeed, the vibration levels given off by these machines overcome the limit value. In conclusion, for the hand-arm system exposure, the study has shown low ($A(8) < 2{,}5\ m/s^2$), intermediate ($2{,}5\ m/s^2 < A(8) < 5{,}0\ m/s^2$) and high ($A(8) > 5{,}0\ m/s^2$) risk situations.

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[2] Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC).
[3] UNI EN ISO 5349-1:2001 "Mechanical vibration - Measurement and evaluation of human exposure to hand- transmitted vibration - Part 1: General requirements"
[4] UNI EN ISO 5349-2:2001 "Mechanical vibration - Measurement and evaluation of human exposure to hand- transmitted vibration - Part 2: Practical guidance for measurement at the workplace"
[5] EN ISO 8041:2005 "Human response to vibration - Measuring instrumentation"

The contribution to the programming and executing of this research must be equally divided by the authors.

Use of simulation techniques to improve tractor operator safety

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Abstract

In the automotive sector, virtual prototyping allows to reduce time and costs of designing. Crash tests can be simulated by computer models, by using multibody-FEM techniques and, among the solvers available on the market, Madymo (TNO Automotive Safety Solutions - NL) has been developed for being particularly suitable for studying problems of impact and crash mechanics. Born as a general-purpose multibody code, Madymo includes (i) powerful routines of contact detection, (ii) libraries of numerical dummies (which reproduce the dynamical behaviour of the real instrumented dummies, with the aim of evaluating injuries to the occupants) and (iii) the principal active and passive safety systems as different kinds of belts and airbags.
We have extended, to our knowledge for the first time, these techniques of numerical simulation to work accidents, analysing the reliability of safety systems aimed at protecting workers and proposing an original approach for their functional design and optimisation. In this paper, the results pertinent to the roll-over of a wheeled tractor with narrow track, placed on a sloping ground, is presented as an application, with the purpose of evaluating the safety performance of a pelvic restraint system.

Keywords: roll-over, restraint systems, dummies, injuries, functional design**.**

Introduction

Agricultural and forestry tractors are often involved in accidents, even fatal, caused by the overturning of the vehicle (Ispesl 2002, Comer *et al.*, 2003). With the aim of reducing and limiting the number of work accidents, the European Community directive concerning the homologation of agricultural and forestry tractors for road circulation (EC 2003, EEC 1979, EEC 1986, EEC 1987, ISO 1989, OECD 2005) has compelled manufacturers to equip the tractor with a ROPS and a seat belt anchorage. Pelvic restraint systems are, hence, installed on the tractors, fastened to the driver seat or, less frequently, to the tractor chassis (Molari and Rondelli, 2007). During tractor roll-over, this type of seat belt restraints the driver movements inside the clearance zone maintained by the ROPS (Nichol, 2005). Seat belts are an important tool for protecting drivers also when involved in on the road head-on collisions (Myers, 2002).

In this area of high scientific interest, we propose a new approach to the analysis of the effectiveness and to the optimal functional design of different type of operator restraint systems, based on multibody techniques. The performance comparison is indeed made by evaluating the driver biological injuries (NHTSA, 1998; Ambrosio, 2001; EuroNCAP, 2004), by means of the multibody-FEM code Madymo (MAthematical DYnamic MOdels), produced by TNO Automotive Safety Solutions (NL). In this environment, the analysis of problems of impact dynamics is allowed thanks to powerful routines of contact detection. More over several types of numerical dummies of different complexity are made available to the user, as models of seat belts and airbags (TNO Automotive Safety Solutions, 2007). In particular, the numerical dummies allow to simulate the dynamic behaviour of the real instrumented dummies, commonly used in the crash tests for road vehicles. As it is well known, dummies present suitable joints calibrated on the basis of the knowledge obtained in the field of biomechanics, through tests carried out on volunteers and dead bodies.

For such reasons Madymo is commonly utilised for safety problems concerning road vehicles, to design the structures and the active and passive safety devices aimed at the protection of the occupants. This approach clearly allows to lower the times and, above all, the costs of designing, as the experimental study carried out through crash tests is reduced only to the final validation of prototypes.

In a very original way, we propose to extend these techniques to the field of workplace accidents and safety, by analysing the reliability of the systems aimed at protecting workers, with the aim of improving their performance (Mangialardi and Soria, 2005). In this paper, in particular, the results pertinent to the roll-over of a wheeled tractor with narrow track, placed on a sloping ground, where the resultant of weight forces falls outside the supporting convex polygon, are reported. The purpose is to evaluate, by means of the proposed approach, the safety performance of a pelvic restraint system.

Materials and methods

<u>*The tractor*</u>

The 3D multibody model of the tractor considered in the paper is represented in Figure 1, where the inertial reference frame utilised is also reported. It is a narrow track wheeled tractor equipped with two ROPS safety frames. The model is composed by seven parts, the body frame, the four wheels, the front and the rear safety ROPS. Moving from the drawings of a commercial model, selected among the ones available on the market, the geometry of each part has been reproduced in Madymo, by using native hyper-ellipsoidal surfaces.

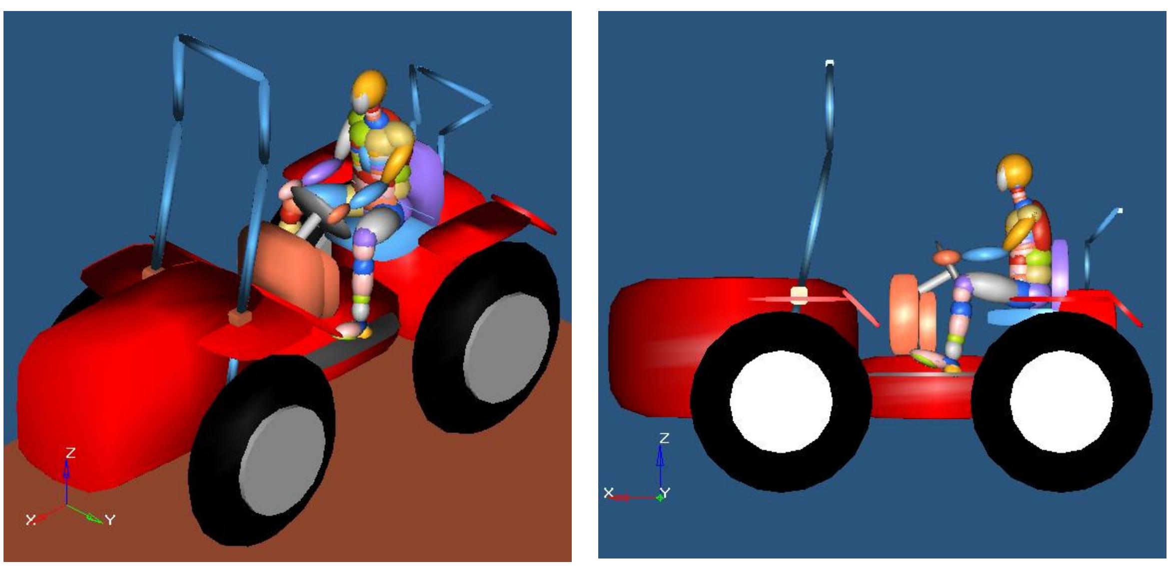

Figure 1. 3D and lateral view of the dummy-tractor model

To each of these surfaces a body reference frame is rigidly connected and the whole spatial distribution of the mass (centre of gravity and inertia tensor) is declared with respect to this frame. The entire tractor model is then obtained by constraining the parts each other, by means of kinematic joints. The safety frames are supposed to be fixed to the body frame, by means of two brackets. Each of the four wheels is connected to the body frame by a cylindrical joint. The whole tractor model is then declared in the input scenario by means of a free joint.

When the tractor does not have any contact taking place with the ground, e.g. in a particular phase of the accident, the model has, in conclusion, 10 degrees of freedom (d.o.f.), the 6 rigid body motion d.o.f. and the 4 wheel rotations.

The ground

The accident scenario is more over composed by the ground where the tractor is leant on by unilateral contacts. Each part of the tractor could actually come into contact with the ground during the accident dynamics. These situations can be foreseen by simply declaring into the Madymo input file all the possible contacts that the solver could have to detect during the numerical simulations. The resultant number of d.o.f. that characterises the scenario in each instant of time depends, indeed, by the contacts taking place at that time.

In the paper, as anticipated, a typical roll-over accident is considered, and the ground is supposed to be composed of three planes of different slope (Figure 2). At the beginning of the simulated dynamics, the tractor is positioned on the plane having the highest slope, in a way that the resultant weight force is able to make the tractor rolling over.

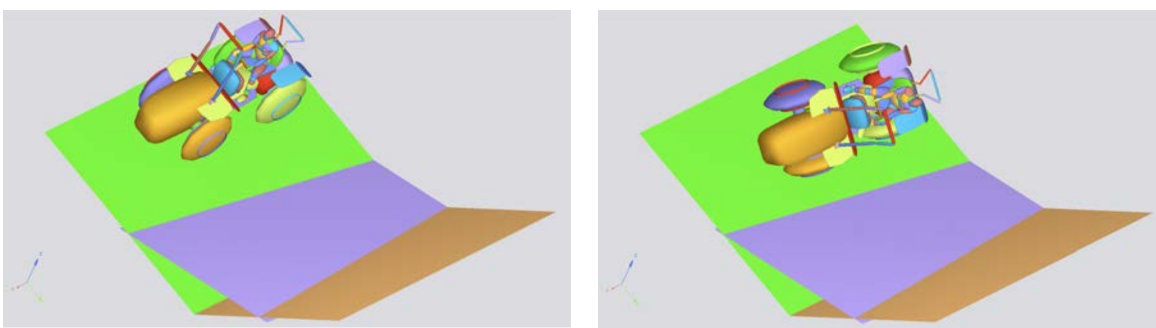

Figure 2. The initial position of the simulations (on the left) and an intermediate instant of time (on the right)

The dummy

The tractor operator is simulated in the scenario by means of a numerical dummy chosen among the ones available in the Madymo libraries, the Hybrid III 50th percentile male dummy, which is the most frequently utilised in the crash tests and in all the NCAP programs (New Car Assessment Programs). The dummy numerical models available in the Madymo libraries are multibody systems, composed by simple geometry bodies and/or FEM models assembled with kinematics joints and restraints, which reproduce the connections present in the instrumented dummies usually employed in the crash tests.

The evaluation of biological damages by multibody techniques: The injury parameters

By means of Madymo, an estimation of the biological damages that occur to the occupants can be obtained through the evaluation of the values of the so-called injury parameters. Therefore the injury severity can be evaluated by utilising the corresponding injury criteria, i.e. by comparing the calculated value of each parameter with a certain threshold value. This thresholds have been established with the progresses made in the field of biomechanics, by carrying out experimental test campaigns on volunteers and dead bodies.

The injury parameters and the corresponding criteria utilised in the paper have been (NHTSA, 1998; Ambrosio, 2001; EuroNCAP, 2004):

- the Head Injury Criterion (HIC) for the estimation of head injuries. It is evaluated by means of a suitable integral average of the head centre of mass acceleration in a time window of not more than 36 ms. The criterion threshold value is 1000 $(m/s^2)^{2.5}$s during an impulsive frontal shock. It has to be stressed that head sudden rotations are not considered in HIC evaluation.
- the Neck Injury Predictor (N_{ij}) for the estimation of neck injuries. It is evaluated by the calculation of the forces and moments acting on the occipital region. The values achieved by these quantities are put in a suitable dimensionless form by using critical values, that depend on the dummy typology and on the neck loading conditions. They do exist four types of N_{ij}, indeed, one in each of the possible cases, tension – extension (N_{TE}), tension – flexion (N_{TF}), compression – extension (N_{CE}), compression – flexion (N_{CF}). In all the cases, to not have severe damages to the neck, it has to be $N_{ij} < 1$.

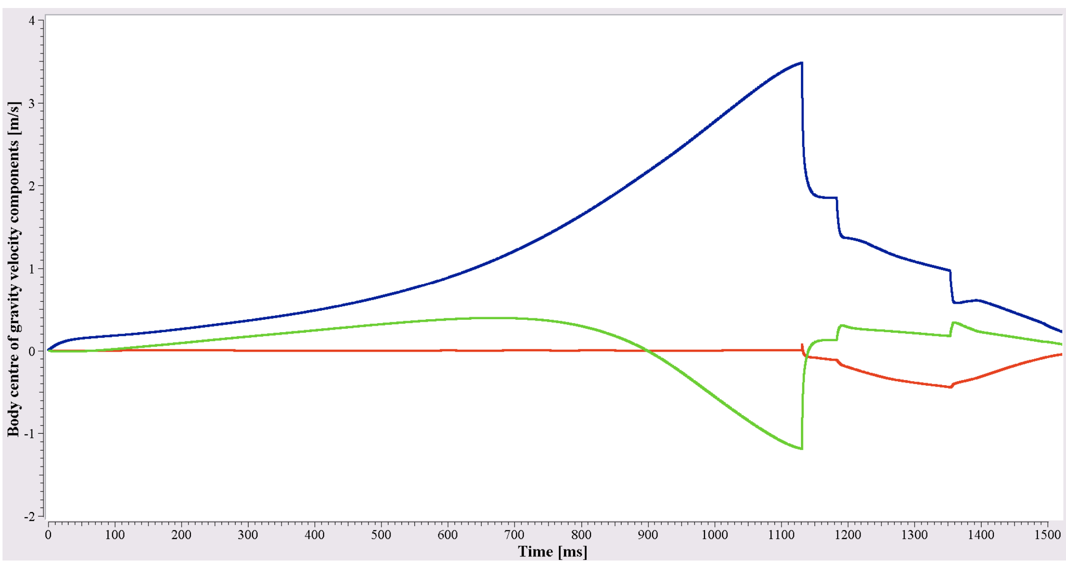

Figure 3. The components of the centre of gravity velocity vector of the tractor body [m/s] as functions of time [ms] (red along the *x*-axis, blue along the *y*-axis, green along the *z*-axis)

- the 3 ms Criterion (3ms) for the estimation of damages occurring to thorax. Thorax injuries are the most critical after head injuries. To not have severe damages, the thorax centre of mass has not to undergo an acceleration higher than 60 g for a time longer than 3 ms.
- the Femur Force Criterion (FFC), for the estimation of femur damages. It allows the evaluation of femur traumas by calculating the longitudinal force acting on each femur. The criterion threshold value is 10 kN.

- the Tibia Index (TI), for the estimation of tibia damages. Moving from the forces and moments acting on the inferior parts of the legs, it is evaluated in a way similar to N_{ij}. The threshold values are 0.4 or 1.3, respectively, for a highly secure or for a less certain estimation of the tibia injury severity.

Results

<u>*The roll-over kinematics*</u>

In Figures 3 and 4 the main kinematic quantities are represented. They are the velocity vector of the centre of mass of the tractor body and its angular velocity vector. The main shock coming to the system when it hits the ground on its side happens at time $t^* \approx 1130$ ms from the beginning of the simulation. In correspondence of this instant of time, indeed, one can see a fast variation of all the components of the two quantities. Other shocks follow the first one and can be, of course, singled out in the two diagrams in a similar way. In figure 5 the snapshot of the time t^* is reported.

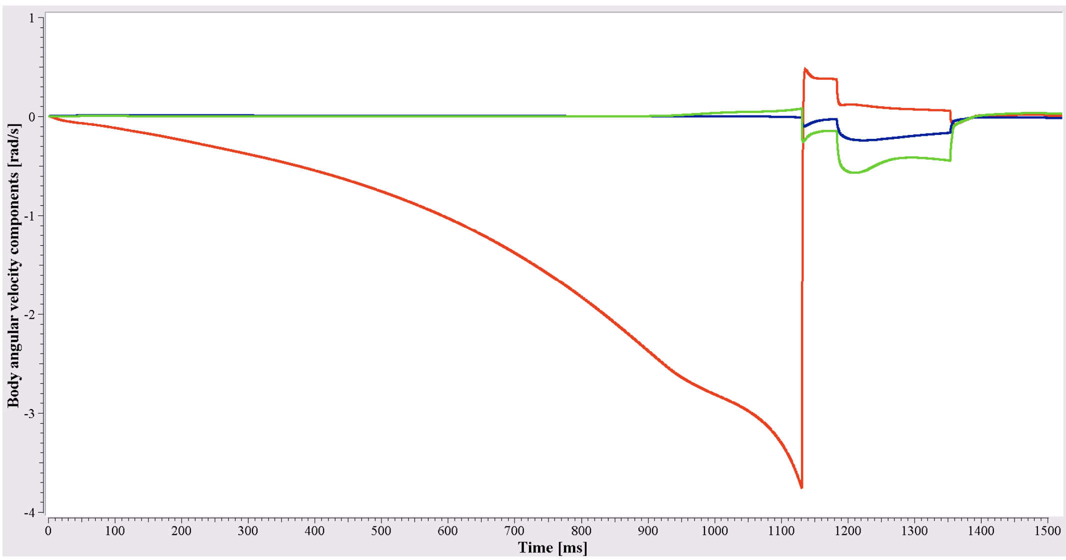

Figure 4. The components of the angular velocity of the tractor body [rad/s] as functions of time [ms] (red along the *x*-axis, blue along the *y*-axis, green along the *z*-axis)

In figure 6 the final time of the simulations is represented. In this Figure the reader is able to see all the parts of the system which are in contact with the ground. The algorithm utilised to detect a contact is, indeed, basically related to the evaluation of the virtual relative penetration between two interacting parts. This quantity allows the evaluation of the reactive forces due to the contact, since a spring-damper system is considered acting at the contact point. It is useful to stress that, indeed, the body surfaces are supposed to have hyper-ellipsoidal form just because in this way the contact region is in each case reduced to a single contact point as the body stiffness approaches infinity. The stiffness and the damping coefficient have, hence, to be accurately chosen by the user, by modelling the dynamical response of the considered contact, in term of relative compliance and energy dissipated. This allows, in a certain, approximated way, to take into account the plastic deformations of hitting parts by choosing the relative penetration equal to the depth of the plastic damages.

<u>*The biological traumas coming to the operator*</u>

The functional design of the passive protective devices can be carried out by comparing the operator biological traumas in the cases he is restrained with different kind of systems or not restrained at all. In this section the comparison between the case of operator restrained with a 2-point pelvic belt and the non-restrained operator will be shown. In Table 1 one can see the values of several injury parameters in both the cases. In particular the biological damages in absence of restraining systems are severe as expected. Injury parameters overcome the corresponding threshold values in the cases of the head, the neck, the thorax and the tibias.

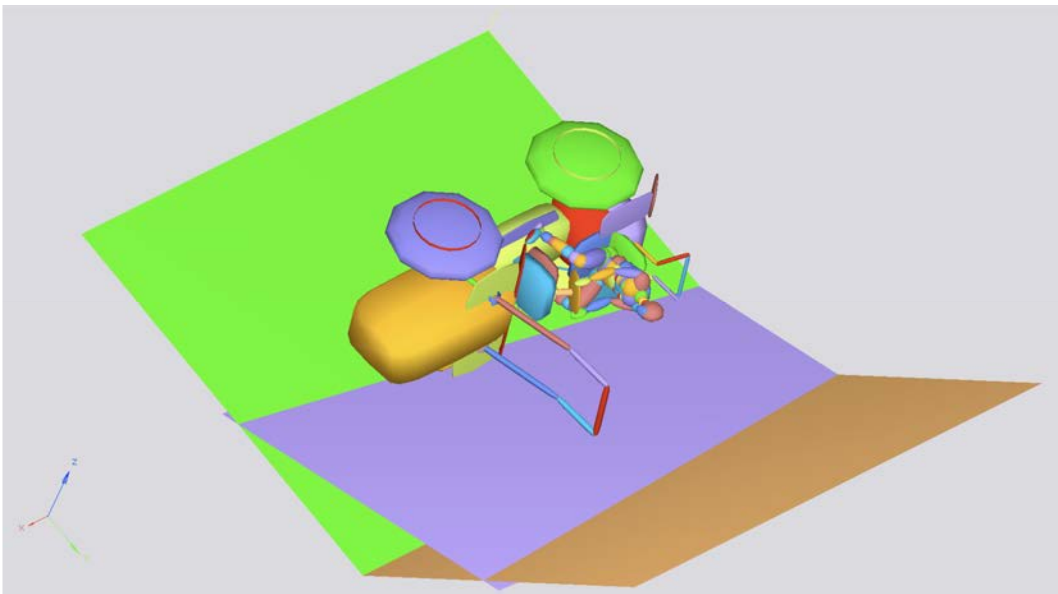

Figure 5. The instant of time in which the main shock takes place (1130 ms)

The possibility offered by the pelvic belt of confining the operator in its safety volume reduces a lot all the injuries, as also expected. In this case, indeed, the criteria threshold is overcome only for the tibias, but less than in the case of non-restrained operator.

Table 1. Comparison of the main injury parameters in the cases of (i) non-restrained dummy and (ii) dummy restrained by a 2-point pelvic belt

Injury Parameter	Injury Criteria	non-restrained	2-point pelvic belt
HIC $[(m/s^2)^{2.5}s]$	< 1000	1465.4	124.65
N_{TE}	< 1	1.1144	2.2696E-01
N_{CF}		5.5008E-02	9.6685E-03
3 ms $[m/s^2]$	< 60 g	718.92	110.42
FFC [kN]	< 1E+04	1.9145E+03	4.0524E+02
TI	< 0.4	1.2021	6.0736E-01

To completely avoid also this kind of injuries a side-bag could be employed, with an opportune counter-reacting structure.

Conclusions

A multibody approach aimed at the functional design and performance optimisation of safety restraint systems for tractor operators is proposed in the paper. To our knowledge, for the first time a similar approach is utilised in the field of work accidents and, in particular, accidents related to the utilisation of agricultural machines. As an example of this possibility, the scenario of a typical roll-over accident has been reproduced in the commercial multibody-FEM Madymo environment (TNO Automotive Safety Solutions - NL).

We show how it is possible to evaluate the severity of the injuries happening to the operator, which becomes the fundamental parameter that the performance of a safety restraint device depends on. By comparing the amount of biomechanical damage to the operator, in the cases different protective systems are employed, is indeed possible to evaluate the safety performance of each device and, hence, to proceed to its optimal functional design.

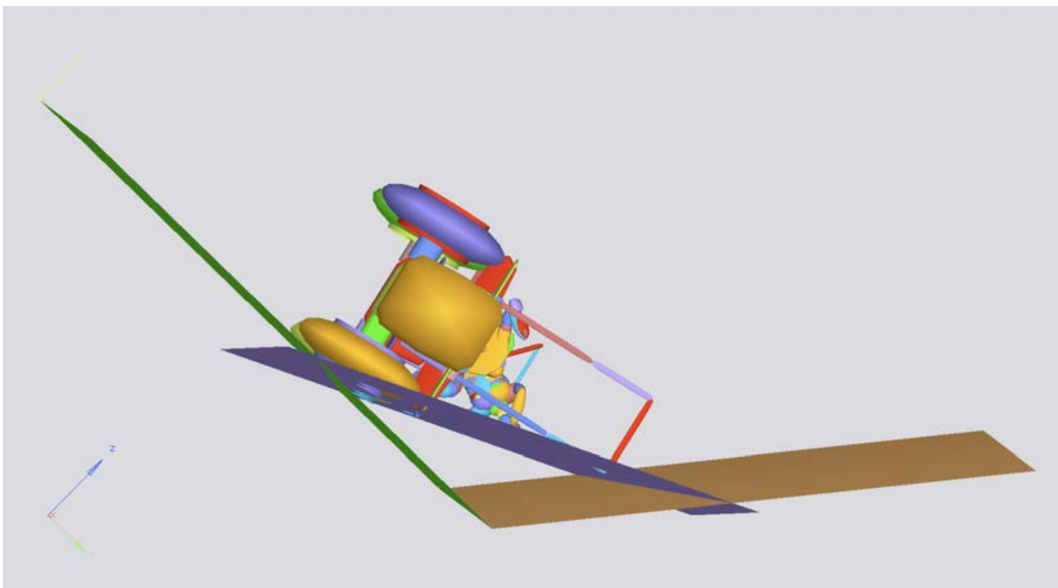

Figure 6. End of the simulation: it is possible to visualise the contacts between the dummy-tractor system and the ground

Acknowledgements
Each of the authors contributed in equal parts to this work.

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Coping with the risk in the wine cellar: the use of check lists to identify hazards

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Abstract
Safety has become an imperative in Europe, in all aspects of the human life. Only improving safety at every level, the length and the quality of life can be increased. The aim of the present work was to set up a method of analysis of the safety levels in the wine industry. To assess occupational risks at the workplace in the wine cellars, we have collected information by using check lists expressly created for this research. The check lists were three, in order to analyze the safety under three aspects: safety of the operator, of the food and of the environment. To each answer we have assigned a score from 1 to 4. The scores are plotted in a radar graph which allows an immediate representation of the "strength and weakness" points of the firm. Food safety has underlined the problem of the formation of the workers (especially if seasonal) and of the traceability (tracking) and the tracing of the product. Within the worker safety, a critical point represented by the management of the emergencies, mainly due to the characteristics of some wine cellar, located in old buildings difficult to manage in terms of safety. In terms of environmental safety, clearly emerges indifference, a closing toward the recourse to energetic alternative sources. The critical points so collected allow the entrepreneurs to quickly formulate a synthetic judgment about the safety levels into their firm. In addition, the method is characterized by its "modularity": the same approach can be used also for the management systems of operational safety and health and of environmental control.

Keywords: integrated safety, control list, radar graphs.

Introduction

Every few minutes somebody in the EU dies from work-related causes. Furthermore, every year hundreds of thousands of employees are injured at work; others take sickness leave to deal with stress, work overload, musculoskeletal disorders or other illnesses related to the workplace (OSHA fact sheets, 2005). All this despite safety has become an imperative in Europe, in all aspects of the human life. Only improving safety at every level, the length and the quality of life can be increased.

Since the employ is the place where we spend the most part of our time, the reduction of the accidents at work and of the professional illnesses contributes in substantial way to improve this quality and this expectation of life. It's important to ensure the health, safety and welfare at work of the employers. Hazards in the workplace, in fact, can be a risk, and need to be managed. So, risk management must become a component of best practice management. The main aim of occupational risk assessment is to protect workers' health and safety. Risk assessment helps to minimise the possibility of the workers or the environment being harmed due to work-related activities. It also helps to keep your business competitive and effective. Under health and safety laws, all employers must carry out regular risk assessment (OSHA, 2007).

Farming has long been recognized as a hazardous occupation: farmers are exposed to a variety of hazards; they often work long hours under severe time constraints and many use older model farm equipment that lack safety features (De Roo, 2000).

Despite recent improvements in Italian directives concerning safety at the workplace, however, agriculture, in fact, still remains one of the sectors of economic activity in which accidents are still occurring with a high frequency (INAIL, 2007).

In Friuli - Venetia Giulia (North-East of Italy), the wine production sector is particularly important, both from the economic and of the public image point of view. But despite this development, very little information is available concerning safety levels. Consequently, in this direction we have turned our research by using check lists to carry out a survey able to identify hazards associated to the work in the wine cellars. The check lists were also used during a previous work (Gubiani et al, 2007; Gubiani et al. 2002; Zappavigna et al. 2002). The score obtained with this study represents a system to determine the possible risk level. The system of attribution of the score allows for a reasonably accurate evaluation and shows a good agreement with the level of risk in the wineries, but is not easy to fix it. It's necessary to train people to compile the check list.

Materials and methods

The aim of the present work was to set up a method of analysis of the safety levels in the wine industry. To assess occupational risks at the workplace in the wine cellars, we have collected information by using the check lists, that represent a rapid tool already used in previous works (Gubiani et al, 2007; Gubiani et al. 2002; Zappavigna et al. 2002). The check lists were three, (Tab. 2) in order to analyze with an integrated approach the safety under three aspects: safety of the operator, of the food and of the environment. This method was based on 10 macro indicator. To each answer of the check lists we have assigned a score from 1 (to indicate the most critical situation) to 4 (for the optimum one).In this way, with a simple algorithm, every macro-indicator can be evaluated, by investigating 3 aspects:

- the "significance" (**R**) of the problem (to be more precise: how important is considered a particular aspect by the firm we are studying)
- the "structural-plant/thecnological" aspects (buildings, plants, etc.)(**S**)
- the "organizational managerial" ones (**E**) (for example: the division of the duties).

If we had more questions for factor, we calculated their average. Finally, for each aspect we multiplied the 3 factors. By multiplying them, we can calculate the priority level (P):

$$\mathbf{P = R \times E \times S}$$

The value we obtain, represented by a number between 1 and 64, gives us some first indication about the actions to undertake for the continuous improvement of the safety management.

SCORE	EVALUATION
1-16	Insufficient
17-32	Sufficient
33-48	Good
49-64	Very good

Table 1. Score Assignment

The scores are then plotted in a radar graph (Fig.1, 2, 3) which allows an immediate representation of the "strength and weakness" points of the firm. The global "safety degree" of a firm can be so represented by the area of the graphics. Data have been collected in a sample of 25 wineries, located in Friuli-Venezia Giulia (North-east of Italy), during 2006-2007. They covered all geographical areas (lowlands, high plain and hills), production volumes (from 1,000 hl to 50,000 hl) and production types (high or medium quality). Before using the check list, our collaborators have been trained about point's assignation. The above data were inserted into a Microsoft® Excel worksheet and then processed using the Cohort® ver.6 statistics software.

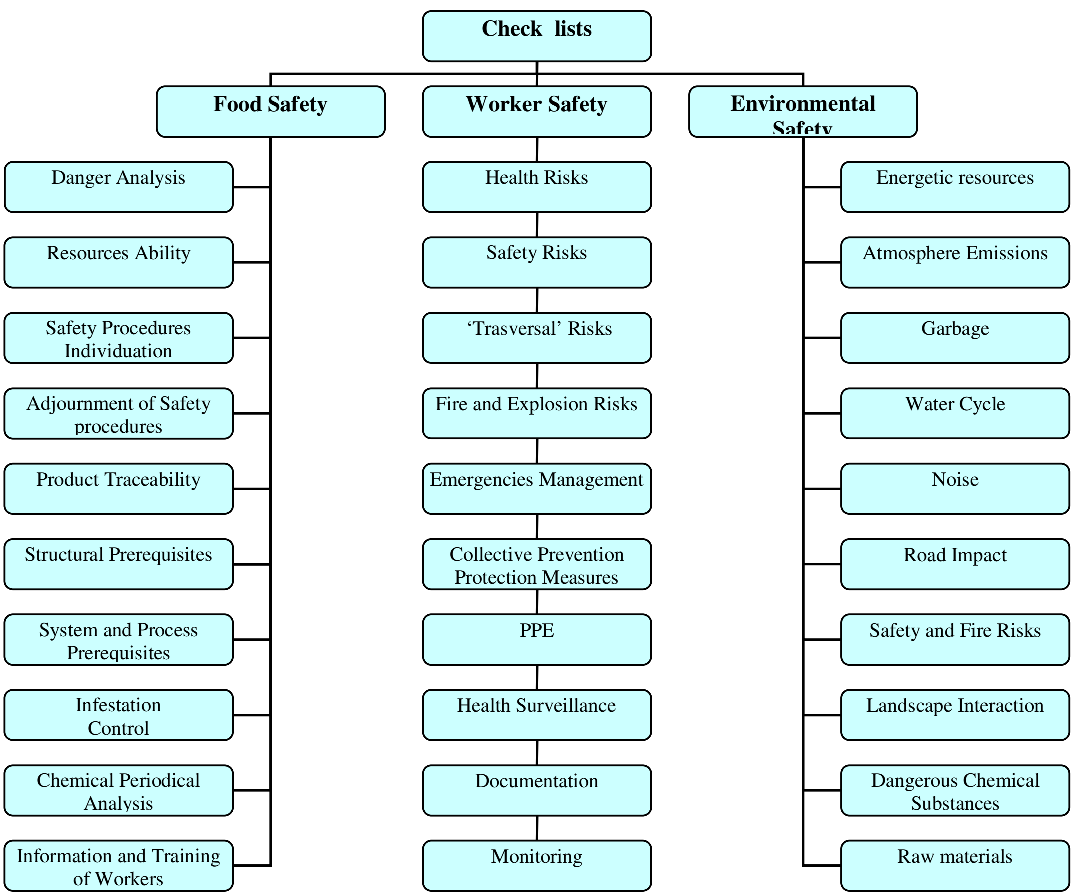

Table 2. General scheme of the check list

Results

The analysis of the risks gives us a summary of the situation in the wineries. This allows a discussion over the three main areas.

The first area we have analyzed (fig. 1) shows that generally all the wineries record a medium score. The lowest value is obtained by the question concerning the information and training of personnel and it's due to the presence of a lot of temporary workers. The employers, in fact, are certainly aware of the necessity of a theoretical and practical preparation of the whole working personnel inside the firm, both for the guardianship of the safety the health of the workers and for the control of the quality of the foods. The necessity, however, in determinate periods, of huge temporary manpower, not always easily available, makes to fall the choice on that a little specialized, often foreigner and without experience. The brief period of permanence of the workers makes the formation and the training not easily practicable but these workers suffer the high frequency of accidents.

Another emerged critical point is represented by the traceability of the product, resulting from a lacking or incomplete application of the system HACCP (the systematic preventive approach used in the food industry to identify potential food safety hazards). The same low score is also recorded by the question regarding the application, maintenance and update of the safety procedures: this is a crucial point in order to have, in the course of time, an efficient system of food safety control. The high score (close to 40) obtained by the area concerning the analysis of dangers and the chemical periodic ones are due to the easiness in the control of these macro-indicators and to the fact that many dangerous chemical parameters are controlled by law. Another important note is represented by the lack of a very good score in all cases. This still means a low attention in the food safety in the wineries, even if the wine is considered as a healthy food.

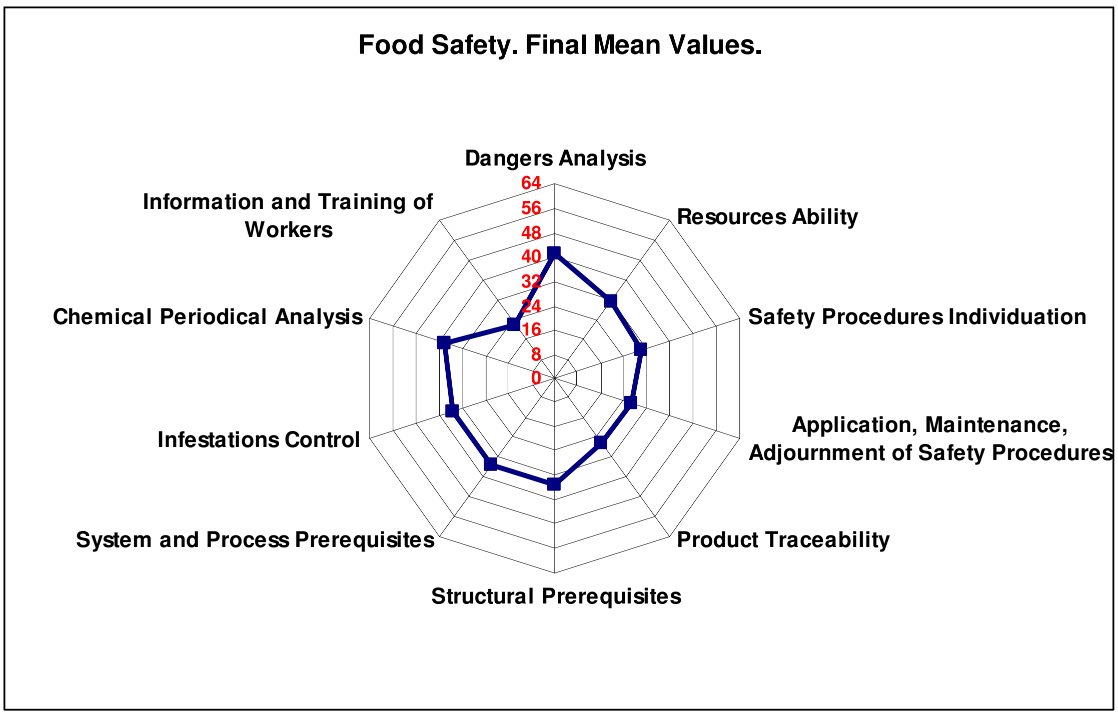

Figure1. Food safety: final mean values

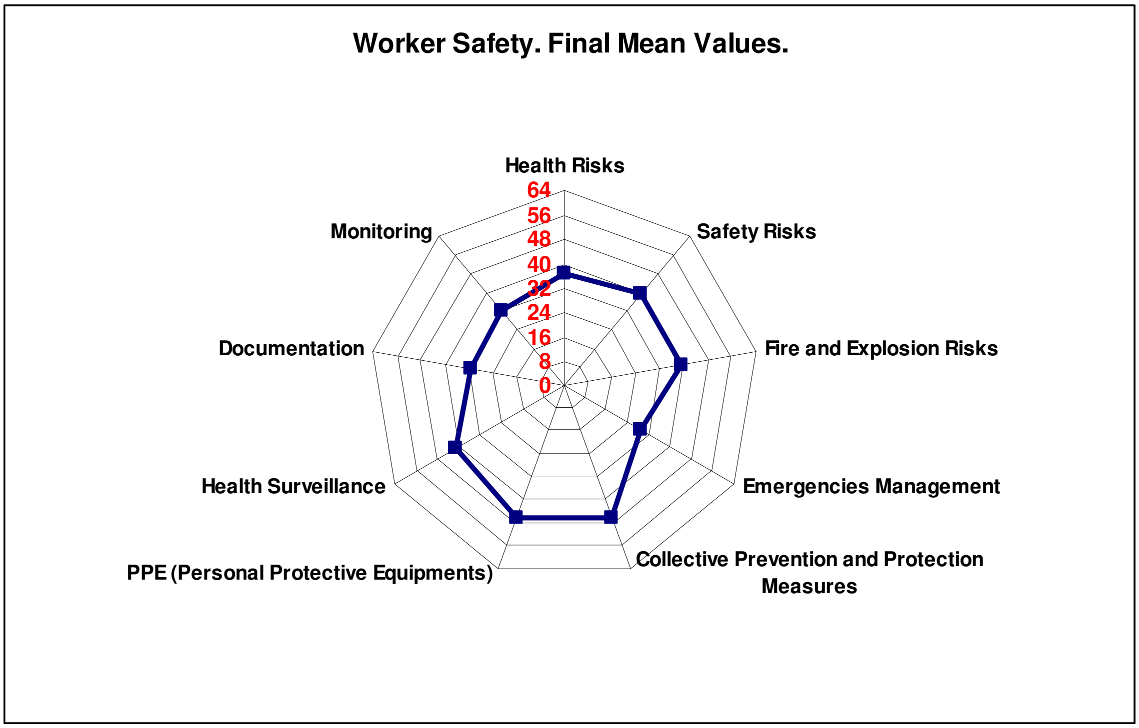

Figure 2. Worker safety: final mean values

The macro-indicator pertained to the safety of the operator (fig. 2) shows the greatest problem in the management of the emergencies. This is what clearly emerges in this study, due to a lack of suitable plans, lack of system of signs, insufficient training of the workers and often imputable to the same characteristics of some wine cellar, located in old buildings, even of great beauty, but difficult to manage in terms of safety. This is a great problem in safety, because nobody is trained to cope with emergency: this underlines a lack of culture of prevention that often dramatically is translated in case of accidents. The monitoring is on the same level of score and this depends on a lower level of culture of prevention; the monitoring must be always carried out in order to obtain a high safety. So, if monitoring records a low score, also the documentation is at same level. More attention has been found in the PPE equipment and in the collective prevention and protection measures (score about 48). This latest indicator is provided for law in almost all cases.

As it regards the environmental safety (fig. 3) what clearly emerges is an indifference, a closing toward the recurs to alternative energetic sources.

A better use of energetic resource is a new issue for wineries. The value found (the highest one) is due to a scarce attention, up to the present, paid at this aspect and only in the recent buildings of the wine cellars a technology in oenology machine or in building construction with energy meter is adopted. In particular, the wineries still haven't adopted machinery with low energy consumption and the renewable sources of energy (i.e. photovoltaic panels) are not still installed. The recovery systems (water, heat, etc) are used only in a sample case, not in all wineries. Also in this case the best score was obtained by the organization and by the sensibility of those people who live around the wineries, more interested in a better use of energetic resources.

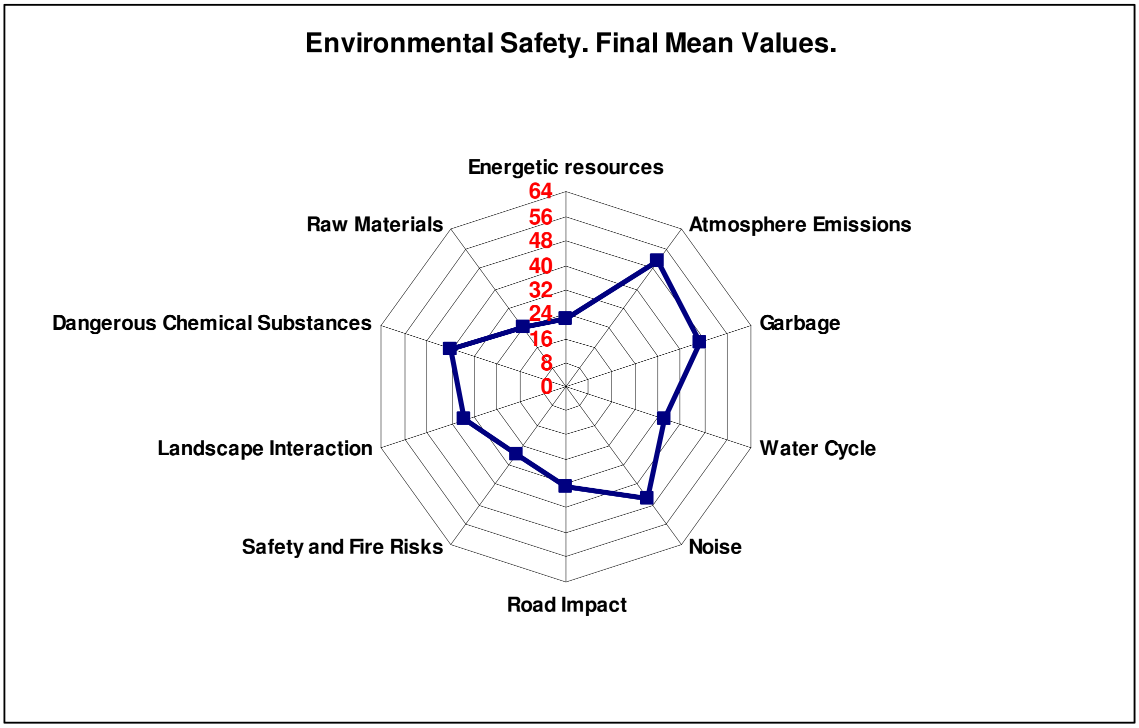

Figure 3. Environmental safety: final mean values

The aspects with a great impact are represented by the raw and auxiliary materials whom input/output doesn't verified the environmental preservation. In the wineries, on the other hand, it's necessary to use much stuff (material for filtration, bottling, package, pesticides, etc.) and is very problematic to control all. Another critical aspect is correlated to the cycle of water. The winery usually consumes a lot of water, that and in this area of Italy abounds: only the new wineries paid attention to reduce or recovery it. Aspects under control are those controlled by law (air emission, hazardous waste, noise, solid waste); the landscape interaction has a good score because many wineries practise the 'tourism of wine'. So, the presence of tourists in wineries or winery insertion in the tourist itinerary aids the winery choice to a good landscape insertion of the buildings and the vineyard.

Conclusions

The use of the check lists to collect data has allowed an immediate representation of the real condition of a farm from the safety point of view: this is important especially in the wine-cellars sector of Friuli-Venetia Giulia, in which there is a lack of studies about safety levels. We have also obtained a picture of the sensibility to the safety problem and the score, also it is not a very fine system for the analysis, is sufficient for the evaluation of the situation of the wineries checked over. Therefore, if for a particular aspect, the score is high; this means that must be controlled by the owner. If the score is low, that particular aspect is under control. In this work we found a high score for those aspects that have a specific regulation (waste and dangerous chemicals) while for others the score is lower. The aspects concerning farm choices (energetic resource, water cycle) have a big impact because, until now, they have been neglected. The choice made in this work, which is to show the aspects by radar graphics, allows a fast representation of the phenomena: in addition, this type of graphic is still used for taste analysis of the wine and so is well known by the winemakers.

At the last, this work can allow a first assessment of the wineries, to discovery the critical points, and can be performed by the wine maker itself.

The method is characterized by its "modularity": the same approach can be used also for the management systems of operational safety and health and of environmental control.

With this study we believe to increase the safety culture in viticulture and in the agriculture sector in general, because only throughout the culture of safety a decrease of the accidents and professional disease will be possible; we could also have a better environment of work for younger people, that could in this way choice to remain in the agriculture sector.

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Some dynamic considerations for agricultural tractor rollover

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Abstract
The potential for tractor rollover exists in some applications within agriculture. To help minimise the danger to the tractor driver Roll-Over Protective Structures (ROPS) were introduced some time ago along with corresponding international testing procedures. Some deaths and serious injuries resulting from failure of ROPS however still occur. This has led to recent renewed interest in tractor rollover research to gain an understanding of the processes involved. The impact that could potentially be experienced by the ROPS is a function of the energy available at the start of rollover. This paper presents some of the initial work on rollover by considering different initial conditions; in particular, the theoretical difference in available energy for lateral rollover on different planes together with the inclusion of forward velocity. Measured data pertaining to 102 narrow type tractors fitted with front ROPS, with mass variation between 700 and 2700 kg, was used to calculate the available energy. Some addition considerations complicate the analysis, for example, the coupling of forward momentum and lateral roll when forward velocity is included.

Keywords: energy, ROPS, velocity, impact.

Introduction

Tractors are particularly prone to rollover due to a number of reasons; unlike road bound vehicles they tend to have a much higher centre of mass (COM) position, they are exposed to large external loads which may arise from implements, they can traverse and work on extreme undulations. Changes in amount of fuel carried, payload and the drying action of the sun on the terrain can change subtly and in combination can lead to a major overall change in stability conditions (Stockton et al., 2002). In addition, many tractor-implement combinations and a large number of operating conditions give rise to infinite potential rollover scenarios with some more likely than others. It comes thus as no surprise that tractor operators of all ages and experience and on a variety of terrains have been victims of rollovers (Hallman, 2004). This paper first looks at some of the work done in this field and then explains some of the preliminary research being conducted by the University of Bologna regarding tractor rollover and Roll-Over Protective Structures (ROPS).

The Introduction of ROPS

Before ROPS could be implemented, an acceptable amount of energy they would have to absorb needed to be quantified. This led to research being conducted in order to understand rollover in an effort to ultimately design systems to protect the operator. This saw studies associated with real rollover of machines on variety of slopes and terrains be performed to determine the relative risk (Schwanghart, 1973; Chisholm, 1979b; Chisholm, 1979d; Chisholm, 1979c; Chisholm, 1979a; Schwanghart, 1982; Langley et al., 1997; Stockton et al., 2002; Nichol et al., 2005). However, as pointed out by Langley et al. some of the statistical information related to real rollover events gives insufficient description as to the true nature of the rollover (Langley et al., 1997).

The intention of ROPS were to prevent or minimise the effects of the majority of typical accidents, as defined in most of the international standards for testing of ROPS (SAE, 1977; EEC, 1987). It is noted that the introduction of ROPS was not expected to prevent all deaths since such a system would almost be impossible to design.

The most important updates of the standards were carried out at the end of the 80s to account for the mechanisation of vineyards and orchards and the operation on hillsides. The main innovations at that time were the evaluation of the lateral stability and the non continuous roll behavior of the tractors (Schwanghart, 1973; Schwanghart, 1982; EEC, 1987; OECD, 2008).

Due to the different operating environments a tendency to develop innovative ROPS solutions is evident in the research field. These proposed solutions, sometimes complex (Etherton et al., 2002; Silleli et al., 2007), aim to achieve the purpose for which ROPS were originally fitted to tractors without restricting the functionality in orchards and vineyards. To further complicate the issue, the evolution of machinery is outpacing the development of ROPS Standards (Stockton et al., 2002). This has led to renewed interest in rollover research and questioning of the formulas presented in the Standards.

Some limitations in the ROPS Standards can become evident if it is made note that several parameters are likely to influence overturning behaviour however only tractor mass is included in the current test formulae (EEC, 1987; OECD, 2008). Part of the reason for this is that Standards' committees, however, have shown an understandable reluctance to base ROPS strength test criteria on complicated formulae involving many parameters (Chisholm, 1979b).

Research on very low mass vehicles, stated that the ROPS performance test criterion may result in an energy overestimate; the criterion appearing to become progressively more appropriate as vehicle mass increases (Scarlett et al., 2006). Following the same reasoning, this would seem to indicate that as vehicle mass continues to increase it will surpass the threshold boundary defined by the equation, eventually becoming inappropriate. In fact, Chisholm (Chisholm, 1979d) noted from personal communication with Schwanghart that "the energy absorbed in the ROPS was found to increase with mass in a relationship that could be approximated by a low order polynomial". This would thus seem to also suggest that a linear relationship may not be appropriate. A more accurate understanding of the relationship would therefore be deemed necessary.

Simple consideration of velocity and height of fall during accidents shows that the amount of "available" energy far exceeds that absorbed in the ROPS in any standard tests or in the severest accident (Chisholm, 1979d). Obviously not all this energy has to be dissipated by the ROPS in all rollover events. The majority of the energy being dissipated in sliding friction, ground penetration and deformation of other tractor parts, particularly the rear wheels (Chisholm, 1979d). Other mechanisms are also available to dissipate the energy and some of these are depicted in Figure 1.

It may be possible that sequence does not stop at the first time the ROPS contacts the surface: this scenario has not been shown but is possible. Chisholm (Chisholm, 1979b) noted that in some instances it is possible for the tractor to become airborne after its first roll and then impact heavily on the ROPS, without energy being absorbed by rear wheel deformation. It is thus the instant at which rollover commences that changes the initial conditions. Once initiated, the sequence describing the rollover stages can take, in theory, an infinite number of forms. The events in which the ROPS impacts the ground, may or may not render failure. The last distribution in Figure 1 shows a very unlikely but possible situation in which rollover begins at the point with the maximum available energy and all that energy is subjected in the ROPS on first impact.

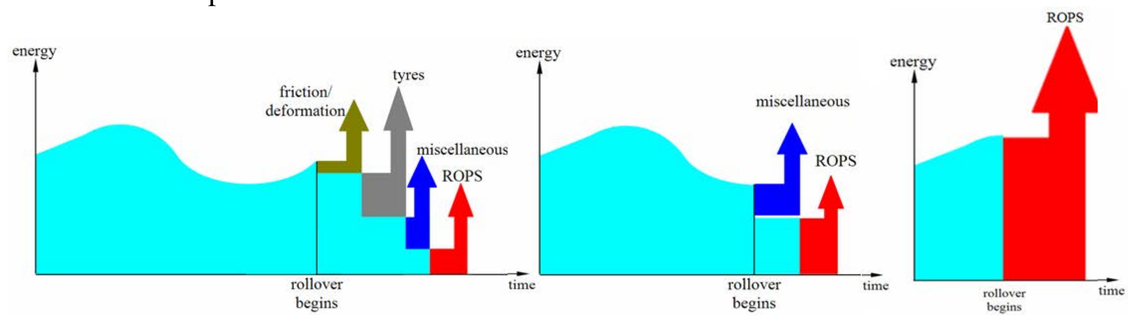

Figure 1. the total available energy for an operating tractor may vary with time. Rollover may occur at any location and be comprised of many steps (left) or just a few (middle), and a very rare and severe event (right).

Materials and Methods

Available Energy

It seems logical that the tractor rolls from an unstable state (for example, when the COM exits the base rectangle) to a stable state (e.g. the plane's surface) via lateral roll. Ignoring any tyre deformation or other dissipation mechanisms and assuming all potential energy is converted to kinetic it is simple to calculate the energy available between the initial, 1, and first impact, 2, positions i.e. $E=mg(h_2-h_1)$. All symbols are defined in Table 1. Considering a tractor with zero velocity at the verge of rollover is not dissimilar to an inverted pendulum released from rest. Thus, the energy available is related to the difference in centre-of-mass (COM) position at the initiation of rollover and when part of the structure first contacts the ground. Thus the potential energy is related to the COM position, the mass and the geometry of the tractor. When considering rollover a horizontal surface is typically utilised, Figure 2a. However, it is also possible for the tractor to roll onto a plane which extends below the rollover point, Figure 2b. Clearly the amount of energy is different for the two cases.

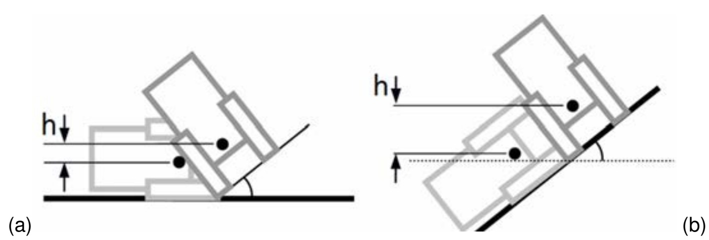

Figure 2. tractor lateral rollover from the slope's surface onto: a horizontal surface (a), and the plane's surface which extends below the rollover point (b).

Narrow-track tractor data has been measured at the test facility of the Laboratorio di Meccanica Agraria, Department of Agricultural Economics and Engineering (DEIAgra), University of Bologna, according to the testing code of the Organisation for Economic Cooperation and Development (OECD Code 6, 2008) for a number of years. The testing procedures require preliminary tests to be carried out before the strength tests of the ROPS:

these are the lateral stability test and the non continuous rolling test. Prior evaluation of the total mass and the COM position have to be done in order to use the information together with the simulation program available in Code 6 to determine the critical ROPS height to prevent continuous roll on a 1/1.5 slope. Measurements were performed on 102 narrow track tractors. The COM was determined using an oscillating platform which can carry the tractors, according to the methods studied by Casini Ropa (Casini-Ropa, 1976). The lateral stability tests were carried out positioning the tractors on a horizontal plane and tilting the part of the tractor rigidly connected to the axle bearing more than fifty per cent of the tractor mass. This was in order to verify that at an inclination angle of at least 38° the tractors were in a state of equilibrium on the wheels touching the ground in accordance with Code 6 (OECD, 2008). The data pertaining to the 102 tractors tested according to OECD Code 6 was used to theoretically calculate the angle required to cause 'longitudinal' and 'lateral' rollover purely from geometry. This required the mass and COM location for each tractor. As longitudinal roll is unlikely only lateral roll results are presented. It was assumed that there was no deformation (tyres/surface etc) nor front axle pivot. Hence rollover occurs at the angle when the COM exits the base defined by the tyres.

Table 1. Notation

symbol	definition	unit	symbol	definition	unit
g	gravity acceleration	$m.s^{-2}$	m	mass	kg
h	height	m	v	velocity	$m.s^{-1}$
I	inertia	$kg.m^2$	ω	angular velocity	$rad.s^{-1}$

<u>*Initial Velocity*</u>

A tractor typically arrives in a rollover event with some initial forward velocity, and this can increase the available energy. Equation (1)[1] may then be used to estimate this additional energy at initiation of rollover. It shows that a small speed increase has the potential to add significant energy to the system since the value is raised to the power of 2.

$$\text{Available energy} = mg\left(h_{xy2} - h_{xy1}\right) + \frac{1}{2}m\left(v_{z2}^{\ 2} - v_{z1}^{\ 2}\right) \tag{1}$$

Considering the more general case in which there also exists initial angular velocity, Equation (1) is modified and Equation (2) is obtained. This assumes that the tractor undertakes fixed axis rotation about a pivot point, for example the lower wheel edges on the slope. Thus the angular kinetic energy and the potential energy in this case occur in the same plane.

$$\text{Available energy} = mg\left(h_{xy2} - h_{xy1}\right) + \frac{1}{2}m\left(v_{z2}^{\ 2} - v_{z1}^{\ 2}\right) + \frac{1}{2}I_{pivot}\left(\omega_{z2}^{\ 2} - \omega_{z1}^{\ 2}\right) \tag{2}$$

Equations (1) and (2) show that, in the presence of velocity components, much greater energy is available. However, it must be noted that the presence of velocity complicates the analysis considerably. The longitudinal momentum would generally render the 2D roll plane analysis inappropriate since it is likely that the tractor during roll continues to travel forward. Thus a 3D analysis would be needed. This may also be true in the subsequent rollover events should the tractor not stop on first impact. It may also be possible for the tractor to not remain in contact with the surface during the roll event. In such cases it is no longer appropriate to use a rearranged version of Equation (2) to determine the conversion of potential to kinetic energy. This is due to the fact that the roll is not about a fixed point. This requires that the more general form of the energy equations be used. Such an equation for rotation, in the *roll plane*

[1] *x,y* and *z* denote Cartesian axes; z is along the tractor's longitudinal axis, positive in the forward tractor direction.

only, would take the form of Equation (3). This accounts for both the translation and rotation of the tractor body. The inertia is that about the COM and it is denoted by $\bar{I}$.

$$\text{Available energy} = mg(h_2 - h_1) + \frac{1}{2}m\left(v_{r2}^{\ 2} - v_{r1}^{\ 2}\right) + \frac{1}{2}\bar{I}\left(\omega_{r2}^{\ 2} - \omega_{r1}^{\ 2}\right) \tag{3}$$

Results and Discussion

The measured COM location, mass for each tractor and the theoretical angle at which rollover occurs when the COM exits the base defined by the tyres are shown in Figure 3. All graphs in this section present data ordered by increasing tractor mass as shown in Figure 3a.

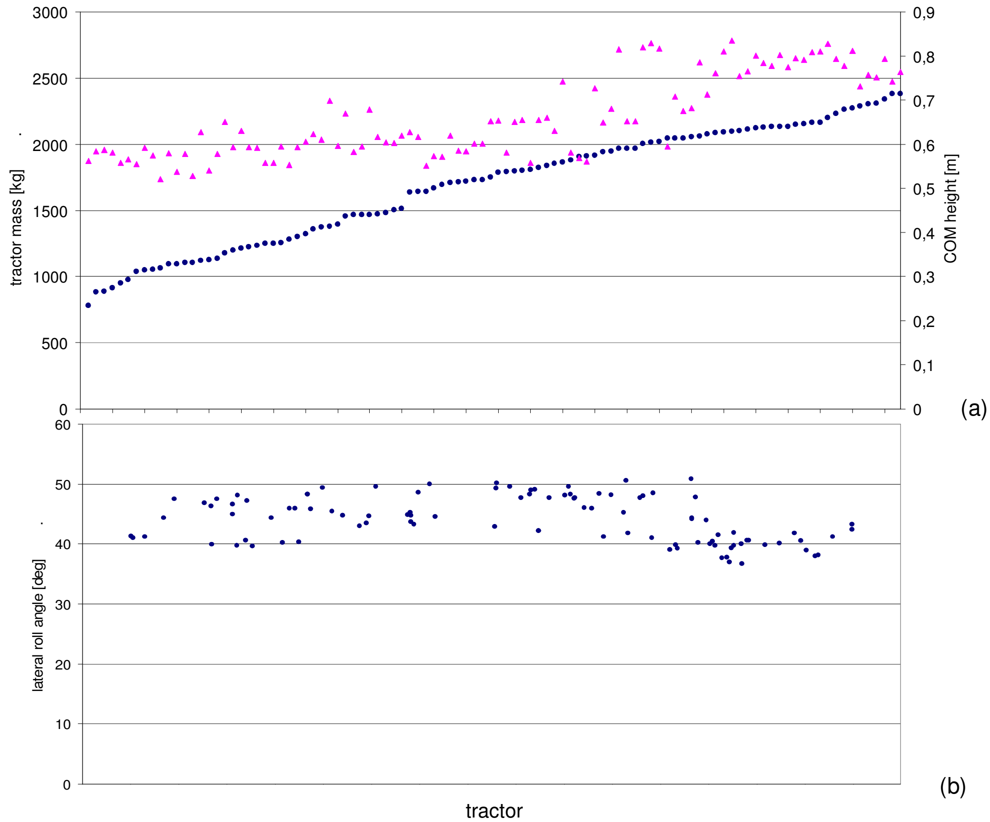

Figure 3. 102 measured tractor distributions for: (a) mass, •, and COM, ▲, and (b) the theoretical lateral rollover angle assuming rollover occurs when the COM exits the base defined by the outer boundaries of the tyres. Assuming the COM is located along the tractors longitudinal axis and its measured height.

Figure 4 shows the calculated available energy at first impact for the two planes represented in Figure 2. Considering the horizontal resting plane, $g\Delta h$ could reach as much as 3.9 m^2s^{-2} (average 2.77 m^2s^{-2}). It is more likely that the inclined plane extends below the tractors initial starting position, Figure 4 (upper data set). In this case, $g\Delta h$ could amount to as much as 10.7 m^2s^{-2} (average 9.03 m^2s^{-2}). If all this energy had to be dissipated on the first impact, then it is clear that there is a lot of energy available. However, the most interesting point to note in both instances, when the data is arranged in the same order as Figure 3, is that, the $g\Delta h$ value appeared to change with mass. This would seem logical since Δh, defined in Figure 3, is a function of the measured COM height and the wheel base geometry etc. In fact, consistent with Schwanghart's communication to Chisholm (Chisholm, 1979d) it would appear that based on these tractors a low order polynomial would indeed be a better fit.

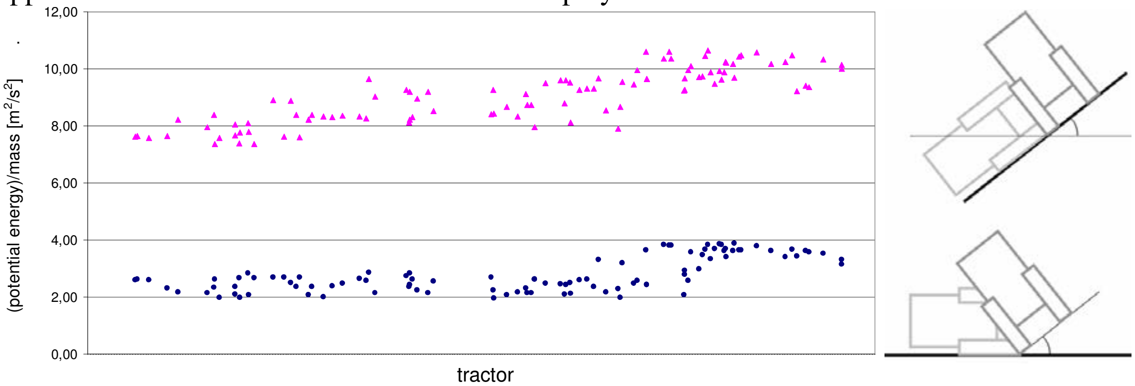

Figure 4: lateral rollover of a tractor on a slope to a horizontal plane, •, and the corresponding magnitude of g□h for lateral rollover on a slope which extends below the rollover point, ▲.

It is possible to combine the information of Figure 4 and Figure 1 into a single figure, Figure 5. This figure shows the average amount of energy available for each case represented in Figure 4 divided by the corresponding tractor's mass and also shows what Code 6 (OECD, 2008) specifies should be absorbed (dissipated) *laterally*. Clearly the total available energy is greater in both cases. However, it is realised that the Code does require that more energy is absorbed via a series of tests which are additionally performed in the longitudinal and vertical directions and that tyre impacts help dissipate some of this available energy. Nonetheless, this simple consideration shows that there is much more energy available at first impact.

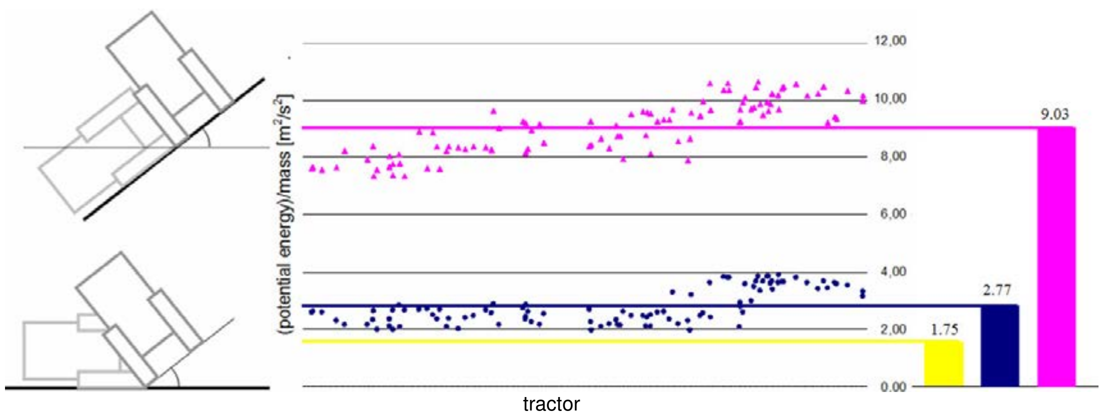

Figure 5: available energy dissipation split based on the two rollover scenarios of Figure 4. That specified in the Code to be absorbed laterally by the ROPS is shown in yellow.

<u>*Influence of forward speed*</u>

Using Equation (1) it is possible estimate how much additional energy is present at the initiation of rollover if forward velocity is included. For simplicity, only the total energy is included here. That is, that arising from velocity in the forward direction and the difference in height assuming that roll occurs on the same planes, as depicted in Figure 4. Although this a very simple case it suffices for demonstration purposes.

Figure 6 shows available energy at first impact calculated from theory from the measured tractor data and assuming a forward speed of 2m/s. It is based on assuming that the kinetic and potential energy are simply added together. No attempt is made here to see how this energy could be dissipated, this is an intended area of future work. Figure 6 shows energy resulting from just potential and with the addition of the kinetic, for the case of rolling onto the horizontal plane. It is possible to see that the inclusion of velocity increases the available energy. Again it is noted that in effect it has been assumed here that all forward velocity and potential energy give rise to a total energy which could be available at first impact: it is only in rare instances that all this energy is subject to the ROPS.

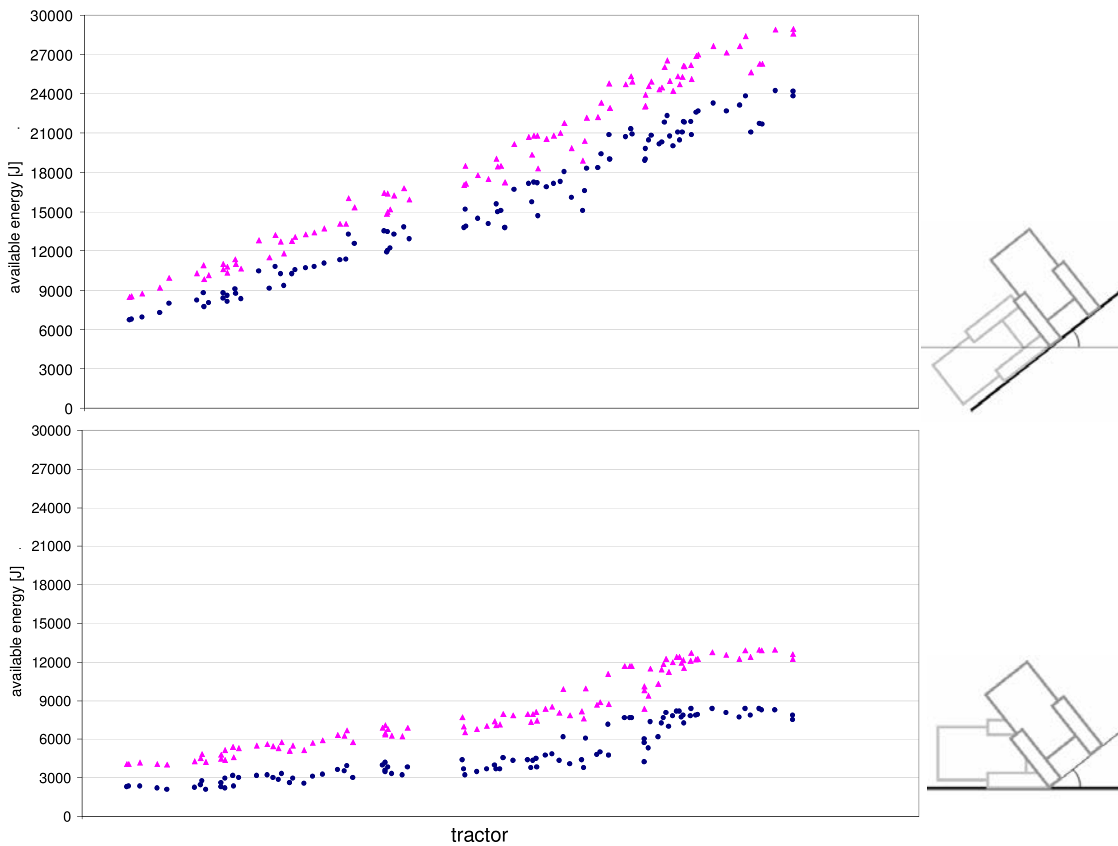

Figure 6. How the total available energy may vary for each tractor: just considering potential, •, and with the inclusion of kinetic for a 2m/s forward velocity, ▲. The cases are those of Figure 4 for the planes as shown.

Conclusions

This paper was mostly concerned with the theoretical energy that may be available at the start of rollover. To that end, using data pertaining to 102 narrow track tractors tested according to the provisions of the OECD Code 6, the energy was calculated for two types of lateral roll. These were the standard roll onto horizontal plane and the rollover onto a plane which extends below the rollover point. The available energy at first impact in the second scenario was understandably shown to be greater than the first. It was also shown, based on the assumptions given, that when the tractors are ordered by their mass, the $g\Delta h$ parameter appears to be nonlinear. This would seem logical since h is a function of COM height and wheelbase. Further calculations and measurements are needed to fully confirm this, and this is intended future work. In addition, it was shown via simple energy calculation that the addition of forward velocity can increase the energy available at first impact. It was noted that the inclusion of velocity however, considerably complicates the analysis and is likely to couple roll into more than the lateral plane. A most appropriate way to determine the nature and extent of this coupling is to perform real tests using modern tractors on a typical slope.

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The use of a capacitive sensor matrix to determine the grip forces applied to the olive hand held harvesters

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Abstract
The hand held olive harvesters increase the work productivity but they submit the operator's hand arm system to high vibration level values and to relevant efforts to drive them through the tree branches. Many scientific works demonstrate that a correlation exists among the intensity of vibration, their direction and the grip force applied by the operators' hands.
It is not easy to measure these parameters, unless instruments which permit the measurement in an objective way are available.
Aim of the work is to present the results of the application of a measurement instrument that allows to detach the operator's hands grip force applied to drive the olive harvesting shaker. This device is done using a capacitive sensor matrix that can be wrapped around the machine handlebars.
The matrix is thin (approximately 0.9 millimetres of thickness): for this reason its presence does not modify the operator's behaviour. The matrix is a device that allows to obtain measures of the pressure dynamic contact distribution and its time history. In this way we have the grip forces applied by the operator's hand over the machine handlebars.
This matrix has been fixed over olive harvesting machine handlebars and the grip forces time histories have been recorded. The tests have been carried out in a laboratory simulating the olive harvesting operations by means of the arms movements towards to targets positioned at different heights.

Keywords: vibration, olives, shaker, capacitive matrix, grip force.

Introduction

One of the major expenses of olive production is the manual harvesting of the fruit: in the little farms the cost may reach the 50-70% of the obtained cultivation revenue, with a productivity that is not higher than the 15 kg/h for each operator. In this situation it is convenient to use olive hand held harvester such as pneumatic or electric olive harvester, shakers with knapsack engine, etc …

The hand held olive harvesters are operators' brought machines, which cause the fruit pick up by means of impacts produced by vibrational tools driven by little i.c. engines or electric motors.

These machines increase the work productivity, doubling the manual one, but they tire the operator, especially if they are i.c. engines driven. They submit the operator's hand arm system to high vibration level values and to relevant efforts to drive them through the tree branches.

Other than the vibratory stress, many other bio-mechanical factor may contribute to the etiopathogenesis of the osteoarticular injuries in the operators using vibrating tools, such as the articular overload, the intense muscular strain and the discomforting postures.

Many scientific works demonstrated that a correlation exists among the intensity of vibration, their direction and the grip force applied by the operators' hands.

Exposure to hand-arm vibration is one of the main physical risks for workers involved in the agro-forestry field. The prolonged use of hand held vibrating power tools like chain saws and hand-held shakers can lead to the hand-arm vibration syndrome (HAVS) that can interest the muscle-skeletal, nervous and vascular peripheral structures of the upper limb (Bovenzi, 1998).

The hand-arm vibration damage depends on multiple factors: the stimulus intensity, the propagation direction, the exposure duration, the operators' grip forces on the tool's handles (Bovenzi et al., 2000). While the first parameters are easily determined by accelerometers positioned over the handlebars, the grip force behaviour is more difficult to measure (Deboli et al., 2006), unless instruments which permit the measurement in an objective way are available. The use of new transducers in hand-arm vibration experimental set-up has been recently improved (Scalise et al., 2007).

Aim of the work is to present the results of the application of a measurement instrument that allows to detach the operator's hands grip force applied to drive the olive harvesting machine shaking tool.

This device is done using a capacitive sensor matrix that can be wrapped around the machine handlebars, allowing to obtain measures of the pressure dynamic contact distribution and its time history. The matrix is thin (approximately 0.9 millimetres of thickness): for this reason its presence does not modify the operator's behaviour.

The tests have been carried out in two laboratories simulating the olive harvesting operations by means of the arms movements towards to targets positioned at different heights, executing the same field movements of machine lifting, hooking and pulling, at different engine speeds.

At the same time acceleration values were measured, both over the handlebars (front and rear) and over the hook.

Materials and methods

Tests have been carried out in two different laboratories: the first was at the IMAMOTER-CNR institute, the second was at an olive shaker manufacturer.

Aim of the test at the IMAMOTER institute was to determine a methodology to verify the data repeatability of the matrix and to simulate the operator behaviour during the effective olive harvesting process by means of the matrix positioning over the handlebars.

In the second laboratory static and dynamic test have been carried out, both with the engine off and at the idling, racing and full load speed. The matrix has been wrapped around the handlebars of one shaker (figure 1), while the acceleration measurements have been revealed over six machines.

Two operators drove the shakers during the tests: the first was skilled, 1.68 cm tall and 70 kg weight, whereas the second was not skilled, 1.73 cm tall, 75 kg weight.

To simulate the field operation, a device has been realized, using a fork lift with wrapped elastic rope bound at the fork (figure 2): in this way the 'tree branch' height was variable.

Figure 1. Matrix wrapper around the front olive shaker handlebar (left)
Figure 2. Device simulating olive tree branches (right)

<u>Operative conditions</u>

At the IMAMOTER laboratory, the olive shaker has been tested with the engine off, to appreciate the operator's gestural expressiveness during the machine lifting, swinging, hooking and the tree branch pulling.

At the manufacturer laboratory different operative conditions have been carried out. For the grip force analysis and the hand-arm vibration measurements, the operative conditions have been the following:

- machine at the idling state (normal condition during the operator transfer among the olive trees) in the same phases described for the IMAMOTER laboratory;
- machine to simulate the operative condition (idling state during lifting and hooking, full load state during pulling);

The hook acceleration has been measured over three machines at the idling and racing state: in this case the acceleration was not frequency weighted.

For acceleration measurements the experiments were conducted according with ISO 22867.

210 tests have been executed: 34 for the grip force, 176 for the vibration measurement.

<u>Measurement chain</u>

The utilized matrix "Fingermat" (by Novel GmbH, Munich - Germany) is composed of 156 square capacitive pressure sensors arranged in 2 different areas: 144 sensors (12 per 12) for the palm and fingers and 12 (4 per 3) for the thumb area.

Each sensor has a surface of 1.094 cm^2, it means that the total available surfaces are 12.55 per 12.55 cm for the palm-fingers and 4.18 per 3.14 cm for the thumb. Three cuts divide the finger area in 4 strips (figure 3).

The matrix is connected to the electronic signal conditioning equipment. It consists of conditioning circuit, analog multiplexer and 8 bit analog to digital converter that scans each capacitive sensor sequentially at a frequency of 20 kHz.

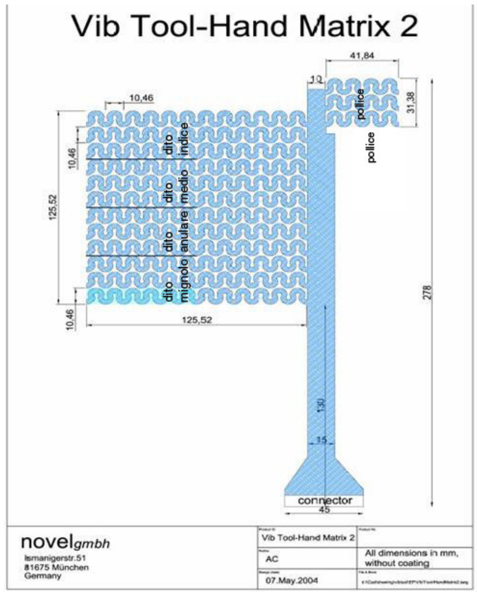


Figure 3. Matrix layout

The acceleration chain for the machine was composed by two tri-axial accelerometers placed both on the front shaker (left hand) and rear (right hand) handlebars (figure 4), a rpm meter and a digital data acquisition recorder. A dual channel frequency analyzer Bruel&Kjaer type 2133 was used to investigate the acceleration data along the x, y and z directions and a personal computer was devoted to investigate on pressure distributions on the two handlebars.

Accelerometers were both calibrated before test session using a on-field mono-frequency calibrator.

Output signals of accelerometers have been weighted using the ISO 5349-1 filters.

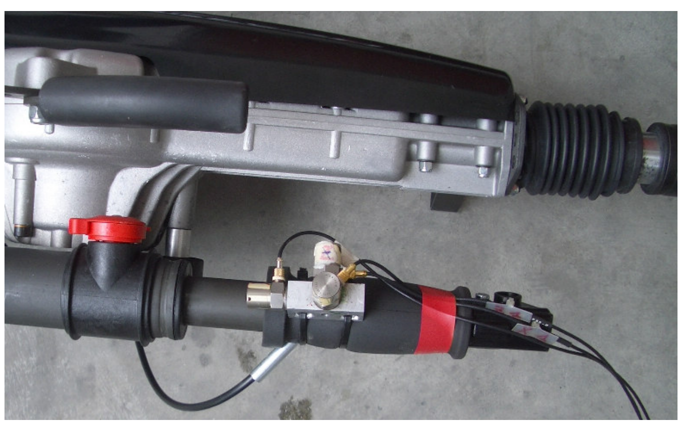


Figure 4. Accelerometers positioned over the olive shaker handlebar

<u>*Machines characteristic*</u>

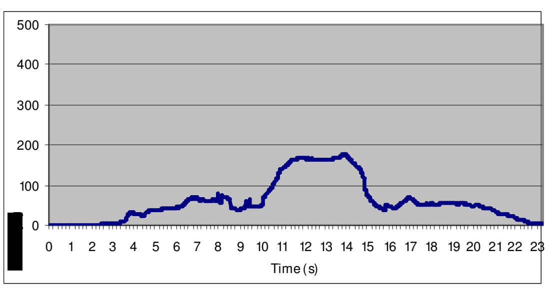
Six olive shaker have been tested (one for the grip force analysis, six for the emitted vibration, table 1): one of them was equipped with an experimental handlebar.

Table 1. Main features of the used olive shakers

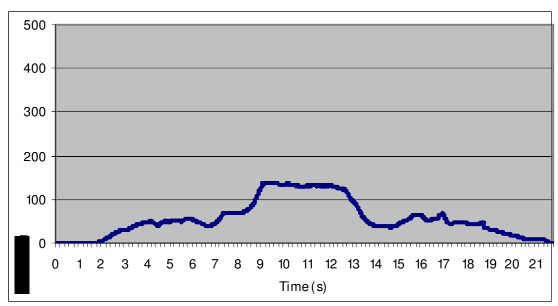
Machine	Displacement (cm^3)	Speed (r/min) Min	Max	Weight (kg)
A (experimental rear handlebar)	52	3600	11300	17
B	52	3600	11300	11
C	52	3600	10200	10.9
D	52	3600	10200	11
E	52	3600	11300	17
F	42	3600	10600	11

Results

<u>*IMAMOTER laboratory*</u>
All the executed tests demonstrates an high repeatability inside each group (lifting, swinging, hooking and pulling).
In figure 5 it is possible to appreciate both the operator handling and the grip force repeatability detected in the same operative conditions: at the beginning the olive shaker is positioned over the simulated tree branch, after around 9 seconds the operator starts to hook the machine and after 14-16 seconds he pulls the handlebars toward the ground.
In both of the cases the grip force augment from 60-80 N at the initial phase until 150-180 N during the hooking, decreasing again to 60-80 N in the pulling phase. The grip force time history permits to understand the operator's behaviour and to quantify the grip force in the different situations.



Graph 5a. 0 rpm. Hooking and pulling. Test 2

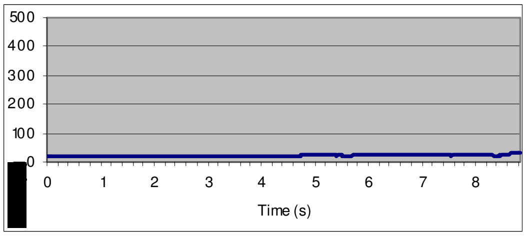


Graph 5b. 0 rpm. Hooking and pulling. Test 4

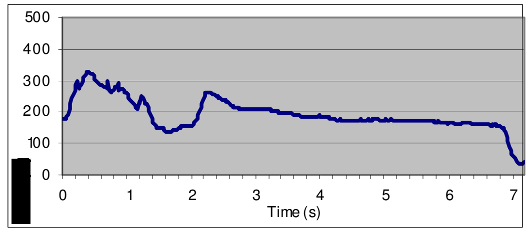
Figure 5. Two of the four hooking and pulling test conducted at the IMAMOTER laboratory

<u>*Manufacturer laboratory*</u>
All these tests have been conducted by a skilled operator.
Graph 6a and 6c report the force time history at the same operative condition (lifting) with the engine off (6a) and idling (6c); graph 6b and 6d, instead, are the same variable representation at the hooking and pulling operative conditions with the engine off (6b) and idling (6d).
In these last graphs it is possible to appreciate the different operation phases: for the around firsts two seconds the hooking phases are present (with an highest grip force), while after the pulling state appears. At the same operative condition, the grip force increase when the engine

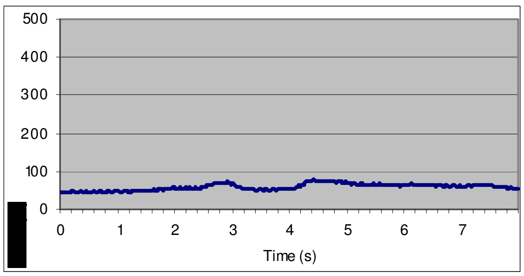
is running in the idling state: only in graphs 6b and 6d in the pulling state (after around two seconds) the grip force stay around 200 N, both with the engine off and idling. In the graph 6b it is possible to notice when the operator ends to pull (at the 7^{th} second).



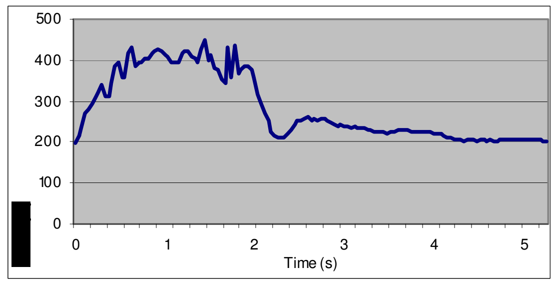
Graph 6a. 0 rpm. Lifting



Graph 6b. 0 rpm. Hooking and pulling



Graph 6c. 3600 rpm. Lifting



Graph 6d. 3600 rpm. Hooking and pulling

Figure 6. Lifting, hooking and pulling tests conducted at the manufacturer laboratory

The grip force time history is very different when the operator simulates the effective field operation (hooking at the idling state and pulling at the full load): the grip force is averagely high during the hooking phase (400 N, from 2nd to the 4th second), while in the pulling phase it is evident the operator's difficulty to maintain the handlebar control (from 300 to 500 N after the 5^{th} second). The high grip force values recorded in this figure are due to the handlebar hits against the operator's hands: the first peak during the hooking phase is caused by the hook which knocks against the branch, the second one is the result of the very high machine vibration level (the operator feels the machine to escape and grippes the handlebar).

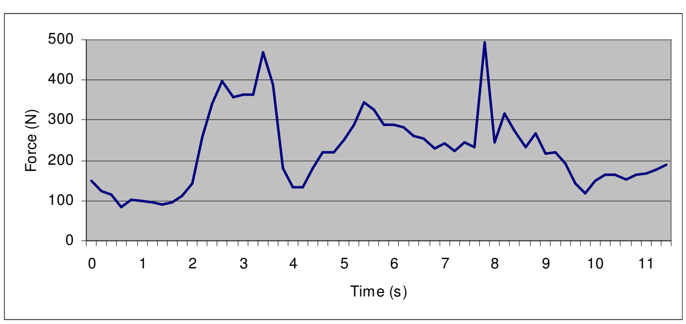


Figure 7. Hooking (3600 rpm, 3 seconds) and pulling (11300 rpm, 6 seconds)

Another matrix feature is to see the pressure spatial distribution, to understand if there are more solicited hand palm parts. In figure 8 the left hand pressure map of the maximum grip force registered during the simulated field operative condition is shown: from the map it is possible to understand the highest red pressure values (from 20 to 30 N/cm^2), corresponding to the fingertips of thumb, index and medium.

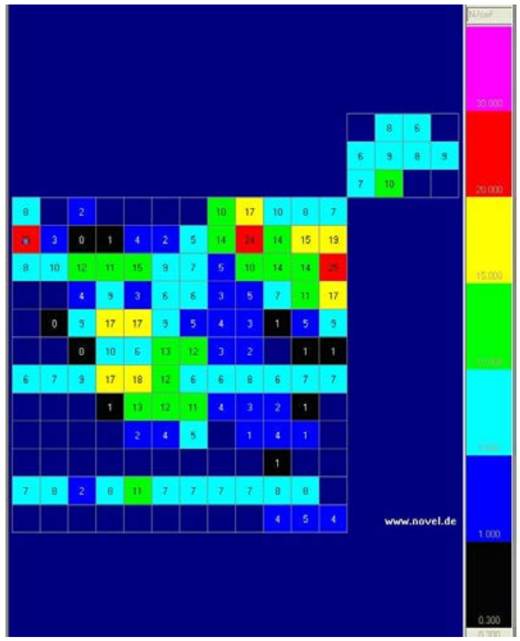


Figure 8. Left hand pressure map of the maximum grip force registered during the simulated field operative condition

<u>*Acceleration values*</u>

The recorded acceleration vary both amongst the machines, the handlebar (front or rear) and the engine state. The results are shown in table 2.

Table 2. Shaker handlebars' accelerations (hooking and pulling)

Machine	Engine condition	Front m/s^2	Rear m/s^2	Hook acceleration (not frequency weighted) m/s^2	
				Off-hook	On-hook
A	idling	3.3	3.8	24.5	
A	full load	22.5	15.5	840	800
B	idling	7.9	7.2	12.5	
B	full load	29	32	825	800
C	idling	11	4.6		
C	full load	20	26	n. r.	n. r.
D	idling	n.r.	n.r.		
D	full load	30.7	22.5	n. r.	n. r.
E	idling	n.r.	n.r.		
E	full load	20.6	17.3	n. r.	n. r.
F	idling	n.r.	n.r.	39.3	
F	full load	71	51	1020	1040

Because of the machines characteristic, the acceleration values are always quite high, especially in the full load engine condition (normally more than 20 m/s^2, with one machine over 50 m/s^2): it is however interesting to notice the lowest vibration data (15.5 m/s^2) in the rear experimental handlebar of the machine A. On the other hand, the hook accelerations were so high that not all the machines have been measured, because there was the serious possibility to damage the measure instrumentation (values higher than 800 m/s^2 at the full load state).

Conclusions

The matrix used in this work permits to appreciate both the grip force time history and the spatial force application, while in the past it was only possible to determine an average applied force with a dynamometer which also modifies the handlebar structure. With the spatial and temporal applied force values, more ergonomic solutions and implementations are possible.

Also if the machines are well balanced, the physical effort to insert the hook on the branch is high, especially in the simulated field condition: probably in the real field, with slippery and uneven ground the grip forces are higher. If to the physical effort we add the vibration values, the load intensity to the upper limbs is significantly high.

The olive shaker acceleration values are high and reflect the actual situation for this kind of machines, but engineering proposal to modify handlebars seem to give good results, as shown in table 2, machine A.

Acknowledgment

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The use of statistical problem solving methods for Risk Assessment

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Abstract

It is typical, also in agriculture industry, that safety is a performance area in which it is difficult to plan and control a real improvement. The normal approach to safety improvement is through Risk Assessment. Unfortunately this approach is strongly limited because the evaluation of the risks is based on evaluator's experience and expertise and so it is affected by low level of reliability.
The aim of this paper is to show how the use of statistical problem solving method, such as Six Sigma, could be useful to improve safety level in working activities. In particular high level of improvement could be obtained by a more structured collection of injuries data considering not only the injuries frequency rate related to the root causes or risks. Following several instructions it could be possible to obtain a database of Risk Indicators based on real data that could be used for a more reliable Risk Assessment.

Keywords: Risk Assessment, Six Sigma, Root Causes Analysis, Stratification, Risk Indicators.

Introduction

Every few minutes somebody in the world dies from work-related causes and every year hundreds of thousands of employees are involved from injuries during work activities. The potential financial devastation caused by the costs associated with accidents necessitates the adoption of an improvement process in the areas of safety, health, and environmental protection. During the last years high technological progresses have been made about safety and health in working activities. Even if the safety rules have became stricter and the concept of risk assessment is now well established and forms the basis of health and safety legislation, the work injury is still a big problem as it is clearly shows by statistics related to many terrible events.

In the industrial field, the accidents situation depends on a wide variety of causes (i.e. diversification and complexity in production processes and technologies, human factors, organization aspects, no application of safety procedures) that are often very difficult to indentify and to analyze. This is the reason why today a proactive approach to safety problems becomes a key factor. The Risk Assessment approach is already known and consolidated; but the problem that is not yet solved is related to the indicators used in order to identify the order of risk priority. Usually these indicators are based on evaluator's experience and expertise, and not necessary deriving from statistical analysis. It is strongly needed to identify more objective principles that allow to characterize the risks in a better way.

This work shows the strong contribution that could be given by a statistical analysis of work injury data in each industrial field. These data are usually available but it is very difficult to use them for risk estimation phase. Therefore, it should be useful to find the relationships between injuries and the real conditions in which these injuries happened. In that way it could be possible to create statistical indicators for each kind of risk. The aim of this paper is to explain, with a guideline, how the injuries data should be collected to obtain a database of statistical risk indicators that could be used for Risk Assessment. This guideline is developed using the Six Sigma Approach that is a statistical problem solving method.

Risk Assessment Approach

Risk assessment represents a careful analysis of the premises, processes and work activities to identify what could cause harm to people to enable decisions to be made as to whether sufficient precautions have already been taken or whether further controls are needed. The aim of Risk Assessment it to individualize an order of risk priority that allow to define a hierarchy of intervention activities (design review, procedures, formation and information) needed to eliminate or reduce the risk. There are many methods for Risk Assessment (FMEA, FTA, HAZOP, What-if, MOZAR, etc.) [Hiromitsu K., 1996] that are all usable. The identification of hazard typology to analyze (ordinary hazards or specific hazards such as noise, vibration) usually establishes what risk assessment techniques should be used as similar techniques may not necessarily yield the same results.

Risk assessment techniques may be either 'subjective – qualitative' or 'objective – quantitative' and their differences are strictly related to the indicator typology.

Qualitative techniques are comparatively cheap and readily applied but are unable to provide numerical estimates and therefore relative ranking of identified risks. Semi quantitative techniques allow some relative risk ranking, but these techniques are still unable to provide detailed assessments of system safety, effects of common cause failures and redundancy features. Similarly neither can effectively be used in the prediction of low frequency high consequence events – i.e. catastrophic risks.

Quantitative methods overcome these shortfalls and are ideally applied where system safety and criticality is to be assessed; but they require a more rigorous approach to recording and interpreting incident, accident and maintenance information to provide accurate and auditable inputs to those studies.

The Risk Assessment usually passes trough the following five steps [OSHA - factsheet 81. 2008]:

1. Identifying hazards and those at risk
2. Evaluating and prioritizing risks
3. Deciding on preventive action
4. Taking action
5. Monitoring and reviewing

The paper is focused on the 2nd step that implies to consider:

- ■ - how likely it is that a hazard will cause harm;
- ■ - how serious that harm is likely to be;
- ■ - how often (and how many) workers are exposed.
- ■ - what are the root cause(s)

The level of risk can be expressed by means of tailored indicators (such as the severity, occurrence, exposure) which in turn are described either qualitatively (i.e. by putting risk into categories such as 'high', 'medium' or 'low') or quantitatively (with a numerical estimate based on statistical data).

Six Sigma method

Six Sigma is a highly disciplined process that helps to focus on developing and delivering near-perfect products and services. The central idea behind Six Sigma is that if you are able to measure how many "defects" you have in a process, you can systematically figure out how to eliminate them and get as close to "zero defects" as possible [Citti, 2004, Breyfogle, 1999]. This approach can be extended to safety problems considering each work injuries as a defect of the process.

The Six Sigma approach is composed by five steps: Define, Measure, Analyze, Improve and Control that compose the DMAIC algorithm (Fig.1).

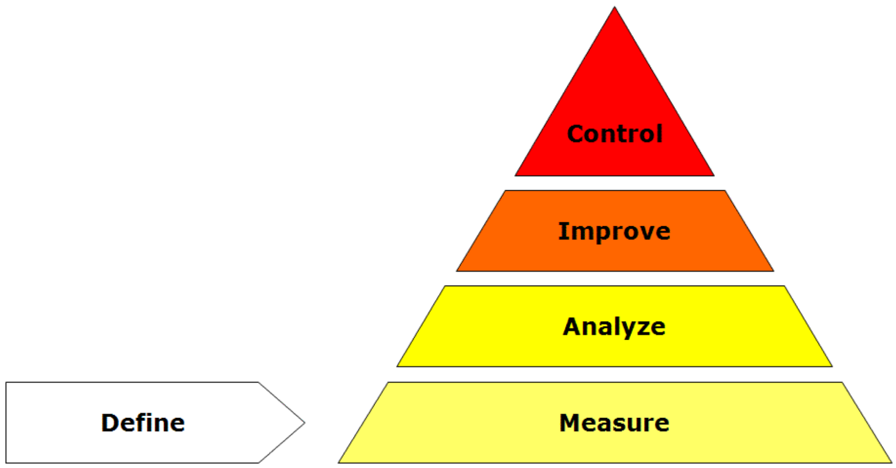

Figure 1. The DMAIC Algorithm used in Six Sigma Project

Define is the phase in which project goals and project boundaries are identify, so it is the phase that defines the problem that needs to be solved. In this phase, the goal is to pinpoint the location or source of the problem as precisely as possible by building a factual understanding of existing process conditions and problems. Having this knowledge will assist you in narrowing the range of potential causes that are needed to investigate in the Analyze phase.

The Measure phase measures the actual performance of the process. Having stratified the data in the baseline performance, it becomes possible to pinpoint the location or source of the problems by building a factual understanding of the existing process conditions and problems, which will help to focus the problem statement.

In the Analyze phase the goal is to identify root causes and confirm those on the basis of data. The verified causes will then form the basis for your solutions in the Improve phase.

In the Improve phase many possible solutions are created and developed. These solution are evaluated in terms of capability to eliminate or to reduce the impact of the identified root causes. The goal should be to demonstrate, through an experiment, that one or more of the identified solutions solve the problem and lead to improvement. During the Improve phase, the solution is piloted, and a plans for a full-scale implementation is made.

In the Control phase the results are verified and planned to maintain the gains accomplished. Control is to make sure that the is corrected and that the new methods can be improved upon further over time.

Six Sigma for Safety Risk Assessment

An analysis of the existing work injuries database shows that they are completely focused on the description of the occurrence and the severity related to the events. For this reason the traditional databases are usually useful only to describe the impact of work injuries problem and so they cannot be functional to Risk Assessment indicators. This depends on the fact that in the existing database there are no connection between the injuries and their root causes. A more complete approach suggests to consider injuries as the consequence of a malfunction in the safety process. In this direction Six Sigma method could help the identification of the probability for each risk by the collection and analysis of appropriate historical data. In this way the use of Six Sigma method, instead of a traditional reactive problem solving methods, can drives to the identification of the real causes of the problems and consequently to the safety improvement of the work place (Fig.2).

	Traditional Approach	Six Sigma Approach
Problem	Focus on symptoms	Focus on causes
Behaviour	Reactive	Proactive
Decision	Based on impressions	Based on data
Analysis	Analysis of injury statistics	Root causes investigation

Figure 2. Comparison between traditional and Six Sigma Approach to problem solving

The Six Sigma approach starts from the real injuries data and then goes back to the root causes.

This path could be done through three main activities:

- Stratification and Investigation to obtain the highest information content from the real injuries data and to identify the root causes of each injury (Fig.3);
- Development of measurable Indicators through which it could be possible to prevent the occurrence of new injuries.

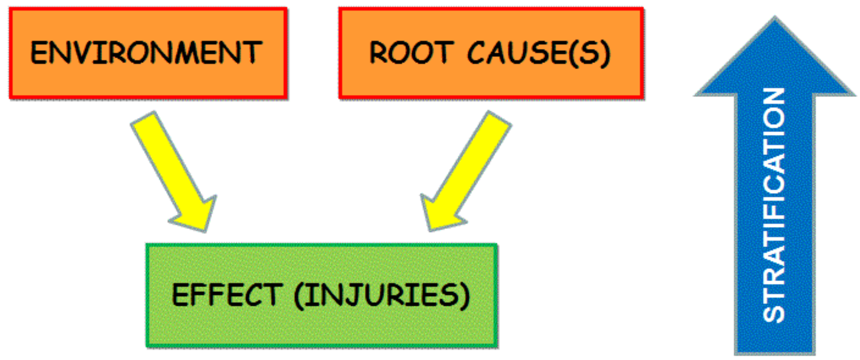

Figure 3. The path from Injury to Root Causes through the use of stratification

Stratification

A first factor to obtain good results using the DMAIC algorithm is the stratification of data. Stratification of data means that each data is collected recording also many connected information. Therefore, the process of data stratification consists in collecting the injury data break it down into layers. The questions who, what, when, and where represent possible layers, in particular:

- The WHO layer – The question "who" is intended to define who is associated with the problem (the characteristics of the injured person should be collected);
- The WHAT layer – The question "what" defines the type of problem which is occurring (type of injury);
- The WHEN layer – The question "when" focuses on temporal context of the injury;
- The WHERE layer – The "where" question clarifies where a problem occurs (regards the environment in which the injury occurs).

This model supports to clarify the problem and its impact. The traceability of this information is necessary to reveal also the root causes of the accident happened [Pande, 2001].

Investigation

The second activity is the Investigation [Marcel, 2002] that is the analysis and representation of the "HOWs and WHYs" of the injury. Investigation is divided in two parts (Fig.4):

- The determination of the events sequence (HOW's) that causes the accident: the events are portrayed graphically through an Event Diagram by arranging them, often chronologically left to right in rectangles, in a logical flow indicating 'what' happened. This sequence of events often, if not always, extends beyond the time of the accident event to include circumstances of the post-accident phase.
- The identification of Underlying Factors and Unsafe Conditions: once the sequence of events diagram is completed, safety significance events can be easily identified for further investigation or analysis to determine "why" it happened. In order to understand the "how and why" of the accident, the investigators need to identify the relevant contributing conditions and underlying factors of such safety significant events. In many situations, investigators cannot confirm, with certainty, why an accident happened. However, short

of determining "why" it happened, we can often find information that can be used to reduce risk. This step helps to create a database that correlates the events with the causes.
All the results of the investigation analysis are also used to define a correct stratification of data.

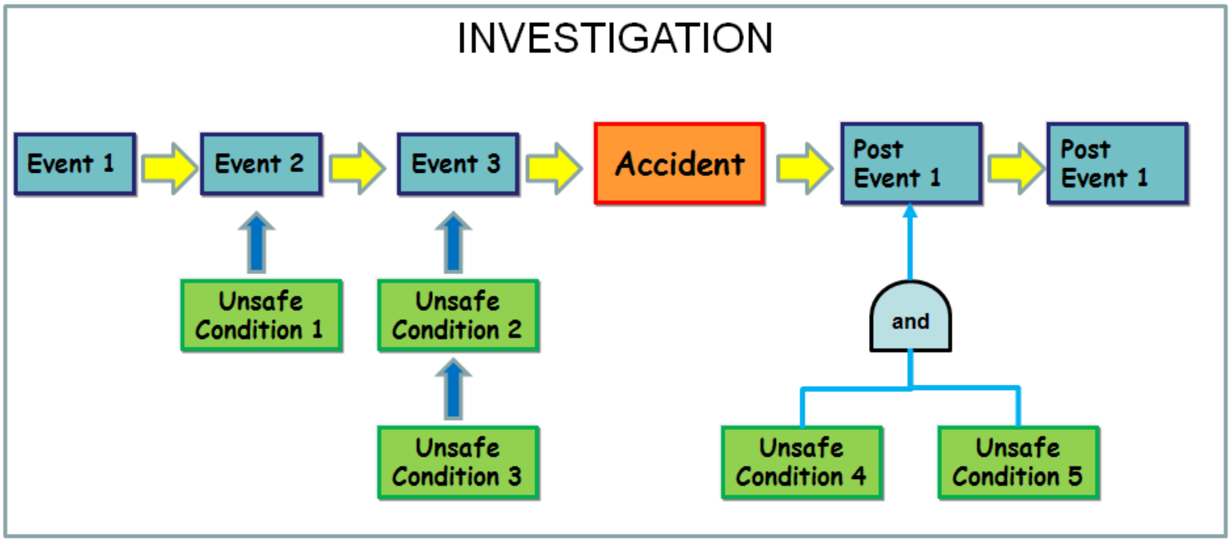

Figure 4: A typical scheme of Investigation results

Safety Indicators

Unfortunately the measure of safety performance has traditionally been accomplished only by means of accident rates, such as Injury Frequency Rate (IFR) or Severity Rate (SR), that are typically categorized only according to the frequency and severity of the accident. On the other hand, significant safety factors are identified by discovering statistically significant correlations between unsafe conditions and the injuries rate data [Grabowski et al, 2007]. These kind of correlations, identified using stratified data, can be functional to the Statistical Evaluation of Risks Index (Fig.5) referred to each cause. It is important to notice that using this approach we can learn by each mistakes and improve our safety processes continuously. For all these reason the last critical activity is the development of indicators for safety performance [Murdoch, 2006]. This is needed because many of the Six Sigma tools, such as Control Charts, Run Charts, and Pareto Diagrams, can be used to track and monitor safety performance, establish trends, and evaluate program performance against accepted tolerances only if there is a clear indicator that can be monitored.
There are two kinds of indicators:

- Trailing Indicators that are based on facts related to past events, such as injury rates, and are usually used to describe the problem.
- Leading Indicators that are connected to the conditions and activities that come before the occurrence of workplace injuries and illness. They measure the level of safety on a jobsite even when no injuries have occurred. Leading Indicators are usually strongly connected with root causes.

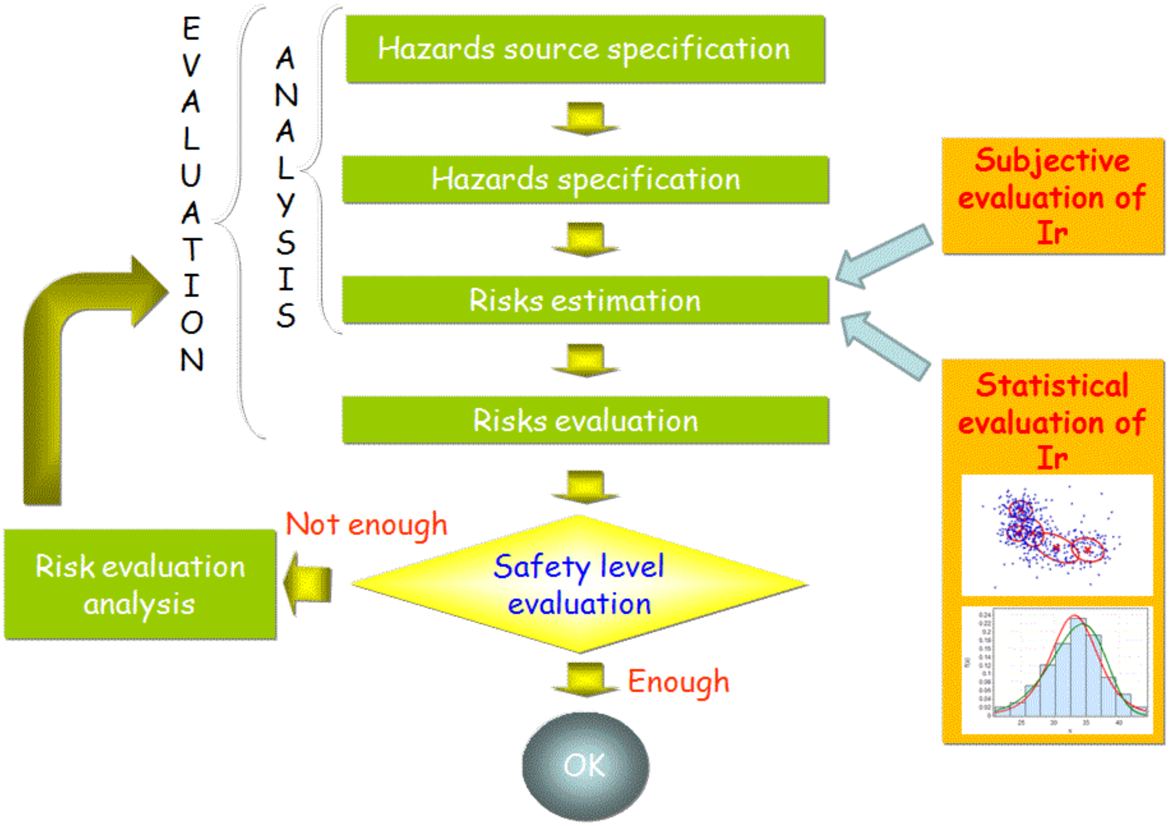

Figure 5: The Statistical Evaluation of Risk Index (Ir) is part of risk estimation step of Risk Assessment logic algorithm

It is important to notice that the development of the leading indicator focuses the attention on the precursors of the injuries. The precursors are the events or situations that could lead both to minor and catastrophic incidents, The entity of the effect depends on slight differences in a small set of behaviors or conditions. Consequently the development of a good skill in precursors identification is a key aspect of injuries analysis. This is mostly due to the following consideration: it is demonstrated by empirical evaluation [Phimister, Bier. 2004] that for each serious injury, about 10 minor injuries and 1000 near miss or property damage incidents should be expected. This is important because the same conditions and causes (the same main precursors) that contribute to minor incidents also contribute to serious ones (Fig.6). The pyramid scheme explains that a single serious incident at the peak has the same root causes of a broad base of non-injury incidents. In that way it is possible to consider an extended amount of data and a consequently accurate risk index even if only few major injuries occur.

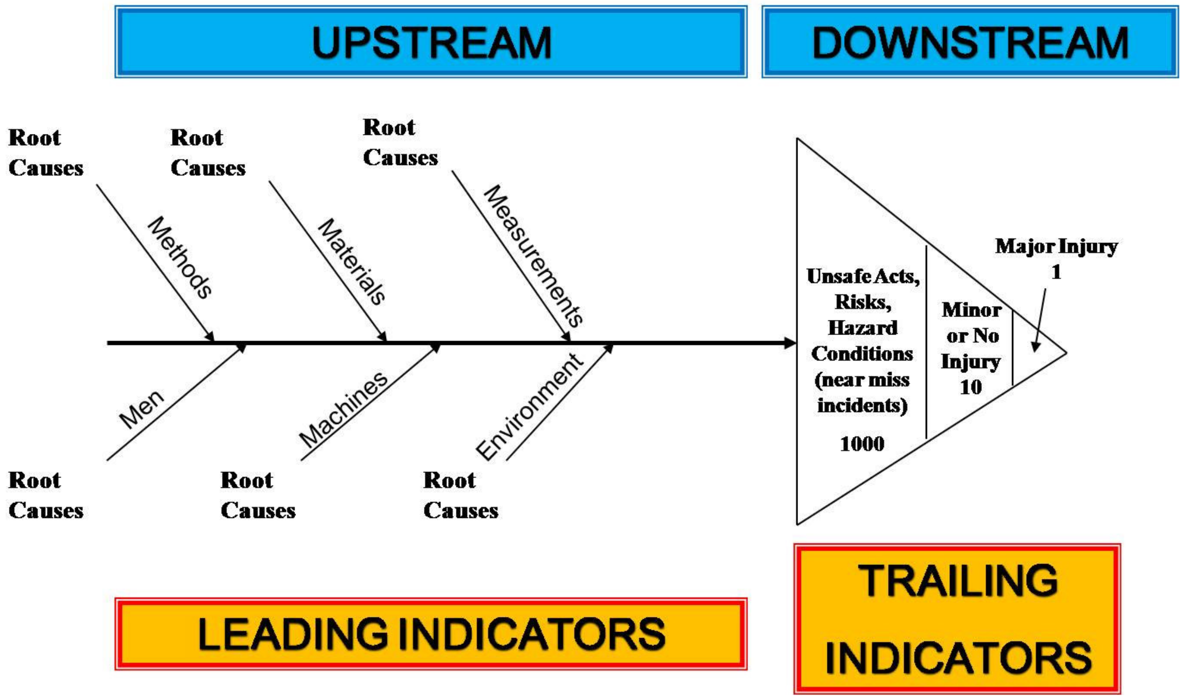

Figure 6: Evolution of Cause and Effect Diagram to show all the data that could be collected in the stratification: upstream with the collection of root causes and downstream with the collection of minor incidents and serious incidents rate

Conclusions

This paper provide some guidelines to develop a correct data collection that allows to define Risk Index based on statistical data instead of subjective factors. At this proposal, particular attention is dedicated to the identification of relationships between root causes and injuries, considering both serious injuries, minor injuries and property damage incidents. In fact, a real improvement in Risk Assessment is strongly related to the skill of collecting useful data when a major or minor injury or a near miss occurs. Six Sigma is the method used to approach the problem; particularly, the proposed path is based on data Stratification, Root Causes Analysis and the development of tailored indicators. Following this approach a database related to a specific industrial context (such as agriculture industry) could be developed. This database with a sufficient amount of real data can support a quantitative/objective risk assessment approach.

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Musculoskeletal disorders (MSD) risks in forestry: a case study to propose an analysis method

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Abstract

Musculoskeletal disorders (MSD) are the most common work-related problem in Europe. In forestry yards we find all the conditions which expose workers to MSD risks: hard environmental conditions (low temperatures, slippery and uneven ground), heavy works (manual handling of loads, back flexed and twisted) and dangerous tools and machineries such as chainsaws.

The high manual work load can therefore cause MSDs amongst the loggers. This pathology risk increases with the component 'vibration' induced by chainsaws, tractors, skidders and other machineries.

In this study we have considered two different logger groups working in public forestry yards and we have analyzed their MSD risk exposure, controlling both the posture of each worker and measuring the induced vibration on the hand-arm system and on the back.

The OWAS (Ovako Working-posture Analysis System) technique has been used to evaluate the load MSD risk and the 2002/44/EC Vibration Directive has been used to detect the exposure to vibration.

In the first loggers group, mechanical trees felling (using chainsaw) and manual deforestation were the performed tasks; in the second, the operations were mechanical trees felling and log stacking (using also a tractor).

The work of eight loggers was analyzed, evaluating all risk types. The result was that both the OWAS index and the vibration indicators were quite high. But others risk parameters came out that are not included in the OWAS or in the 2002/44 EC directive methodology: for example, the work related neck and upper limb disorders, which may be detected using the OCRA procedure.

Keywords: OWAS, OCRA, forestry, MSD, vibration.

Introduction

In Europe musculoskeletal disorders (MSD) are common work-related problems. Almost 24% of all the European workers report suffering from backache and 22% complain about muscular pains. Moreover, almost 2/3 of workers in Europe report being exposed to repetitive hand-arm movements and ¼ to vibrations: these are significant risk factors for developing WRULD (Work Related neck and Upper Limb Disorders, European Agency, 2008).

Most work-related MSD and WRULD are cumulative disorders, resulting from repeated exposure to high or low intensity loads, from repetitive movements and from vibrating tools utilisation over a long period of time: however, MSD and WRULD can also be acute traumas, such as fractures, that occur during an accident. Different groups of factors may contribute to develop these pathologies, including physical or biomechanical factors and organisational and psychosocial factors (Waters, 2004).

From the analysis of the INAIL data in Italy during the period 2002-2006 (www.inail.it), it emerges that the professional illness related to the MSD is augmenting (figure 1).

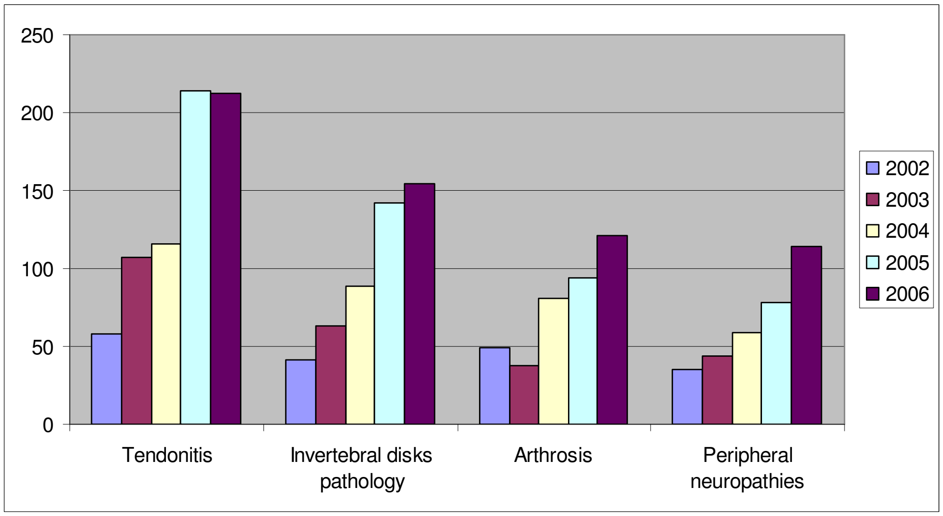

Figure 1. Professional MSD related illness reported in Italy (2002-2006. INAIL data)

In forestry yards we find all the conditions which expose workers to MSD risks: hard environmental conditions (low temperatures, slippery and uneven ground), heavy works (manual handling of loads, back flexed and twisted) and dangerous tools and machineries such as chainsaws.

The high manual work load can therefore cause MSDs amongst the loggers (Ashby et al., 2001). This pathology risk increases with the component 'vibration' induced by chainsaws, tractors, skidders, harvester and other machineries (Bovenzi, 2003). In fact, both the WBV (Whole Body Vibration) and the HAV (Hand Arm Vibration) have been detected as important risk factors which may cause MSDs and they must be strictly controlled.

Also upper limb movements need attention: the odds ratios for neck and shoulder symptoms were between 2.3 and 4 among 215 forest machines operators. Moreover, a study conducted over 909 forest workers showed that 16% had some kind of diagnoses in the locomotor system (Lewark, 2005). The same study shows that musculoskeletal disorders in loggers tend to cause longer sick leaves than accidents.

How to detect the risk to develop these pathologies? Concerning MSD disorders, many methods have been developed, referring to different work condition: for repetitive static works the NIOSH system has been improved, while in dynamic conditions OWAS (Lundqvist et al., 1987), PATH and OSHA may be used. For WRULD analysis, OCRA, Strain Index and HAL-ACGIH/TLV are the most common systems. Among these the OCRA may be successfully used in forestry. The method OCRA (OCcupational Repetitive Action) (Colombini 1998) is particularly indicated for exposure analysis to tasks concerning various upper limbs risk factors (load, awkward postures, repetitiveness, lack of recovery periods). The method has been applied in different working sectors that involve repetitive movements and/or efforts of the upper limbs. It consists in a index (OCRA index, Occhipinti, 1998) calculated as the ratio between the actually technical actions carried out in the work as repetitive tasks and the number of technical actions recommended. Higher is the OCRA index, more severe is the risk to develop MSDs.

The vibration doses to the body and to the hand-arm system may finally be detected using accelerometers under the seat and over the handlebars, following the indications of both the EN ISO 5349-1 and the ISO 2631-1.

Materials and methods

To evaluate the risk of MSD in forestry, this study is based both on OWAS posture work analysis and on hand arm plus whole body vibration exposure regarding two different logger groups in forestry yards of the Valle d'Aosta Region (managed by the Regional Department of Agriculture and Forestry) in the north-west part of Italy at 1500 meters over the sea level, in a very sloped mountain area.

In the first yard, mechanical trees and branches cut other than manual log extraction have been analysed, while in the second skidding and log stacking have been considered. While the cutting phase has always been performed with the use of the chainsaw, the manual extraction has been done with a short-handled timber hoe, while the log stacking has been executed by a couple of loggers manually lifting the logs on a pile after the logs have been moved near by a tractor. After the cut of tree and branches, the logs were manually pushed down to reach the nearest street border. All the logs were measured and, according to the volume, their mass was calculated, using the volume relative mass for each tree type. Then the static and dynamic weights were calculated, referring to each operation phase.

The work team consisted of eight loggers and five of them were considered in this study, aged between 40 and 50 years. Only one of them used the chainsaw, another one was the tractor driver, and the others performed only the manual log movements. In order to comply with the safety guidelines of the last years (European Agency, 2005), in addition to the work posture analysis for each working activity, the vibration risks have been examined.

<u>*Posture analysis*</u>

During the trees and branches cut phase the operator used a 6 kg chainsaw. For limbing and bucking the hoe (1.8 kg) has also been used, other then the bush knife and the peavey (1.5 kg). For the manual log extraction, the four operators used the hoe to move the logs (without branches and with bark) and let them to glide in natural ground dells to the collecting point. The log length was between 3 and 7 meters and the diameter between 10 and 30 cm.

Three operators were present at the skidding operation and one of them was the tractor driver. The operators moved the logs with the hoe on the street and attached them with chains to the pulley of the tractor. Then the logs were trailed for about 500 meters to the stacking point. For the log stacking, four operators were present to detach the logs from the tractor: two operators stacked one log each time, lifting it from the ground.

<u>*The OWAS method to measure the working posture safety risk*</u>

The OWAS (Ovako Working-posture Analysis System) system was used to identify and evaluate working postures. This methodology has been widely used in the past (Karhu et al., 1981), codes 252 posture combinations (4 for the back, 3 for the arms, 7 for the legs and 3 for the load) and it is based on observation. Each posture is expressed with a number code (e.g. the code 2162 means bending back, arms under the shoulder, kneeling with 1 or 2 knees touching the floor and a weight to move between 10 and 20 kg).

After recording all postures by the observation of the work cycles, the data analysis follows. A coloured scheme is used, where it is possible to find out the necessity of interaction (figure 2):

1. class 1: the green cell is connected to normal postures with no discomfort and no effect on health, without any special attention except in some cases;
2. class 2: the yellow cell refers to postures which must be considered during the first check of the used working methods;

3. class 3: the orange grey cell means postures which need consideration as soon as possible;
4. class 4: the postures in the red cell need immediate action.

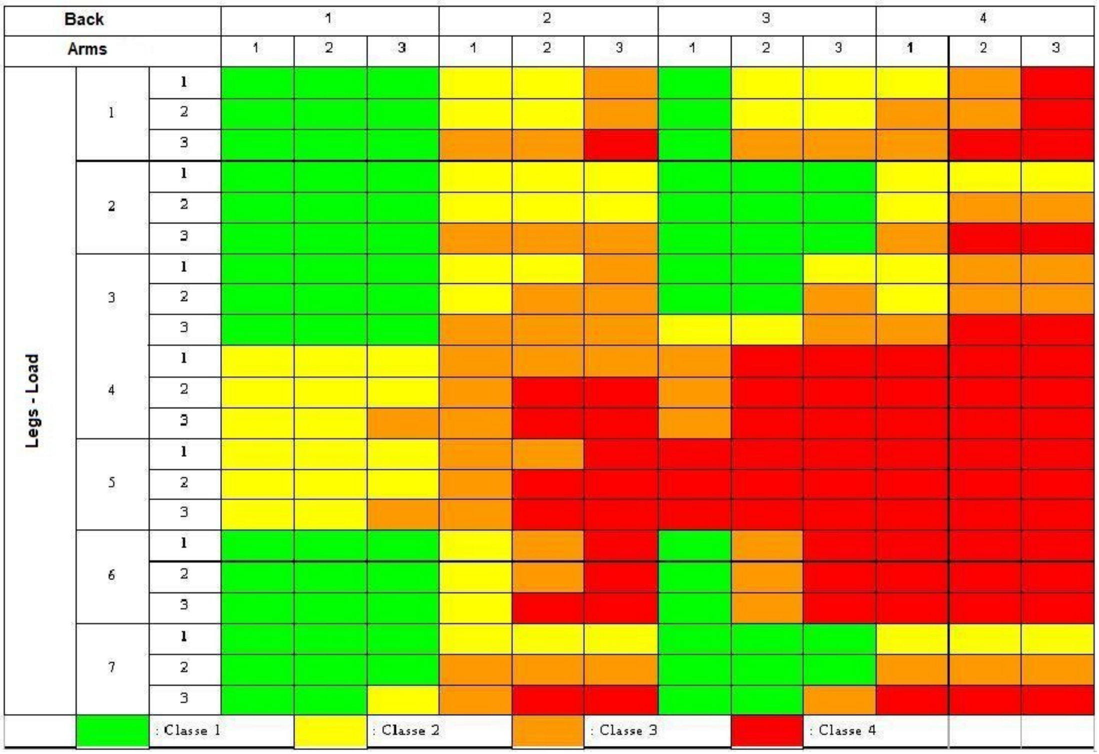

Figure 2. OWAS classes

When all codes have been determined for a specific work, the related index risk *I* is calculated. It is before necessary to calculate the frequency rate in each OWAS class. The index risk formula is:

$$I = [(a \cdot 1) + (b \cdot 2) + (c \cdot 3) + (d \cdot 4)] \cdot 100$$

where:

a, b, c and d are the frequency observation rates in class 1, 2, 3 and 4 respectively. The index risk ranges between 100 (100% of posture observations in class 1) and 400 (100% of posture observations in class 4): more the risk factor is close to 400, higher a MSD risk does exist.

Concerning data collection and elaboration, for each phase and for each operator, all the postures and the moved weight have been evaluated and 825 risk classes have been calculated.

<u>*Machine characteristic*</u>

The tractor type for the WBV analysis was 57 kW power, used 6 hours/day during skidding, while the two chainsaws (A and B) were 4.6 kW and 4.8 kW and both of them were used 3.5-4 hours/day.

Vibration analysis: HAV

To obtain the correct exposure times in the different work phases, the idling condition (chainsaw simply in the operator's hands, without performing any type of work), the racing (corresponding to an engine speed of 133% of the speed at maximum engine power, when the operators starts to cut) and the full load condition (cut phase), were considered. To have a more detailed picture, both right and left hand vibration measurements were carried out, separating the obtained results.

All the hand-transmitted vibration magnitudes (which are expressed as a frequency weighted root mean square acceleration value – RMS - in units of meters per squared second, as defined in EN ISO 5349-1) have been revealed on the chainsaws using a triad of mono axial accelerometers positioned on aluminum blocks fixed over each handle: then they were connected to a vibration meter (HVM100, Larson Davis) put over the operator's belt. In this way the logger was free to work without any kind of obstacles.

The accelerations have been measured using the accelerometers over the three perpendicular directions x, y and z to obtain the vibration value for each operative condition (idling, racing and full load), to permit the calculation of the total acceleration value (a_{hweq}), used to calculate the A(8) value, as requested by the 2002/44 EC Directive:

$$A(8) = a_{hweq}\sqrt{\frac{T}{T_o}} \qquad \text{m/s}^2$$

(T_0 represents the number of working hours/day, assumed to be equal to 8 hour).

Vibration analysis: WBV

To measure the whole body vibration, the same vibration meter (HVM100) has been used, connected to three mono axial accelerometers inserted into a rubber structure, fixed to an aluminium disk (inserted between the tractor seat and the operator's body).

Also in this case the acceleration value along the three axes has been furnished, to calculate the vibration total value a_{vi}, as indicated by the ISO 2631-1 1997, clause 6.5. The daily exposure value *A(8)* was then calculated, starting from the a_{vi} furnished by the instrument and from the sitting time T (when the operator was sit on the moving tractor):

$$A(8) = a_{vi}\sqrt{\frac{T}{T_o}} \qquad \text{m/s}^2$$

Results

During the cut operations the logger was kneeling or standing with the weight on one or two legs, twisting or bending the back and the arms always under shoulder height. For example, the OWAS code analysis of the cut mark realization was 4131, which falls in class 2. During the manual log extraction the operators normally worked with bended or twisted back, standing with the weight on one leg or the knees bent, the arms below shoulder level and the moved weight higher than 20 kg (a frequent code was 4173, class 4). In the skidding the two operators that moved the logs with the hoe on the street and attached them with chains to the pulley of the tractor worked with a bended back, the body weight on one leg or one knee bent, the arms below shoulder height, the weight over 10 kg. For the log stacking, two operators stacked one log each time, lifting it from the ground and working with the straight back and the knees bended at the beginning of the movement, to finish with straight back and with the weight over the 2 legs (code 2143, class 3).

The elaboration of the collected data highlights the presence of the OWAS posture codes especially in class 3 and in class 4 for all the operations. The consequence is the high frequency rate both in class 3 and in class 4 in the two forestry yards, independently from the performed works.

Concerning manual log extraction, the presence of posture codes in class 4 is high for two operators (49% of the total, table 1), while manual log stacking has the highest values in the third class (86% and 83%, table 2). For the cut operation the class 2 is predominant (46% and 60%, table 1 and 2), also if high frequency rates are found in class 4 in both yards. The class 1 is almost absent in all the cases. These numbers underline the severe risk for the operators to develop MSD.

Considering the different parts of the body, twisted and bended back is present in 43% of the observed back postures during the manual log extraction. In this operation, for the legs, knees bent are also revealed in 31% of the total observed leg postures. Load is an important factor to determine posture values in class 3 and 4, both for the manual log extraction and manual log stacking: in fact during these operations the 65% of the moved load is over 20 kg.

Table 1. Frequency rates in the OWAS classes (yard 1)

Yard number 1	Cut	Manual log extraction (operator 1)	Manual log extraction (operator 2)	Manual log extraction (operator 3)	Manual log extraction (operator 4)
Class 1	0	2%	1%	1%	1%
Class 2	46%	24%	21%	21%	21%
Class 3	18%	57%	29%	51%	29%
Class 4	36%	17%	49%	27%	49%

Table 2. Frequency rates in the OWAS classes (yard 2)

Yard number 2	Cut	Manual log stacking (operators 1 and 2)	Manual log stacking (operators 3 and 4)
Class 1	0	0%	3%
Class 2	60%	4%	7%
Class 3	0%	86%	83%
Class 4	40%	10%	7%

Moreover, all the operations in both yards are characterized by high index risks: in both the yards all the index values are around 300. Also if manual log extraction reports the highest numbers (326), other activities are not too much lower. For the cutting phase the average index risk is 287, for the manual extraction it increases to 311, while 300 is the average index risk for the manual log stacking.

<u>*Vibration results*</u>

Concerning cut operation, the advantage of lower OWAS index risk values is lost considering the HAV values transmitted from the chainsaws to the operator's hand-arm system. Also the operator using the tractor during the log stacking is heavily affected by WBV while he sits on the tractor. In fact, for both HAV and WBV, the obtained values are over the daily exposure action value, as stated by the 2002/44/EC Directive.

For the WBV, the calculated *A(8)* amounts to 0.901 m/s^2 for the operator who drives the tractor: also when he does not perform manual works, the fact that he sits on the tractor and he drives on an uneven ground, it does not ensure him that he will not risk low back pain.

For the HAV, the situation is worst (table 3), because 3 of the 4 calculated values (referred to two different chainsaws) are over the daily exposure limit value (this means that immediate actions must be considered to reduce these numbers). The cut operation expose loggers not only to low back pain risk, but also to upper limbs risk.

Table 3. Daily *A(8)* values during the cut operation

Chainsaw	Daily *A(8)* values (m/s^2)
A, right hand	6.1
A, left hand	3.7
B, right hand	6.5
B, left hand	5.3

Conclusions

It is not easy to state some proposals in order to improve forestry works as cut and manual log extraction and stacking, with the aim to reduce both the OWAS index risk and the HAV – WBV daily exposure values. The high results obtained in this work are due to the difficult environmental situation of the examined forestry yards (high slope, irregular ground with the presence of musk and branches) and to the machinery type (especially chainsaw). In the high mechanised forestry yards, where processor, forwarder and harvester are present, a major productivity may be associated with ergonomic side effects. For the lumberjacks, heavy manual tasks have been replaced by long period of lever operations placing a low and static load on the shoulder-neck region, plus a long period of whole body vibration transmitted by the seat of the vehicle (an interview of 118 forestry machine workers showed that most skidders are not satisfied with vibrations in their machines, Walker et al., 2005).

It seems that mechanization is not a panacea to solve MSD risks for the loggers: however, some indications can be useful. One of the most improved way to reduce the risk is to increase the number and the duration of the pause; in this way the OWAS and the OCRA frequencies become lower and the A(8) is positively affected too, because the exposure time to the vibration source diminishes.

Training is also important: to train and to inform operators about the correct positions and the manual movement techniques may reduce many incorrect postures.

Also a good tractor and chainsaw maintenance may reduce induced HAV and WBV vibrations. In mechanical advanced forestry yards, the high mental demands on the operator may appear to be more important than the mechanical work demands: in this case the most effective strategy to prevent musculoskeletal disorders is probably to reduce the duration of lever operation and to add other tasks in order to achieve an enriched job exposure.

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Innovative technology to improve safe control of snow-groomer under critical conditions

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Abstract
Authors report on new technologies to control snow-groomer by DGPS system. Many are the advantages of the utilization of an instrument able to give the position of the conducted vehicle, moreover under adverse weather conditions.
Such an utilization has been done in rise crop where parallel drive of the tractor-equipment system is required even if it is not possible to use ground reference.
The management of snow recreational areas has more problems due to frequent adverse weather conditions, such as snow or fog, that do not allow the vehicle positioning with the required precision. In addition, the borders of the managed areas are very often represented by ditches, lakes, precipices, and plants that may provoke accidents.
DIAF and LeicaGeosystem *[Machine Automation Division –Emilio Palchetti]* in cooperation with Leitner-Prinoth Service and Val di Luce s.p.a (Abetone snow area in the northern Tuscany) have realized the first tests with these technologies.

Keywords: safety, risk management, ski snowgoomer, ski run.

Introduction

The management of snow recreational areas has many problems due to frequent adverse weather conditions, such as snow or fog, that do not allow the vehicle positioning with the required precision. In addition, the borders of the managed areas are very often represented by ditches, lakes, precipices, and plants that may provoke accidents. (Figure 1)

Figure 1. Some risk situations on snow-grooming activities.

Authors report on new technologies to control snow-groomers by DGPS system. Many are the advantages of the utilization of an instrument able to give the position of the conducted vehicle, moreover under adverse weather conditions.

Such an utilization has been done in rise crop where parallel drive of the tractor-equipment system is required even if it is not possible to use ground reference.

DIAF and LeicaGeosystem [Machine Automation Division –Emilio Palchetti – *www.leicageosystem.it*] in cooperation with Leitner-Prinoth Service (F.lli Nizzi srl) and Val di Luce s.p.a (Abetone snow area in the northern Tuscany) have realized the first tests with these technologies.

Methods

The tests have been carried out within the Val di Luce snow area, in the northern Tuscany, province of Pistoia and municipal district of Abetone, extending on a 300 ha area from 1200 up to 1890 m a.s.l. (Figure 2).

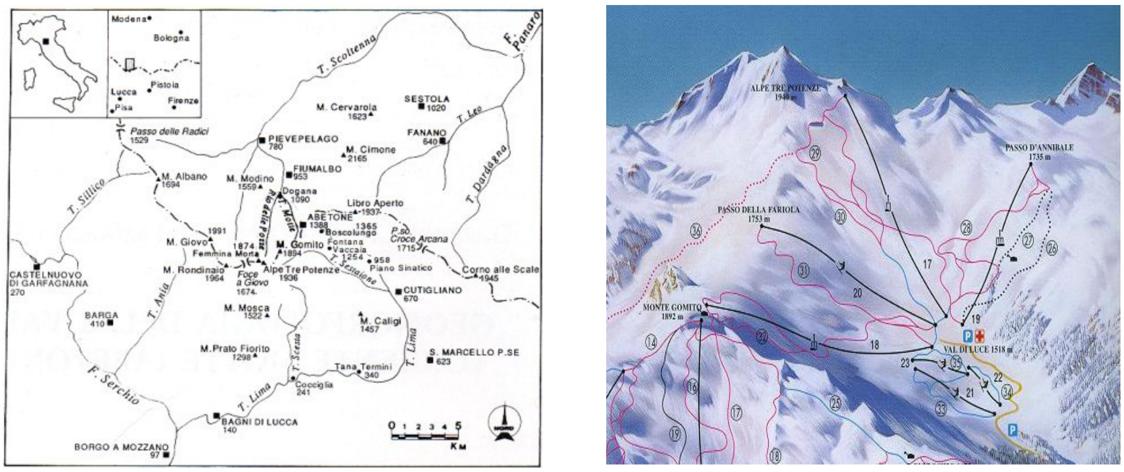

Figure 2. Ski area Abetone - Val di Luce (Tuscany, Italy)

The valley, characterized by a wide semicircle of glacial origin (Quaternary) is surrounded by numerous peaks, on the South *l'Alpe delle Tre Potenze*, on the East side *i Denti della Vecchia* and on the North-East side *il Monte Gomito*.

In the low part of the valley, up to 1650 m a.s.l., the landscape is characterized by beech presence (*Fagus Silvatica*), white fir (*Abies Alba*) and red fir (*Picea Abies*). Further that limit there are not particular arboreous formations, there are ex grazing zones not yet invaded by the wood due to the altitude. In those zones, the blueberry settled with areas of juniper and bare soil as it is in the *Alpe delle Tre Potenze* and *il Passo Annibale*, that are above 1700 m a.s.l.

The valley is rich in sources and, at 1830 m a.s.l., there is a depression hosting the Lago Piatto, whose original natural formation is clearly glacial and its periodic alimentation is due to snow fusion.

The mean annual value of precipitation, for the 1961-2003 period, taken in the Abetone station, located at 1340 m a.s.l. is equal to 2568 mm; the mean annual temperature is of 6,7 °C, the maximum peaks verify in July and the minimum ones in February.

The first snow in general falls in October, but more frequently in November. The snow lies on the ground for 5-6 months, the total height of snow fallen during the season exceeds normally the 3 meters avec peaks of 8.

The Val di Luce area includes numerous recreational structures such as mountain refuges and ski lifts, allowing an easy exploitation both in winter and summer time. The zone includes six ski runs for a total length of 14 km, with maximum difference in height of 400 m, served by five ski lifts, recently renewed, functioning also in summer.

Among the morphologic parameters, the slope (45÷60%) is one of the most important together with the frequent variations of the orography in the ski runs.

The orographic sector of the Val di Luce presents a medium avalanche risk and, in some sites, high. The presence of recreational activities in the Abetone- Val di Luce area justifies the necessity of intervening with systems able to guarantee the safety of the zones explorable by mountain tourism and with limited time of intervention.

Figure 3. Positioning of the basis station

The investigated ski run in Val di Luce is called "Tre Potenze" [44°07'38.04"N; 10°37'40.83"E] and starts at an altitude of 1.866 m a.s.l. and ends at 1.503 m a.s.l. with a 2.800 m length.Two are the critical points: the first 200 m from the start in which there is first a precipice on the left side and then a the lake ; the other one is the "Rocce" gorge where i there are a lot of safety and technical structures: avalanche and rock protection nets and water plugs for snow-maker.

Ski run has been geo-refered and vectorialized by Leica 1200 System that gives a precision of less than 1 cm both in latitude and longitude as well as in altitude. This System is composed by a base antenna that keeps relations with base point and gives satellite coordinates adjustement paramethers. It is placed at the arrival of the *tre Potenze* ski-lift. A mobile antenna (*Rover*) equipe with a data logger it is used to collect position data of the ski run. (Figure 3).

The 20 Hz points updating frequency of the 1200 system represents an important feature because it allows the points typing with a 4 m/s velocity with a ± 0,20 m precision (Figure 4).

The surveyed sequence points on the ski run has been imported into the AutoCAD system and then vectorized 3D attributing the path value to the points within the ski run and interesting point to elements such as ditches, lakes, precipices, and plants (avalanche and rock protection nets and water plugs for snow-maker) that may provoke accidents.

The file has been put in the LeycaGeosystem Machine Automation System GEOROG and MICRODOZER MICROFIN that is able to control devices with output both serial and ISOBUS. That device is fully utilized on escavators and is able to operate with a sub-centimeter precision.

There are already experiences of such machines utilization for the snowpark and half-pipe (Figure 5 e 6).

The devices have been mounted on a snow-groomer Leitner-Prinoth Everest model (Figure 7, Table 1).

Figure 4. Points typing and the CAD georeferencing of the ski run

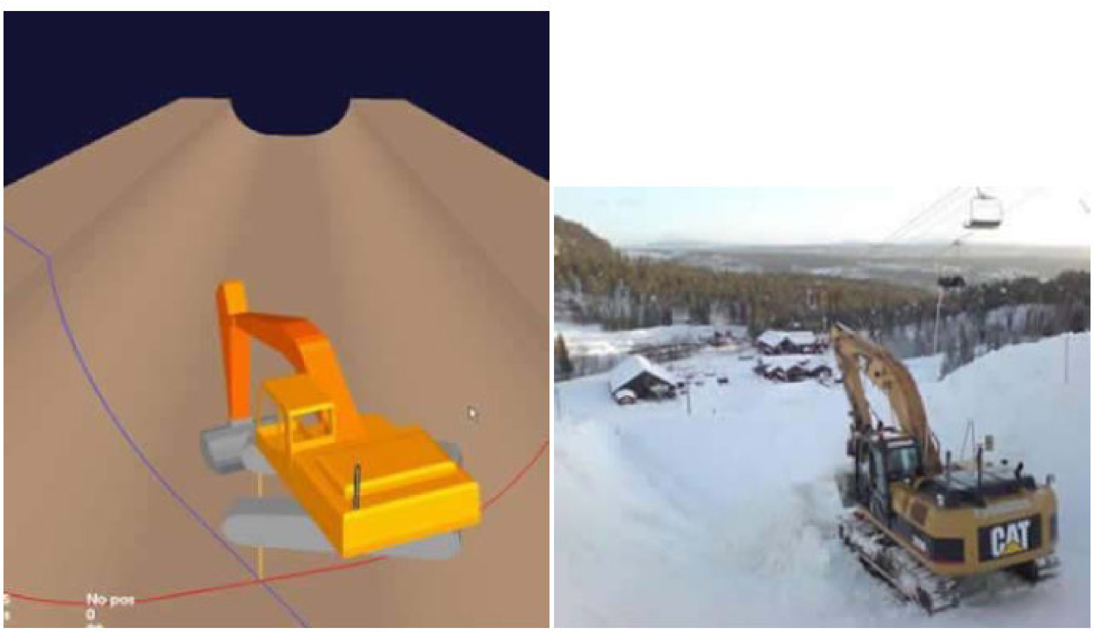

Figure 5. The DGPS Machine Automation System applied to an escavator making an half pipe

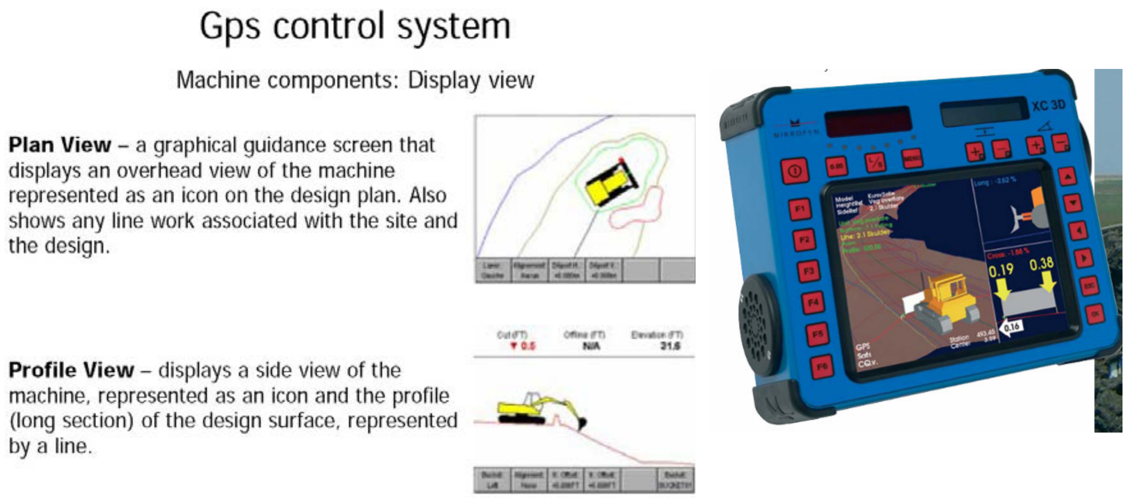

Figure 6. Information on the monitor of the DGPS Machine Automation System applied to an escavator making an half pipe

Figure 7. The snowgroomer Prinoth Everest equipped with the Leicageosystem Machine Automation System.

Another device already available for the snow-groomers has been developed by the Georadar Division, Department of System Engineering of Pisa and utilized for measuring the snow thickness on the highest peaks on the planet and defining the rock stratus altitude. The device may be utilized such a rover or placed on the inferior side of the snowgroomer for measuring the different thickness of the snow.

If the GPS measurement of the ski run is made on bare round the snow-groomer position defines the difference in height referred to the ground.

This second choice has been selected also for the prospect of the utilization of another technology: the GeoScanner which is able to scan automatically a 360° area with the acquisition of thousand points in a minute.

Table 1. Snowgroomer Prinoth Leitner model Everest: technical references

DIMENSIONS	
Veihcle lentgh	5.050 mm
Veihcle length equipment included	8.850 mm
Veihcle width out tracks	4.260 mm
Veihcle maximun high	2.800 mm
Maximum higth from ground	400 mm
Length of the charging floor	1.250 mm
Width of the charging floor	2.000 mm
WEIGHT	
Total weight	8.500 kg
MOTOR	
Manufacturer	Daimler Benz AG
Model	Mercedes OM 501 LA
Turbodiesel & Intercooler – Electronic controller high pressure Injection	
Number of cylinder	6 a "V"
Total cylinder colume	11.950 cc
Maximum power	315 kW (428 CV CEE) a 1.800 g/min
Maximum momentum	2.000 Nm a 1.080 g/min
Consumption	204 g/kWh a 1.800 g/min 188 g/kWh a 1.300 g/min
DRIVING PLANT	
Digital electronic system allowing the programming of the guide parameters and the optionals management.	
TRASMISSION	
Hydrostatic transmission at closed circuit	
Pumps Hydromatik A4VG180, motors Hydromatik A2FM107 (a cilindrata fissa)	
Forward speed 0 - 24 km/h	
PERFORMANCES	
Working capacity	102.000 m^2/h
Maximum climbing slope	120%
Specific ground pressure	0,044 kg/cm2
Swerving radius	0 – the veihcle revolves on his axes

The joining of the scanning obtained from the different surveyed points allow to obtain a 3D vectorialized representation of the whole area. The great scenic effect of the graphic representation is also utilized for virtual journeys in those areas.

Results

The ski run has been scanned with the DGPS and vectorialized in CAD. The file has been imported into the instrumentation mounted on the snow-groomer and the ski run maintenance has been done following the route highlighted on the monitor through parallel courses (Figure 8).

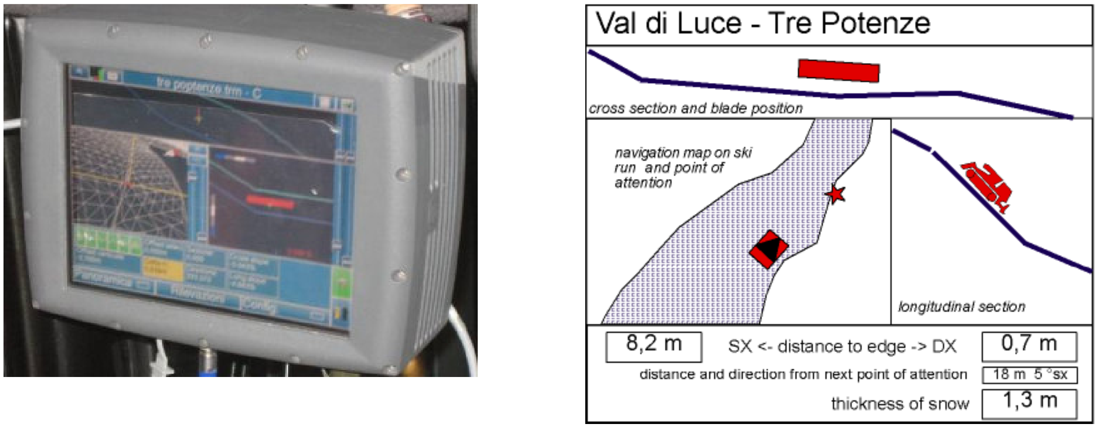

Figure 8. The control monitor mounted on the snow-groomer.

The operator has been able to constantly control his position with respect to the risk points ditches, lakes, precipices and the structural devices to be avoided avalanche and rock protection nets and water plugs for snow-groomer) (Figure 9).

Figure 9. Avalanche and rock protection nets and water plugs for snow-groomer

The display shows also the snow thickness under the blade with transversal section of ground profile and blade inclination. In another windows is shown longitudinal section with slope.

The data collected sequence is stored in a data logger that allows the registration of the route taken tracks with the control on times, of the worked surfaces, of the consumption. The data of the snow groomer height with respect to soil level, equal snow thickness, allows to obtain a map of snow quantity, as shown in Figure 10.

Conclusions

The carried out tests, making the snowgroomer only an instrumental drive, have shown really interesting results reached also in the gorge:

- ✓ it is possible to adopt parallel drive;
- ✓ the system gives a draw of the ski track with different colours referred to the thickness ratio of the snow; giving information on the sites where to move snow

- ✓ it is possible to control the snow-mower use and productivity of the snow management operations.

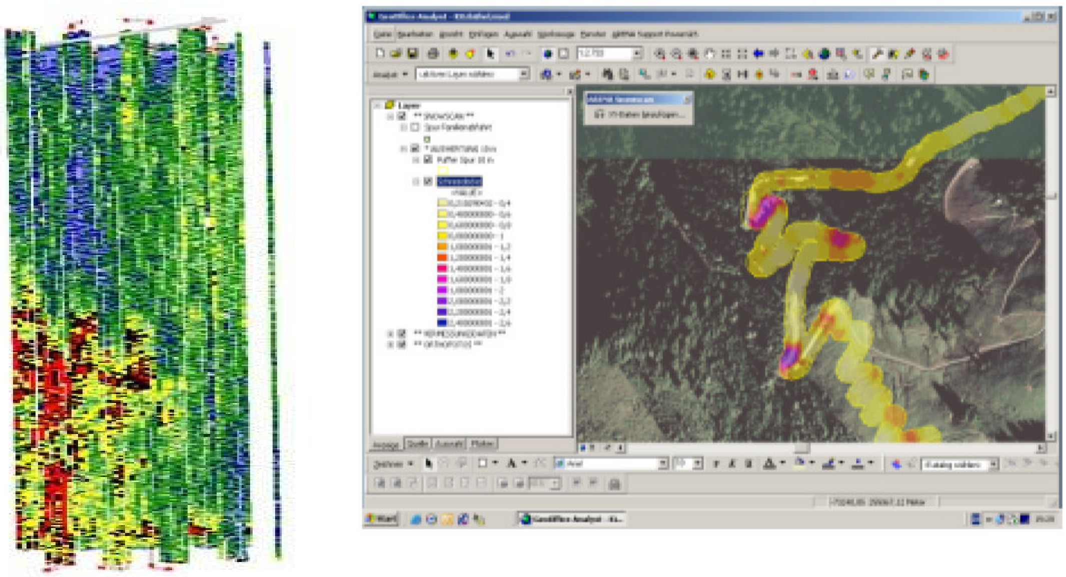

Figure 10. Maps of the snow thickness on the ski run.

Acknowledgements

The authors acknowledge Emilio Palchetti of the Leicageosystem Machine Automation Division of Calenzano (FI), the NIZZI company of Pievepelago distribution and assistance snowgroomer Leitner in Central Italy, dr. Diego Mazzolini forest doctor collaborating with the DIAF, guide of the alpine assistance, dr. Andrea Formento of Società Val di Luce.

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Developing and testing of a device to disengage the power transmission between tractor and feed mixer wagons

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Abstract

The risk of contact between the operator and the augers of a self-loading horizontal-type feed mixer wagon is one of the most critical situations connected to the safe use of these machines. To prevent this hazard, a research project funded by the Italian body for the agro-mechanical industry (ENAMA) and carried out by Comer Industries, Reggiolo, Italy, with the scientific support of CRA-ING and CNR-IMAMOTER research institutes, has been planned. A transmission device consisting of an automatic limiter able to disengage or to reverse the augers movement has been designed and tested. Aims of the device were: *i)* to transmit the torque required to the augers without limitations during the normal working process; *ii)* to continuously detect the torque values reversing the augers rotation if threshold values are exceeded and *iii)* to continuously detect the position of the rear self loading device stopping the augers when the loading arms are raised. Tests were carried out both in laboratory and in farm conditions; in this last case, the device was fitted into the driveline of a self-loading 10 m^3 feed-mixer wagon driven by a tractor PTO. The test ration was composed of an high quota of long stemmed hay quickly loaded into the mixing box in order to reproduce an high torque demand on the augers thus soliciting the intervention of the limiter. Laboratory tests show that the disengagement of the power from the tractor and the intervention of the internal brake, takes a short time to be realised and it occurs when the pressure of the oil exceeds a set value. Moreover, the functional parameters show that the reversion of the rotation in case of mixing box overloading, concurs to avoid the need for the operator to keep in contact with the augers to clear them.

Keywords: safety, sensor, automatic PTO disengagement.

Introduction

Self-loading horizontal-type feed mixer wagons (FMWs) represent a particularly dangerous category of agricultural machines for at least two main raisons; firstly, as many other agricultural tools, they are powered by a tractor power take-off (PTO) thus exposing the operator to the risk of become entangled in the implement input driveline (IID). Many case reports, unfortunately, testify this type of accident in feed mixer wagons operations (NIOSH-FACE Program, 2002a; 2003) as consequence of the specific tasks to be accomplished in the front side of the wagon during feeding (i.e.: adjust and check the electronic scale display, invert the sense of rotation of the IID, operate some controls, etc.). Secondly, the self-loading horizontal-type feed mixer wagons to be operated need that the worker approaches also the rear side of the machine and its uncovered moving parts – in particular augers and loading device – to push the uncollected feed closer to the loading device, to adjoin additives to be inserted in small quantities, to clear the augers from possible wrapping of long stemmed forages, to inspect the regularity of the chopping-mixing process, etc. Also in this case, the literature reports accidents occurred, with always devastating consequences for the operator (NIOSH-FACE Program, 2002b).

A specific standard rule for this kind of machines (EN 703: 2004) has been developed in order provide design guidelines for manufacturers.

Besides, local programs to inform and to advise the farmers on the correct use of feed mixer wagons (i.e. Wisconsin FACE, 2007) have been carried out.

Moreover, several researches have been done to develop novel safety systems for tractor powered machines taking into account both the possibility of modifying the tractor transmission (Thomas and Buckmaster, 2005) or to apply safety sensors (Venem *et al.*, 2006), whether still at prototype level.

Aim of this research project was to design a system focused on horizontal type feed mixer wagons including both transmission and sensors safety components. The project was funded by the Italian body for the agro-mechanical industry (ENAMA) and carried out by the manufacturer Comer Industries, based in Reggiolo, Italy, and planned with the scientific support of CRA-ING and CNR-IMAMOTER research institutes.

A transmission device consisting of an automatic limiter able to disengage and/or to reverse the movement of the mixing augers under the control of sensors has been designed and tested.

Materials and methods

Aims of the purpose-designed device were: *i)* to transmit the torque required to the augers without limitations during the normal operation of the mixer; *ii)* to continuously detect the torque values at the wagon level and reverse the augers rotation if a set threshold value is exceeded; *iii)* to continuously detect the position of the rear self loading device and to disengage/stop the augers rotation when the loading arms are in their raised position. The device was designed to be integrated in the gearbox reducer of a trailed horizontal-auger feed-mixer wagon and consists of oil-bath clutch disks, hydraulically driven. The clutch engages or disengages the mixing augers if anomalous values, imposed by the manufacturer, occur and/or depending on the cutter arms' position. This working mode enables the operator to leave the manual controls area and get close to the rear of the wagon to load manually some diet components. Moreover, the system is able to invert automatically the sense of rotation of the augers in case of their blockage due to the wrapping of long stemmed forages.

Secondary aim of the project was to produce an universal device that could be fit also on second-hand mixers in order to improve the safety conditions of these machines. Tests were carried out both in laboratory and in farm conditions.

Laboratory tests

The tests in laboratory conditions (Figure 1) were necessary to set up the sensors and the electronic control unit (ECU) both in the case of disengagement of the power and in the case of reversion of the rotation.

The test bench was composed by an electric engine connected to a gearbox that transmitted the drive to the main shaft of the limiter device and by a dynamometer that provide the load simulating the mixing action. Thanks to this configuration it was possible to reproduce different situations – also the most critical ones – that may be checked during the work cycle of a trailed feed mixer wagon.

The sensors fitted on the limiter and controlled by the ECU were two oil-pressure gauges, a torque meter and two shaft revolution counters. Three main button controls were prepared to operate the ECU of the device ("start mixing", "stop mixing", "auger inversion") and all the functions scheduled have been tested. The laboratory assessments were replicated for 100 test cycles.

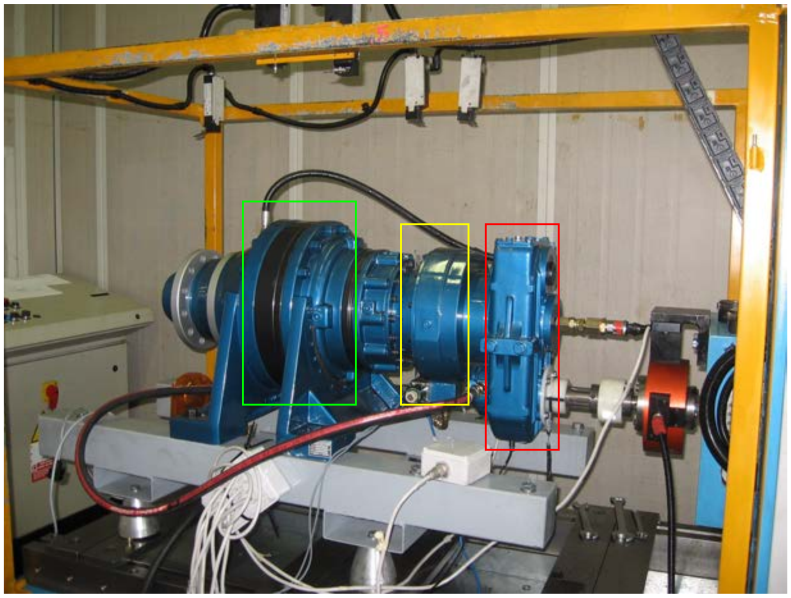

Figure 1. The test bench arranged for the automatic limiter' sensors and electronic unit set up (the automatic limiter = yellow square; the gearbox reducer = red square; the dynamometer = green square).

The main functions planned for the ECU were as follows:

1. running inhibition whether only one of the sensor detects anomalous values at the starting of the MFW;
2. starting of the augers rotation when pushing the "start mixing" button;
3. stop of the augers rotation when pushing the "stop mixing" button;
4. starting of the reverse rotation of the augers when pushing the "auger inversion" button; this counter rotation action is automatically maintained for a maximum of 15 seconds. In this case a 2.5 reduction factor of the auger speed in counter-rotation is adopted;
5. stop of the rotation to the MFW whether the pressure values are greater of a set threshold;
6. stop of the rotation to the MFW whether the pressure values are lower of a set threshold;
7. stop of the rotation to the MFW if a difference between the speed from the tractor PTO and the expected speed to the MFW shaft is recorded;
8. stop of the rotation to the MFW whether torque values are greater of a set threshold;
9. in the case of raising of the loading arms:
    a. stop of the rotation to the MFW,
    b. inhibition of the start of the transmission to the augers,
    c. stand of the augers rotation till the loading arm come back in their lower position,
    d. automatic re-start of the augers when the loading arms are completely lowered;
10. in the case the PTO stops:
    a. stop of the rotation to the MFW,
    b. inhibition of the start of the transmission to the augers,
    c. stand of the augers rotation till the PTO speed exceeds a minimum set value,

d. automatic re-start of the augers when the PTO re-starts.

For all the previous conditions has been assessed that the "stop mixing" button stops the rotation to the FMW and inhibits the automatic re-start of the safety systems.

Farm conditions tests

The tests in farm conditions were intended to assess the functionality of the device during the preparation of a standard TMR (total mixed ration) for dairy cows. In this last case, the device was fitted into the implement input driveline (IID) of a self-loading feed-mixer wagon, driven by the PTO of a standard agricultural tractor (Figure 2).

For this purpose, a new function has been added in the control system in order to consider the case of the tractor that moves and draws the wagon; if the PTO is disconnected during the displacement, the safety device automatically stops the augers rotations and inhibits its movements till the tractor PTO is re-started.

Also in the farm conditions the machine running is inhibited whether only one of the sensor detects anomalous values at the starting of the MFW, but in this case a sound signal and a flashing light inform the driver of the trouble.

Figure 2. The 10 m^3 trailed horizontal-auger self-loading feed mixer wagon used for the farm tests; 1) limiter device; 2) sensors for the loading arms position; 3) the ECU positioned in a safe working place inside the tractor cab.

A particular of the transmission limiter is showed in Figure 3 where the detailed position of some sensors are also showed (two oil pressure gauge into the limiter gearbox and two speed sensors, these last respectively at the inlet and at the outlet of the limiter). A torque-meter was interposed in the tractor-wagon driveline.

An on-board datalogger permitted to recording of the data. Five replications of the TMR preparation have been carried out in a commercial dairy farm using a 10 m^3 nominal volume feed-mixer wagon, with horizontal augers and a rotating silo-unloading device.

The feeding ration was composed of an high quota of long stemmed hay (for a total ratio of 31.5%, w.b.) quickly loaded in round bales into the mixing box (150 to 290 kg/min working rate); besides, the mixing volume of the hopper was completely filled (1230 kg of

TMR) in order to reproduce an high torque demand on the augers level to chop the steams and to mix the components thus soliciting the intervention of the limiter or provoking an overload.

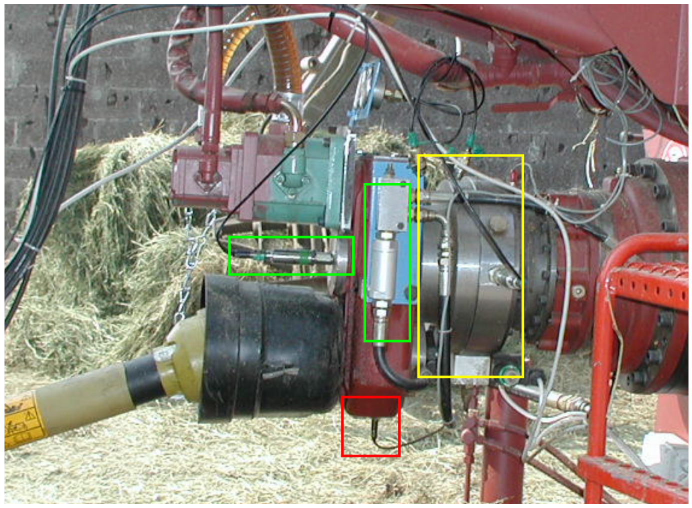

Figure 3. The automatic limiter (yellow square) fitted in the IID of the trailed, self-loading feed-mixer wagon. Sensors assist the limiter to monitor the set work conditions of the FMW (two oil pressure gauges = green squares; one input speed sensor = red square).

Results

Laboratory test

Laboratory tests show that the disengagement of the power from the engine and the intervention of the internal brake, takes a short time (0.04 s av. time) to be realised and it occurs when the pressure of the oil exceeds a set value. Moreover, the functional parameters reproduced at the bench (table 1), show that the reversion of the rotation in case of overloading of the mixing box, occurs without problems thus avoiding the need for the operator to keep in contact with the augers to clear them of the overload.

Table 1. Torque transmission capacity of the limiter in normal and reverse rotation

Parameter	Shaft rotation	
	normal	reverse
Engine speed (min^{-1})	540	540
Engine torque (kN)	911.3	346.3
Output torque (kN)	29430	29430
Hydraulic pressure (kPa)	2000	2000

Farm conditions tests

Figure 4 shows the results recorded during a typical TMR preparation where any problem has been registered or provoked in order to solicit the transmission limiter. The working period was divided into five phases correspondent to: the load and the chop of hay in round bales (phase 1); the self-load of silo maize (phase 2); the chopping-mixing action (phase 3) and the unload of the final TMR into two different mangers (phases 4 and 5).

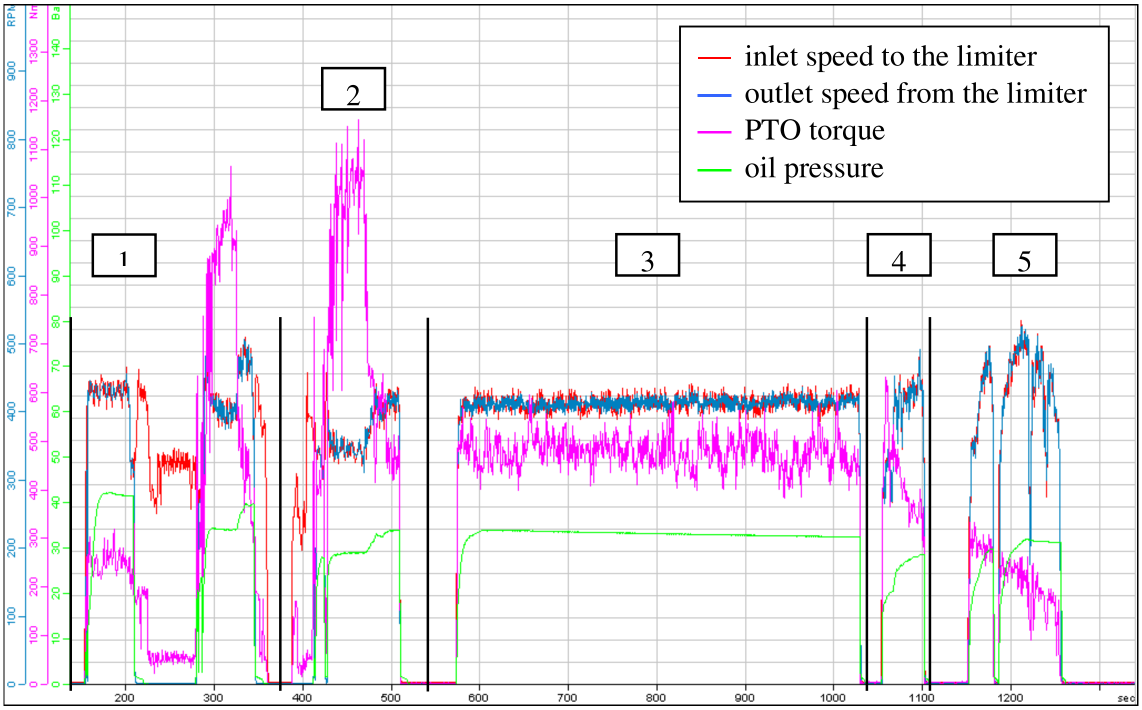

Figure 4. Typical trend of monitored parameters during TMR preparation for dairy cows in different working phases (1=load/chop of hay; 2= load of silo maize; 3=chop and mix of the ration; 4 and 5=unload on the TMR).

As shown, the speeds from the PTO and to the MFW (inlet and outlet speeds to and from the limiter) are quite almost coinciding because the slipping of the clutch occurs only in two occasions: at the start of the wagon (probably due to the too high PTO speed selected for the showed test) and after the hay round bale load and chop where the torque measured at the PTO suddenly reach a peak of 1050 Nm. During the silo maize loading phase the torque values were higher (1200 Nm) both because of the quantity loaded (1071 kg of silo maize) and the intervention of the hydraulic silo cutter drum (668.1 kg min^{-1} av. working rate); nevertheless these values were obtained more gradually in comparison with the previous phase as the lower rotating speeds (500-560 min^{-1}) and the maximum oil pressure values (3000-3500 Kpa) confirm. After the phase 2, the PTO was disengaged to manually load the concentrates.

Tests were replicated in order to provoke an overload of the wagon mixing system; the most probable phase for this kind of event is the hay load phase. Figure 5 shows one of the case occurred and reports the actions carried out by the operator to re-start the working process. As shown in the figure, the suddenly increase of the torque value (> 1800 Nm) due to the wrapping of hay on the augers, produced the contemporary reduction of both the inlet and the outlet speeds at the limiter level without recording any clutch slip; this behaviour is confirmed by the coincident trend of the two relevant curves; the oil pressure also drops and the tractor engine stops. After this trouble, the operator tried to re-start the tractor two times without success because the safety system sensors detected too high levels of torque due to the augers blockage.

The operator decided to push the "auger inversion" button, thus causing the counter rotation of the augers and their clearing from the long stems of hay wrapped around. The figure shows that the outlet speed in counter rotation (blue line) was 2.5 lower than the inlet one as set (av. 240 min^{-1} *vs.* 600 min^{-1}). The single counter rotating action performed had 12 s lasting and was sufficient to clear the augers; after that the working process was re-started and accomplished without any risk exposure for the operator.

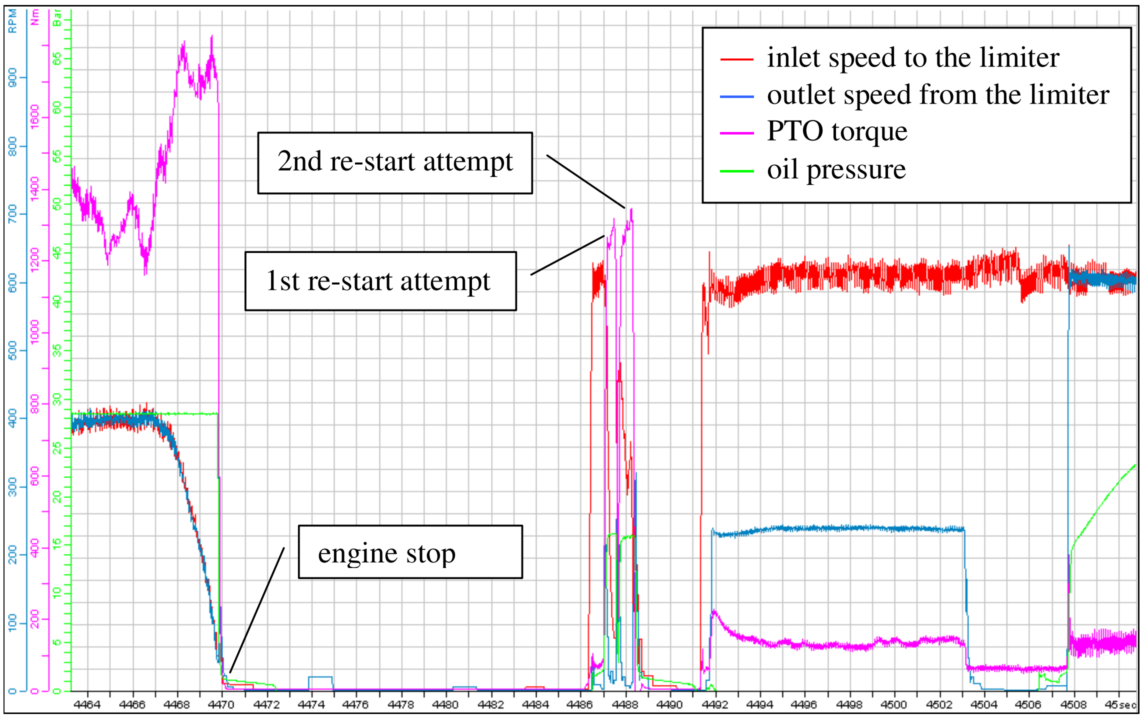

Figure 5. Trend of monitored parameter during an augers blockage due to the wrapping of long stemmed hay.

Conclusions

The use of an automatic disengagement device on a trailed feed mixer wagon has demonstrated to be an effective tool in order to manage the main dangerous operations deriving from the TMR preparation process; the possibility of trouble solving directly from the tractor seat reduces the risk for the operator to became in contact with mechanical rotating parts. In particular, the following conclusions can be drawn from this tests:

- the automatic limiter device assisted by sensors can transmits the torque required to the augers without limitations during the normal working phases of the mixer, but automatically stopping their motion if set threshold values are exceeded;
- the possibility of reversion of the augers rotation can solve auger blockage with few interventions without exposing the operator to the risk of contact with the augers or with the PTO shaft;

- to strengthen the safety conditions supported by the limiter device, an automatic auger stopping system has been set up, depending to the rear loading arms position.

Acknowledgements
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Use of a Helmet Endowed with Forced Ventilation and Air Filtration Devices in Greenhouse Application of Agrochemical Treatments Using an Innovative Prototype of Self-Propelled Sprayer Vehicle

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Abstracts

During pesticides spreading operations into greenhouses sited in Mediterranean area many workers don't use all the PPD prescribed by low because the high temperature and humidity.

Recent tests of small self-propelled sprayer vehicles conducted in greenhouses demonstrated a very good efficiency in pesticides distribution. In view of the possible diffusion of such vehicles, this work intends verify if the driver of such vehicle can easily use the prescribed PPD and a full helmet endowed with forced ventilation and air filtration devices, comparing the level of comfort to a traditional personal protection device (PPD). Tests were filmed to analyse repetitive arm movements and calculate the OCRA risk index. Use of vehicles and of a full helmet endowed with forced ventilation and air filtration devices for greenhouse agrochemical application appears to be related to greater comfort and better operator ventilation.

Further testing could address the minimum air flow rate required to operate in warm, humid spaces, like greenhouses, and air flow distribution within the helmet. We use an innovative tracked vehicle manufactured in Sicily.

Keywords

Self-propelled sprayer vehicle, tomatoes, safety, welfare

1. Introduction

Greenhouses crop are characterised by a great amount of pesticides spread periodically over all the life cycle. During pesticides spreading operations into greenhouses sited in Mediterranean area many workers don't use all the PPD prescribed by low because the high temperature and humidity. Recent tests of small self-propelled sprayer vehicles conducted in greenhouses demonstrated a very good efficiency in pesticides distribution. In view of the possible diffusion of such vehicles, this research intends verify if the driver of such vehicle can easily use the prescribed PPD and a full helmet endowed with forced ventilation and air filtration devices, comparing the level of comfort to a traditional personal protection device (PPD).

2. Material and method

As spraying equipment we use a little tracked tractor equipped with a spraying system is at an advanced stage of development thanks to a close cooperation between the Mechanics Section of the Department of Agricultural Engineering (DIA) of the University of Catania and the manufacturer. It is powered by an air cooled, 4-cycle, single cylinder, gasoline engine. Continuous and maximum power are 2.6 and 4.2 kW at 3000 and 4000 rpm, respectively. The main dimensions, including the tank, are: length = 1650 mm, height = 1100 mm, and width = 730 mm. Presently, driver seat of the prototype in not particularly comfortable.

We hope to automatize the vehicle thanks to a cooperation with the Dipartimento di Ingegneria Elettrica Elettronica e dei Sistemi (DIEES) of the University of Catania.

Traditional spraying was conducted by walking along the rows and using spray gun, (1 nozzle), mass 0.25 kg. The linear mass of the pipe was 0.19 kg m^{-1}.

The greenhouse in which we conducted the experimental trials was located in the province of Ragusa (Sicily). The tomato plants, cv *Panarea*, full developed, were arranged in twin rows, with distance between rows of 0.40 m, distance between twin rows of 1.20 m, and row spacing of 0.70 m. The plant density was therefore about 21000 ha^{-1}. The crop was geometrically characterised measuring minimum and maximum height of the foliage to be sprayed.

The greenhouse had a metallic structure, covered with plastic film. The minimum height was 3.5 m, the maximum 5.70 m. A central aisle 3 m wide provided for internal movements of operators during crop activities; half greenhouse has 12 spans, each 38 m long and 9 m wide, so the half surface was some 4100 m^2 and the total one was about 1100 $m^{2.}$ A lateral aisle 1 m wide provided for the movements of the vehicle was obtained by removing some tomatoes plant.

The full-face safety helmet has a mass of 0.7 kg and the flow rate of the fan was not less 180 L min^{-1}; noise was certified lower than 75 dB.

As previous *experimental planning* , ten healthy volunteers (mean age 32.5 ± 4.1 years) were studied as they dispensed agrochemical products in a greenhouse. Their main characteristics are reported in Table 1.

Table 1. Main characteristics of the sample.

Subjects	**N=10 (100%)**
Gender	Male (100%)
Age – yrs	32.5 ±4.1
Job seniority – yrs	10.6 ±5.4
Smokers	None (100%)
Alcohol consumption – g/day	22.1 ±17.6
Body mass index – BMI (kg/m^2)	24.8 ±3.5

They were asked to refrain from smoking and from consuming caffeine for 12 and 2 hours, respectively, before each trial and before the study all subjects signed an informed consent form.

Trials lasted 20 minutes; each subject performed the test in three conditions: 1) standing and wearing a conventional PPD (mask with filter) (test 1); 2) walking and wearing the helmet (test 2); and 3) driving the vehicle and wearing the helmet (test 3).

A questionnaire was administered to measure the degree of discomfort experienced using each PPD (from 0=comfortable to 4=extremely uncomfortable).

Before each test ad hoc paper pads were accurately weighed and then applied on forehead, chest and back with anti-allergic plaster strips for the qualitative and quantitative analysis of sweat according to Bates and Miller (2008). The devices did not restrict movement and were worn throughout each test; then they were collected, placed in a sterile plastic container and finally delivered to the laboratory, where they were weighed and subjected to atomic absorption spectroscopy analysis for sodium loss.

Medical measures, assessed at baseline and after each test, were tympanic temperature (TT), systolic/diastolic pressure (SBP/DBP), heart rate (HR) and respiratory function parameters: forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) and peak expiratory volume (PEF). Ventilation parameters were expressed as a proportion of ECSC reference values (1971) and adjusted for age, gender and body weight.

The following equipment was used: a portable spirometer (MIR); a tympanic thermometer (Braun; resolution 0.1°C); and a sphygmomanometer.

Each test was filmed with a camera to analyse repetitive arm movements and calculate the OCRA exposure index (Occhipinti and Colombini, 2007). This is the ratio of the number of repetitive upper limbs actions actually performed by the worker to a maximum recommended frequency of 30 actions/minute; the exposure index is modified as a function of the presence and characteristics of additional risk factors (or multiplier factors), e.g. posture and duration of the recovery period, which are attributed values ranging from 0 to 1. When the potential risk factor corresponds to an optimum condition it is attributed a value of 1, which entails no decrease in the exposure index. The more the risk factor diverges from the ideal condition the more its value diminishes and the value exposure index is reduced.

The values of the exposure index fall into three levels: level 1, ≤2.0 "green area", absent or non-significant occupational risk; level 2, >2.1 ≤3.9 "amber area", mild or borderline risk; and level 3, >4.0 "red area", high occupational risk.

Statistical analyses were conducted with the SSPC-PC program (SPSS, Italia). Between groups differences were subjected to one-way analysis of variance (ANOVA). The level of statistical significance was set at ≤0.05.

Fig. 1

Fig. 2

3. Results

Workers speed during the trials vary from 0.42 and 0.46 m s^{-1} and vehicle speed was about 0.52 m s^{-1}. Trials were conducted from 10.30 to 12 in the morning**,** temperatures were about 38 °C and relative humidity from 41%. Baseline and post-exposure values of physiological measures are reported in table 2.

Values demonstrated greater operator comfort in test 3 (subject driving the vehicle while wearing the helmet) and in test 2 (subject walking while wearing the helmet) compared with test 1, where he was wearing a traditional PPD (mask with filter).

The qualitative and quantitative analysis of pads demonstrated increased sweat rates, and consequently sodium loss, after each test. Comparison of the three sets of pads demonstrated that sweat rates were lower, albeit non significantly so, in the two tests where the operator was wearing the helmet compared with the test where he was equipped with the mask (tests 3 and 2 *vs.* test 1).

Although SBP and DPB were significantly higher after the tests compared with baseline values, their comparison demonstrated a significantly lower increase in test 3 than in tests 1 and 2. HR increased after each test, but did not show significant differences among the three conditions. Similarly, TT increased after each test but differences among tests were not significant.

All respiratory measures decreased significantly after each test. The largest reduction was measured after test 1, where the operator was standing and wearing a traditional PPD (mask with filter). Significantly better values were measured after test 3, where the operator was driving the vehicle and wearing the helmet.

Finally, analysis of the images enabled calculation of the OCRA index. It demonstrated that manual spraying (tests 2 and 3) entailed similar actions and OCRA scores, whereas the exposure index was significantly reduced in test 3 due to a reduction in the biomechanical demands on the upper limbs related to repetitive movements.

Table 2. Baseline and post-exposure values of the physiological measures studied

	Vaseline	Test 1	Test 2	Test 3
Dis/comfort	-	3.2 ±0.6*	2.3 ±0.7*	1.6 ±0.6*
NaCl $mmol.L^{-1}$	46.4 ±23.1^	48.4 ±26.6	47.7 ±25.2	47.5 ±25.9
SBP mmHg	114.8 ±6.4^	129.3 ±7.8	126.9 ±8.5	123.3 ±8.1*
DBP mmHg	76.3 ±6.1^	83.4± 6.1	81.7 ±7.0	78.2 ±5.7*
HR (beats/min)	74.3 ±5.4^	78.3 ±5.9	76.7 ±6.1	76. 3 ±6.5
TT °C	36.2±0.3^	37.4±0.5	36.9±0.8	36.7±0.9
FVC %	101.4±2.4^	97.6±4.3	97.7±3.7	99.3±4.1*
FEV_1 %	102.7±3.2^	97.4±4.6	98.2±3.4	100.7±3.5*
PEF %	100.5±4.1^	96.8±5.1	97.4±3.3	99.5±3.7*
OCRA index	-	3.3 ±0.3	3.3 ±0.3	1.5 ±0.8*

^baseline *vs.* test; $p \leq 0.05$ (ANOVA);
*test *vs.* tests; $p \leq 0.05$ (ANOVA).

4. Conclusions and prospects

The trials showed that a modern and well designed full-face light safety helmet provided with a little fan able to cool and to prevent the condensation on the visor can be used with driver liking during pesticides spread mechanised operations.

Moreover, during traditional operations workers prefer the safety helmet vs face mask.

Finally, we also can claim that the use of the spraying developing vehicle allows a great level of safety because the dramatic reduction in terms as pollution on the driver and, moreover, because drivers can willingly use a modern full-face efficient light safety helmet.

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POSTER PRESENTATION

Development of a drivehead for the coupling between power take off drive shaft and operating machine within the project CRA-ING and MED S.A.S.[(1)]

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Abstract

Connecting and disconnecting the PTO-drive-shaft to the Power-Input-Connection (PIC) of an operating machine is often made difficult by the presence of most protection models. The locking system of the PIC yoke is actuated by means of both the hands and can be reached through a narrow space between the PTO-drive-shaft cone of guard and the PIC protection: sometimes, it is necessary to disassemble one of them. The aim of the project was to develop a protection that, through a proper opening, could simplify the connection/disconnection between PTO-drive-shaft and PIC, keeping in compliance with the requirements of the ISO EN 12100-2: 2003, ISO EN 4254-1:2005 and EN 953 1997. In the first phase of the project, the standards' general requirements for the product-design and construction of fixed and mobile guards have been studied. It emerged that a mobile guard was needed, planned for frequent accesses to the danger zone, with the following requirements: 1) it can be opened only by means of a proper tool; 2) if opened, it must keep solid to the operating machine; 3) it must automatically close and lock itself without any tools; 4) the type of risk against which it has been developed has to be shown on it.

As a consequence of the characteristics of its components, the prototype is in compliance with the mobile guards standard requirements. A further contribution to the increase of safety level is represented by a device determining the automatic closure of the guard.

Finally, the prototype allows to completely cover the PTO-drive-shaft transmission system. It makes easier the connection/disconnection between PTO-drive-shaft and PIC and the maintenance of the PTO-drive-shaft. It could hopefully contribute to reduce the frequency of accidents.

Key words: protection, Power-Input-Connection, prototype.

Introduction

Agricultural tractors are commonly used as mobile power sources driving operating machines in for the execution of a wide range of operations.

The power transmission from the power-take-off (PTO) to the power-input-connection (PIC) of the operating machine is made by means of a PTO-drive-shaft. With the aim of avoiding dangerous detachments of the PTO-drive-shaft during the rotation, its extremities can be equipped with different kinds of safety locking devices, such as button victaulic coupling, conic bolt coupling, sprag clutch coupling, etc.

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(1) The prototype has been developed within the 12th ENAMA project upon the experimental activity on innovative mechanic devices for agriculture, in accordance with the MiPAF

The connection and the disconnection between the PTO-drive-shaft and both operating machines PIC and tractors PTO yokes often represent difficult operations, even for effect of most of the drivehead models present in the market, that leave a narrow space in which unlock the above mentioned safety locking devices. In particular, as regards the PIC yoke, these operations require to operate, with both the hands, inside the space between the drive-shaft cone of guard and the PIC protection: sometimes it is necessary to tear down one of them.

The access to the coupling zone is also requested for the normal maintenance operations on the PTO-drive-shaft: the PIC-yoke bore must be kept in good conditions, periodically cleaned and lubricated, avoiding excessive wear and rust formation; the safety locking system must be lubricated and perfectly working in order to be easily actuated for locking or releasing the PIC-yoke from the bore, respectively during the connection and the disconnection of the drive-shaft.

In the present paper the aspect of the driveheads for the PIC of the operating machines has been studied with the aim of developing a prototype of protection system capable to provide a complete isolation of the connection zone and allowing, at the same time, the execution of all the operations of maintenance, connection and disconnection of the PTO-drive-shaft.

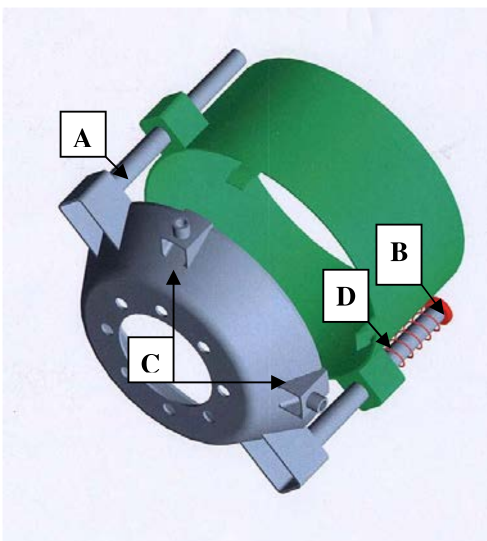

Figure 1. Three-dimensions sketch of the prototype of guard developed according to the requirements of safety and functionality.
(A) Sliding system with cylindrical guides;
(B) End-stop removable only by means of a suitable tool;
(C) Protection against accidental opening;
(D) Spring system for the automatic locking of the guard.

Project design and development

The work started with an examination of the existing standards on the matter. In particular, the EN 953: 1997 provides the general requirements for the design and realization of fixed and mobile guards. Considering that a guard is defined as an "element of a machine aimed at providing protection by means of a physical barrier", the subject of the work could be considered a guard, according to the standard. In particular, among the foreseen different kinds of guards, it seemed to better adapt to the definition of "mobile guard", capable to facilitate the locking and unlocking manoeuvres of the safety device of the PTO-drive-shaft under safety conditions.

- The standard requirements of mobile guards, aimed at guarantying the safety f the operators are the following:
- The guard can only be open by means of a voluntary action;
- When the guard is open, its mobile part must be solid to the fixed part;
- The elements keeping solid the mobile part and the fixed part can be removed only by means of a suitable tool;
- The guard locking must occur without any tool, automatically.

Further aspects of the mobile guard took into consideration were its working mode, its lifetime and the characteristics of the work environment in which it should be used.

After having defined the guard requirements according to the standards, among different technical possibilities, it has been chosen the solution that also seemed capable of better guarantying the functionality of the system.

Particular attention has been paid to the system that must allow the access to the danger zone, that have to occur only through a voluntary action and not accidentally. As a consequence, it has been chosen a wedge shaped locking system allowing, on one hand, the guard opening only with a voluntary action and, on the other, the automatic locking of the system, when the intervention is concluded, by means of a spring system avoiding that the guard could remain open during the rotation of the PTO-drive-shaft.

As to the dimensions of the access opening, the project-design based on the indications reported in the EN 547-2:1996 reference standard, also considering the points of action of the automatic locking system on the operator's hands.

The choice of the guard material has been based on the impact strength, the stiffness, the thermal stability, the resistance to the vibrations, the time life of the cylindrical guides, the prevision of the sliding system efficiency, the presence of cutting edges, the colour.

The previous considerations are synthesized in the 3-D sketch of fig. 1, in which the main elements are represented by: a sliding system (fig. 1-A) that must by capable of high performances under the sever condition typical of agricultural work (presence of dust, mud, plant residues, vibrations, etc.); a stop-end that can be removed only by mean of a proper tool (fig. 1-B); a system protecting against the accidental opening of the guard that can be unlocked by mean of a sharpened tool as well (fig. 1-C); a spring based system operating the automatic locking of the guard as soon as the hands are taken out (fig 1-D).

Basing on the characteristics determined in the preliminary study, the work proceeded with the realization of a prototype that underwent the first experimental test at CRA-ING in Monterotondo (RM, Italy).

Finally, in order to facilitate the series production by means of dies, the guard has been divided into three main components.

Figure 2. Particular of the die for the production of the bottom of the guard

Tests

The first prototype of the guard has been mounted on a series of operating machines (a stump grinder with horizontal axis, a rotary harrow, a two-axle trailer, a spading machine, a ditch cleaner on a slewing arm) and tested with the aim of verifying the correct installation and working and its adaptability to the different types of machines. The tests results suggested some modifications of the structure and shape of the prototype (aimed at increasing the stiffness of the automatic locking system) and of the section of the guides of the sliding system (that became cross-shaped, instead of cylindrical, in order to reduce the friction surfaces, increasing the efficiency of the system).

The realization of the dies for the series production started after these modifications on the prototype (fig 2). The lash-ups produced represented 2nd level prototypes, the behaviour of which has been observed in further experimental tests under operating conditions similar to those describe for the first series of tests.

The tests regarded the evaluation of the correct use of the protection and its functionality, verifying both the effectiveness of the sliding system and of the automatic locking and the actual simplification in the connecting and disconnecting operations of the PTO-drive-shaft from the PIC-yoke and the resulting increased comfort (fig. 3).

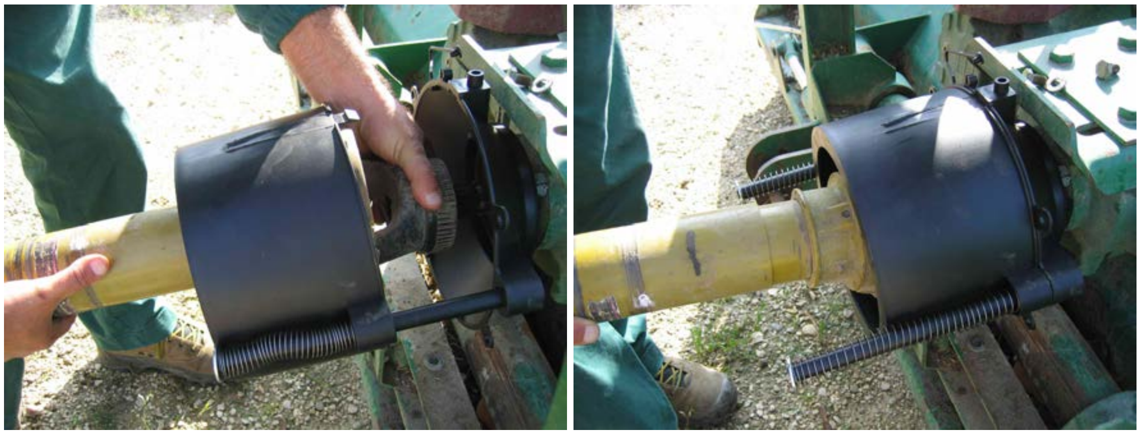

Figure 3. Tests on the functionality of the 2nd level prototype of the guard. Left: guard open for the connection of the PTO-drive-shaft to the PIC-yoke. Right: guard automatically locked by the spring system

Observing the performances of the 2nd level prototype during the tests, provided indications about the effectiveness of the modification on the first prototype and for the alignment of important details such as the maximum length of the sliding guides and the correct working of the automatic locking system.

Figure 4. The prototype has been tested under different working conditions such as the chopping of poplar residues with a stump grinder (left) and soil refinement with a rotary harrow (right)

Basing on these indications, the first exemplars have been realized and tested at CRA-ING. The first series of tests has been made in laboratory and had the goal of verifying the effectiveness of the safety hook against the accidental opening. If the locking system has not been unlocked voluntarily by means of a sharpened tool, the opening can also occur by applying on the safety hook a force of at least 9.3 daN.

Then the guards have been used with different operating machines and tested during the execution of normal works in field. The operating machines were a stump grinder, a rotary harrow, a rotary cultivator and a slurry spreader.

In particular, the use with the stump grinder (fig. 4) represented a severe test for the guard. It has been executed in a field with forestry woody residues, that determined high vibration levels and important shocks on the tractor-operating machine system. Such conditions, in one case only, caused the breakdown of the guard

No troubles arose from the remaining utilizations of the guard, testifying its reliability.

Conclusions

The final version of the guard is shown in fig. 5. The prototype resulted functional, coming up to the project's expectations. The tests evidenced that, after a short training, the operators become capable to easily perform the connection and the disconnection of the PTO-drive-shaft with the PIC-yoke of the operating machines, under significantly increased conditions of comfort. At the same time, the aspects of safety are guaranteed by the described devices aimed at avoiding that the guard could be accidentally opened if not requested, or could be forgotten open after the end of the intervention. All the operator involved in the tests expressed positive evaluations about the different aspects of the use of the prototype (safety, functionality and comfort).

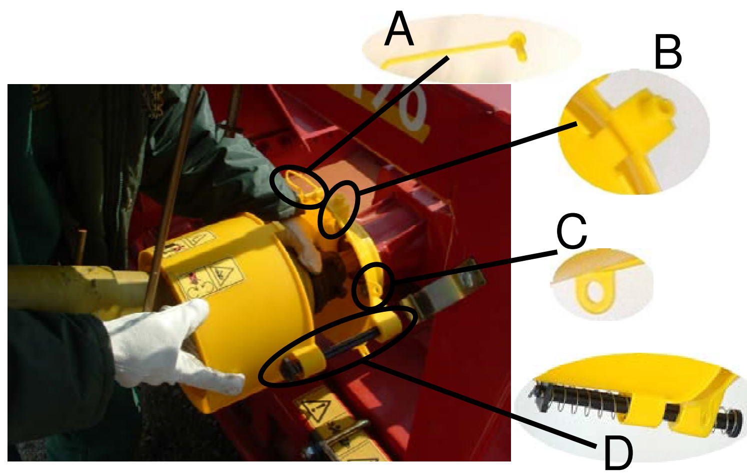

Figure 5. Main components of the drivehead: A) pin locking the guard closure; B) guard locking system; C) hooking holes for the PTO-drive-shaft retraining chain; D) automatic closure system

At the end of the study, an evaluation of the residual risks, determined by the use of the guard, has been made, revealing the necessity of applying a series of pictograms warning, for instance, about the danger of entangling with the PTO-drive-shaft during the rotation, prohibiting to get on the guard itself, etc.

Possible improvement of the prototype guard could be represented by shielding the sliding guides by means of a further external protection or directly realizing them inside the guard.

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Execution of experimental tests on agricultural machinery under safety conditions

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Abstract
The different aspects of safety and health protection (prevention, exposure to chemical or physical agents, etc.) are regulated by specific national and international laws and standards. It is often difficult to apply them to agricultural work, characterized by seasonality and extreme variability of activities and implements. In a research centre such as the CRA-ING, performing test on agricultural machinery, such difficulties are increased by the use of prototypal instrumentations and equipments that, for their nature, could represent further source of risk. Different, parallel ways must be covered, with the purpose of reducing the the risks for the operators in test activity. Their skilfulness must be constantly updated by means of periodical courses both on technical and safety matter. The test activity has been planned in a "test safety protocol", indicating the responsible and developing the above mentioned points. Instrumentations and equipments highly reliable and precise have been developed and allow to reduce the number and duration of the tests. Furthermore, the introduction of remote control systems, particularly in heavy duty trials (traction tests, p.t.o. torque and speed tests), enables the operator to set the test parameters and to monitor their behaviour at a safety distance.

Keywords: health protection, risk, testing, safety protocol.

Introduction

The different aspects of safety and health protection (prevention, exposure to chemical or physical agents, etc.) are regulated by specific national and international laws and standards. It is often difficult to apply them to agricultural work conditions, characterized by seasonality and extreme variability of activities and implements. In a research centre such as the CRA-ING, performing test on agricultural machinery, such difficulties are increased by the use of prototypal instrumentations and equipments that, for their nature, could represent further source of risk. This determines a variety of conditions under which the "normal" risk in the use of the machines is associated to the risk deriving from the sequence of operations involved by the tests, such as the correct installation, calibration and use of the sensors, the number of replications, the use of suitable test rigs, etc. The paper describes the different measures that CRA-ING adopted with the aim of increasing the safety level during the execution of the tests and the quality of the measurements.

Materials and methods

Kinds of agricultural machines tested and relative risks

CPMA most important activity is represented by experiments directly conducted in collaboration with the manufacturers and aimed at studying prototypes or modified existing machines and at improving the level of their performances. Moreover, CPMA is accredited for the ENAMA certification tests of a wide range of agricultural machines and accessories, regarding both their operative performances and the aspects of safety. As regards the performance tests, the main categories of tested machines are: agricultural tractors, machines for soil tillage; sowing machines; combined machines; machines for special works; flail mowers; some types of harvesters (dry fruit and vineyard harvesters); agricultural tyres (Fanigliulo *et al*., 2007). As to the safety tests, in addition to the above mentioned machines, other categories are involved, such as bush-cutters, chain-saw and portable olive tree shakers. The risk commonly associated to their normal use derives from the exposure to physical agents such as noise and vibrations, high temperatures, moving elements, machine stability and ejection of materials during the work. They are evaluated in dedicated tests in compliance with national and international standards (Lgs. D. 277/1991; Dir. 2002/44/CE; Dir. 2003/10/CE; ISO 2631-1:1997; ISO 5349-1:2001; Lgs. D. 626/1994) and the presence of suitable guards and warnings must be ensured.

Further sources of risk for the health of the operators have been more recently individuated in the conditions of comfort during the work (for example in tractor cab), including climatic parameters, the presence of dusts and the posture (Fig. 1) (Pochi *et al*., 2007).

Beyond these kinds of risk, someway codified because occurring on machines normally accompanied by the CE conformity, difficulties sometimes rise when the tested machines are out of the schemes, as in the case of prototypes, modified machines, etc., requiring to pay particular attention at individuating new situations of danger.

Figure 1. Tillage tests with a tractor equipped with a self-levelling cab

Kinds of tests, instruments and devices required by test methodologies and relative risks.

The performances of farm machinery are evaluated through the measurement of significant parameters, during the execution of normal operations, made by means of sensors and instruments installed on the machines. The test procedures increase the level of interaction between machine and operators. Moreover, testing operating machines requires the use of tractors, so that the tractor-operating machine system becomes the subject of the study and the source of potential risks. The tests at CRA-ING are conducted on the basis of a "Quality System" developed according to the ISO/IEC 17025:2005 standard. In this context, all test activities are strictly planned with the purpose of guarantying high quality results. Among such activities, the calibration of sensors and instruments requires the realization and use of suitable devices and equipments: for each instrumental chain, the calibration is planned, step by step, in documents called "Operative Instructions". Similarly, for each kind of test, the activity is rationalized in the "Quality Plans". The main risks associated to the most significant CRA-ING activities are described in the following.

1. Tractors - According to the "Quality System" plans, the efficiency of the tractors used in the tests of machinery is periodically verified through p.t.o. tests at the dynamometric brake. The main risks associated to these tests are represented by: p.t.o.-drive-shaft rotation; high temperature of the parts of the tractor to which the fuel consumption measurer is connected; damaging of the dynamometric brake cooling system.

Figure 2. Prototype of mobile test bed developed at CRA-IN aimed at performing dynamic tests on tractors. The AC supplier, the cooling system and parts of the hydraulic system are visible. In particular, the right picture shows the pump and the torquemeter were the p.t.o. - driveshaft is connected

Furthermore, CRA-ING developed a prototype (fig. 2) aimed at studying the performances of tractors under operative conditions, integrating the OECD standard codes (OECD, 2008). By means of an hydraulic system, it can apply predefined values of resistant torque at the p.t.o. of the tractor, simulating the action of p.t.o.-driven machines. The risks mainly derive from: rotating elements (p.t.o.-drive shaft); high pressure values reached in the hydraulic system; heating of parts of this latter, up to fire, caused by heat exchanger damaging.

Figure 3. A) a torquemeter is interposed between a tractor p.t.o. and the drive-shaft of an operating machine. B) a truck pulls the tractor-operating machine system at the same working velocity for the measurement of the net force of traction. C) device interposed between tractor and operating machine, directly measuring the three components of the force acting on the three point linkage

2. Tractor-operating machine system during the tests (Fanigliulo *et al.*, 2004) - In the case of machines driven by tractor's p.t.o., a torquemeter is commonly interposed between the p.t.o. and the drive-shaft connected to the operating machine (fig. 3A). The force of traction can be indirectly measured using a traction vehicle, that pulls the tractor-operating machine system by means a drawbar supporting a load cell (fig. 3-B) or, directly, with the structure of fig. 3-C, equipped with load cells and applied at the three point linkage. In all cases, the installation of sensors and devices is difficult (displacement of loads) and particular care is

needed when moving components are involved. Sometimes, in order to find the machine best adjustment, it could be necessary to control closely how it works (for example, proceeding by its side), being exposed to the projection of materials.

Figure 5. Test rig used in the tests for studying the performances of tractor hydraulic lift (A) and tyre deflection under load conditions (B)

3. Agricultural tyres - The tyres undergo static and dynamic tests. The static tests (fig. 5) aim at observing the deflection as a function of the vertical load and the force needed to determine tyres transversal displacement under load conditions. They are performed on a test rig where hydraulic systems generate the forces that are measured by load cell. The risk is represented by the stress of hydraulic and mechanic elements of the test rig. As to the dynamic tests on tyres tractive performances, they are commonly performed mounting the tyres on a tractor that pulls a braking vehicle. The force of traction is measured by a load cell supported by the drawbar interposed between the two vehicles.

As an alternative, CRA-ING developed a prototype of mobile test bed (MTB, fig. 6) with the aim of increasing the reproducibility of the tests conditions and the reliability of the results. It allows the test of a couple of tyres, theoretically of any model and dimensions (Pochi and Santoro, 2004). It is characterized by adjustable mass and by an hydraulic braking system electronically controlled. By means of a feed-back system each test can be executed on preset values of force of traction and/or slip. The risks are associated to rotating elements, to the operations for ballast adjusting, to the high pressure and temperature of some components of the hydraulic system, up to fire (heat exchanger damaging).

Figure 6. Mobile test bed aimed at studying the tractive performances of the tyres

4. Calibration of instruments - As required by the "plans" of the "quality system", all the instruments are periodically calibrated in dedicated places. Particularly difficult is the calibration of torque-meters and load cells, requiring the managing of masses in order to reach predefined values of load, torque, etc. The improper use of the equipments can determine risk of mass crashing down and crushing.

Measures adopted

Different lines of actions can be followed in order to reduce the risks deriving from the complex reality just described.

<u>Use of the tractors-operating machine system in field tests</u>

As in normal work, the personnel must be provided with safety equipment and skilled in mounting operations, adjustments and work execution. This activity must be performed according to the requirements of the reference standards for each kind of risk. For instance: the level of noise on a tractor should not exceed the limit of 80 dB(A) at the ear of the driver (Lgs. D. 277/1991; Dir. 2002/44/CE); if the cab's acoustic insulation is not in good efficiency and/or the operating machine exceeds the limits (it could be a prototype), the driver should use the protection headset. Similarly, the suspension system of the driver seat should always guaranty an effective reduction of the vibration levels (Lgs. D. 277/1991; Dir. 2003/10/CE).

<u>Realization of test rigs and prototypes to be used in the tests</u>

The project design and development of the test devices used at CRA-ING had to consider both the purposes of their realization and the aspects of safety (Lgs. D. 626/1994). All choices have been made suitably over-dimensioning the components. For example, in the prototypes for the dynamic tests on tractors and tyres, proper protections avoid every accidental access to rotating/moving components (fig. 7); the frameworks have been realized for resisting to load values up to the double of the maximum load foreseen in the tests.

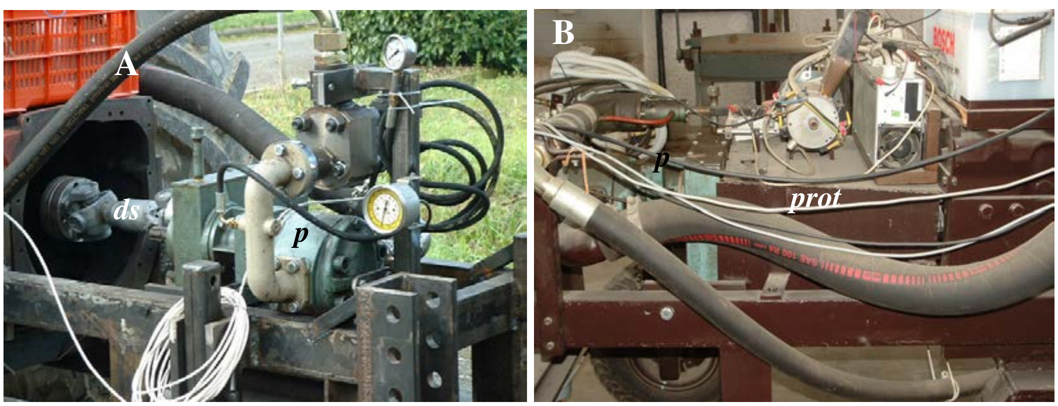

Figure 7. Prototype for tyres dynamic tests. A) free access to the connection between the gear-box shaft and the hydraulic pump (*p*) during the realization. B) the access to the drive-shaft (*ds*) is now completely protected (*prot*)

Similar criteria have been adopted for the tow-hook, basing on the expected values of force of traction; all the elements of the hydraulic system have been chosen considering the power required by the tests and the corresponding hydraulic oil pressures; the heat exchangers have been dimensioned on the basis of the energy to dissipate, of the duration of the tests and have been set on temperatures of intervention below 50°C in order to ensure the system correct working and avoiding the risks of overheating parts; the electronic system continuously monitors pressure and temperature values, releasing the pressure if needed, by means of safety valves. All the components have their certificates of conformity. In order to limit the risks of fire, the electric components are suitably screened and separated by the hydraulic systems. In some cases, as for the calibration of load cells, it has been possible to eliminate the risk of mass falling or crashing by means of suitable equipments, as those shown in fig. 8-A. Other devices can displace heavy manual measurements (fig. 8-B).

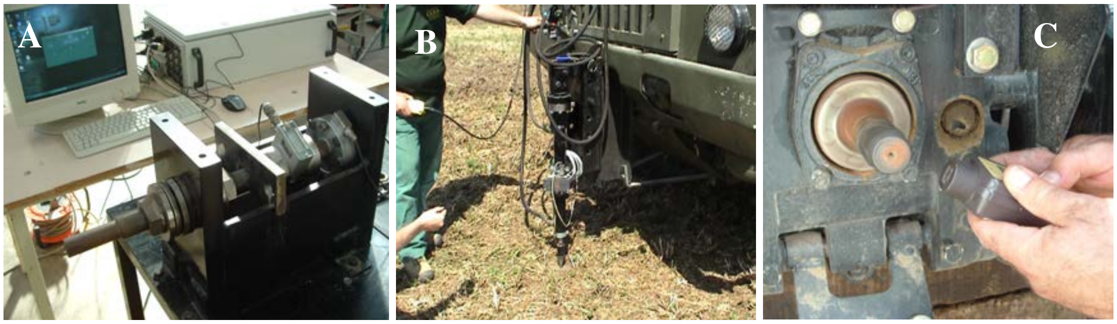

Figure 8. A) calibration of load cells: a reference load cell and the load cell that must be calibrated contemporarily measure the same force impressed by means of a screw system that avoids the use of big suspended masses. B) penetrometer represented by an hydraulic cylinder with a steel cone point, a load cell and a position transducer, displacing manual measurements of soil cone index. C) the measurement of tractor's p.t.o. speed is an apparently simple operation

<u>Use of test equipment and instruments</u>

An adequate competence is required in order to reduce the risk of improper use and the consequent health damages that could occur (fig. 8-C). As a consequence, the skilfulness of above must be extended to the calibration and mounting operations and to the controls aimed at verifying their status of efficiency before and after the tests, as required by the Quality System procedures as a guarantee of the results. From this point of view, it is important that all the elements used are in compliance with the safety standard requirements; then, as to their assembling and use in the tests, the experience deriving from a deep knowledge of all the aspects of the test system is the best instrument of prevention of accidents from moving elements (rotating drive shaft, displacement of ballast, lifting of masses, execution of p.t.o. or engine speed measurements, etc.), hot bodies (installation of thermocouples and fuel consumption measurers), electric shocks, damaging of mechanical and hydraulic elements. As all the test rigs and equipments have been developed at CRA-ING, the personnel has got a consolidated experience, knows the most sensitive components and, even in the most unexpected cases of danger, it is capable of the most timely and proper measures.

<u>Organization of test activity</u>

The experience in the use of machines and test equipments, associated with the standards requirements, has been helpful in rationally organizing CRA-ING test activity. On purpose, a "safety protocol" has been developed and is adopted in performing the test. It is based on the following points:

1. Designation of a responsible for each type of test, whose function is the care of all safety aspects (Lgs. D. 626/1994) described in the following points. The responsible must also possess a proper technical knowledge in order to manage the test activity according to the requirements of both safety standard and performance test methodologies.
2. Each type of test is performed in a defined area (a field plot, a test bench, etc.). The area must be clearly delimited and free from unnecessary elements for reducing the risk of crashes. Only the personnel and the vehicles involved in the test are allowed to enter the area.

3. Before the tests, the correct assembling and efficiency of all the elements used in the test must be controlled by the technicians and the responsible for the safety. Particular care must be taken in controlling the braking and the hydraulic systems, the protections on the rotating organs and against the projection of material during the work. The controls also involve calibration, mounting, adjustments and preliminary tests of the test devices (according to the "*Operative Instructions"* cited in par. *2*) and represent the most sensitive phase for the test good outcome from the point of view of both quality and safety.
4. Case by case, the personnel involved in the test must be equipped with the necessary protections such as headset, shoes, gloves, glasses, helmets. The responsible has also to consider the presence, in the test place, of fire-extinguishers and first-aid equipment.
5. Performing the tests according to the "Quality Plans" ensures a rational consecution of the operations. The test system is based on a mobile laboratory collecting and immediately processing the test data. This way it is possible to monitor the trend of each replication that, if necessary, is repeated, as necessary replications are avoided. Moreover, as most of safety and performance parameters (as temperatures, pressures, torques and forces) are remotely monitored (fig. 10), they can be kept inside the desired range, preventing the damaging of the related equipments and the consequent risks of accident.

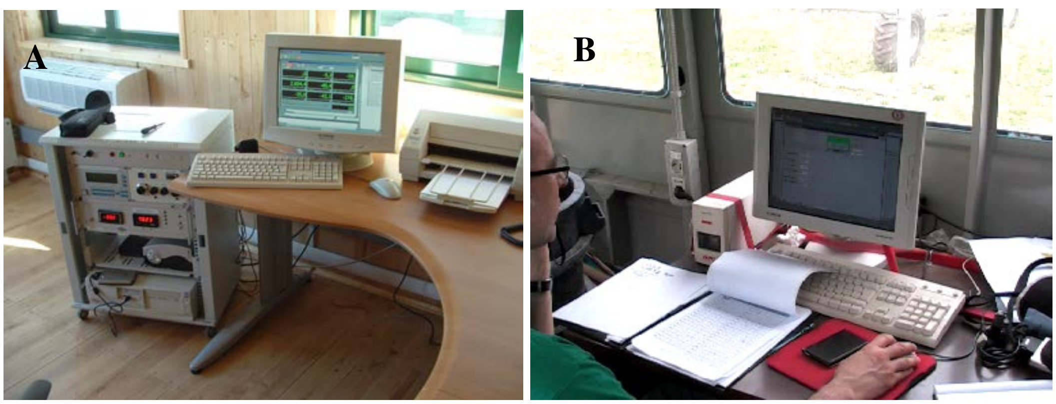

Figure 10. The remote monitoring of the tests contributes to the reduction of the risks of accident. A) control room annexed to the tractors' test bench; B) monitoring of the field tests from the mobile laboratory

Finally, the "Quality System" provides the realization of courses aimed at keeping the personnel on a good skill level. Their purpose is to continuously update the skilfulness of the personnel involved in the activity, both on performance tests and safety matter. They represent a moment of discussion of the different aspects of the activity, such as: the introduction, in the test system, of new instruments and equipments; the individuation of the most critical aspects of their calibration and use in the tests and of the risks associated to them; the application of new safety standard requirement in the test activity.

Conclusions

The described complex test activity at CRA-ING results from the application of the requirements of the standards on safety combined with the "quality system" procedures aimed at guarantying the quality of measurements. In this context, all the aspects of the activity underwent a rationalization process the aims of which can be summarized as follows: to avoid any unnecessary operation; to reduce the number of manual interventions; to increase and continuously update the personnel skilfulness; to keep an high quality level of the measurements. It is an interesting point that, according to this approach, increasing the quality of measurements contributes to significant improvements of the safety conditions.

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Improved Database for the Assessment of Operator's Vibration Risk in Agriculture

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Keywords: tractor, implement, daily exposure, action and limit values

Objectives

The European Directive 2002/44/CE includes the definitions of hand-arm and whole-body mechanical vibrations and, among others, establishes the daily exposure limit and action values, giving provisions related to the determination and the risks assessment.
Many studies confirmed that the vibration levels recorded in agricultural tasks are often widely exceeding the limits, as considering the whole body action value on an 8 h period (0.5 m/s^2), as that relevant to the daily exposure (1.15 m/s^2). On the other hand, the working conditions are extremely variable, resulting from the use of many different implements coupled with wheeled or track-laying tractors of various dimensions, engine power, etc. Due to this extreme variability, a careful assessment of a given operator's vibration risk could be carried out only through direct measurements but, due to the very high time consuming and cost requirements, this is evidently a very unlikely occurrence. So, many attempts were carried out recently to acquire data in order to build suitable databases.

Methods

The most frequent default of the major part of the these databases is relevant to a lack of operating condition details, that are fundamentally affecting the vibration levels. In particular, the following main parameters are always to be considered: tractor and implement characteristics (or those of the self-propelled machine considered); task performed; soil conditions; crop/material conditions to be harvested/distributed; travelling speed; fitting of suspension devices (on the tractor, on the cab, at the driver's place). Taking into account all the described parameters, a series of detailed database tables was then prepared, and the data coming from different sources (included the data available in the ISPESL database on vibration) were introduced, in order to cover a high number of agricultural tasks.

Results

The results show that, as expected, in many situations not only the daily exposure action values, but also the limit values are exceeded. Important warnings belong expecially from ploughing, high speed transportation and front loader handling tasks, but more data are strongly needed to cover as widely as possible the variability of the several parameters affecting the vibration risk.

(Research carried out in collaboration with Lombardy Region, Health Care Division).

Pesticide application over covered crops with hand held equipment: analysis of the contaminations[1].

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Abstract

The use of hand held equipments for treatments over covered crops produces, among the other, drawbacks connected to the risks of the workers (skin contacts with chemicals or their inhalation) above all when suitable PPE (personal protective equipments) are not worn.
The present paper reports the results of simulated treatment tests carried out in tunnels on strawberry crops, using a watery solution with a 2% concentration of food dyestuff.
The tests involved 3 types of hand held equipments connected with a hose to a pressure-driven atomizing sprayer, placed outside at the opening of the tunnels.
The measures regarded the deposits of dyestuff on the PPE worn by the workers during the tests and the «off-target» losses, measured by Petri capsules, placed on the ground, along the lanes where the workers walked. These deposits were then analysed with a spectrophotometer.
For all the tested equipments, the deposits registered on the PPE sensitively increase from the head, to the thorax, to the lower limbs, because of the "prostrated" vegetative behaviour of the crop, not more than 30 cm from the top of the ridge high.
Although the afore-mentioned equipments allow to carry out localized treatments on the ridge, considerable «off-target » losses were registered on the transit lanes. The amount of the losses along rows turned out unsteady and in inverse relation to the leaves deposits.

Keywords: exposure, strawberry covered crops, PPE, «Off-target » losses.

Introduction

The small sizes of the covered structures (numerous tunnels, covered with plastic sheets) (Baldoin *et al.*, 2007), the "prostrated" vegetative behaviour and the products often resting on the ground, the high investment for hectare (from 7 to 9 plants/m^2), the arrangement of lands into mulched ridges with plastic film, reduce the choice of the suitable sprayers in most the southern strawberry crop between these two types:

- sprayers equipped with diffuser "cannon", operating from either one of the openings at the ends of the tunnel;
- hand held equipments provided with one or more nozzles connected to ordinary mechanical sprayers by hose, placed outside the tunnel, driven by the operator along the narrow lanes (≤ 0,40 m), obtained between the twin rows (Guarella *et al.*, 2007).

These manual equipments, widely used in the recent past, are still utilized in particular conditions (small horticultural farms) and circumstances (especially virulent or hard to control

[1] Research developed within the 2005 MIUR project «Machinery and their adjustment for a sustainable pest control in glasshouses», Scientific Coordinator prof. Paolo Balsari.
Each of the authors contributed in equal parts to this work.

parasitary attacks) (Oggero *et al.*,2008).

The use of hand held equipments produces drawbacks connected to the high times taken to carry out the treatments and to the workers' hazards (skin contacts with chemicals or their inhalation) above all when suitable PPE (personal protective equipments) are not worn.

The "cannon" sprayers, that allow greater safety for the workers as the afore mentioned risk of contamination is almost nil in normal operating situations, share with the hand held equipments the risk of environmental contaminations, because of the off-target losses along the lanes and, in case of incorrect positioning and adjustment of the cannon, the risk relating to the sprinkling of the inner surface of the protection cover (Guarella *et al.*, 2008).

From the normative point of view it needs to remember the Community, National and Regional Legislation, concerning the correct management of the pesticides; in particular, the D.L. 626/94, with the subsequent modifications and integrations, which forces the employer to draw up the risk prevention plan, by an evaluation of the hazards and the adoption of able measures to reduce or remove these and, more than recent, the D.L. 25/2002, concerning the putting into effect of the 98/24/ CEE directive about the «Protection of the health and safety of workers from the risks related to chemical agents at work».

Also the Food and Agriculture Organization of the United Nations (FAO), within the Inter-Organisation Programme for the Sound Management of Chemicals (IOMC), developed "The International Code of Conduct on the Distribution and Use of Pesticides", to provide a comprehensive standard for pesticide activities and a point of reference in relation to sound pesticide management practices. In June 2006 the "Guidelines on Monitoring and Observance of the Code of Conduct" were published.

This Code, among the other, urges the National Competent Authority to promote or support the use of methodologies and sprayer equipments able to reduce the operators' exposure to pesticides, also including the personal protective equipments.

These PPE differ from one another according to the category of risk which the worker is exposed (89/686/CEE Directive). For each one of the category to which the PPE belong there are: a) careful fulfilment for the introduction on the market (CE trademark, declaration of conformity, information concerning the conservation modes, use, cleaning, control and disinfection, technical performances, required fittings, level of insured protection, dates of expiry, etc); b) different methods to make a choice of the protective equipment in relation to the parts of the body (skin, eyes, respiratory and digestive tract), the typology and length of exposure (direct spray, solid or liquid dispersions, aerosol) and the sprayer (with or without knapsack, connected to the tractor with or without cab, etc).

With reference to the division of the covered crop, in the tunnel or the greenhouse, there are not in Italy systematic surveys concerning the health hazards of the workers rising from exposure to pesticides, above all during their distribution.

A survey carried out in Europe points out, in the Southern Nations, included Italy, worrying absorbable by the derma (up to 900 ml/h) amounts of pesticides as well as the possible fumes and/or powder in the air because of the bad management of the changes of air or non-fulfilment of the re-entry times (Glass *et al.*, 1999). However, the overall theme is quite well-known in his general terms:

- during the treatment the workers' contamination widely arise from the typology of the used sprayer and the arrangement of the target[2];

[2] The employment of hand held equipments during treatments is the cause of the following contamination of the parts of the operator's body: hands (25%), trunk and head (25%), lower limbs (50%), according to the POEM (Predictive Operator Exposure Model) used for the evaluation of the workers' risks.

- the amount of the above-mentioned contamination is due to: a) the closeness between the worker and the spray, b) the direction of the spray, c) the worker's way of walking (for the hand held equipments): forwards or backwards;
- the re-entry times, the criteria ventilation (whether or not forced) and therefore the changes of air influence the contamination in greenhouses or tunnels (Tab. 1) (Van Os *et al.*,1994);
- the methods to make a choice with regard to the ergonomic-protective qualities and to the couplings (compatibility, complementarity) result from the effective circumstances, above all the typologies of worker's exposures (liquid or solid treatments, diameter of drops or granulometry of particles, volumes/ha, machines with o without knapsack, etc.).

The present paper reports the results of tests of simulated treatment carried out on strawberry crops in twin rows in tunnel in Basilicata, using three hand held sprayers. The aim of the research was the evaluation of the qualitative and quantitative contamination on the PPE worn by the workers in this area and the so called «off-target » losses along the lanes where the operators walked during the treatments.

Table 1. Minimum workers' re-entry times in greenhouses after treatments

Typology of distributed pesticides	Re-entry warned minimum times
All the products except those: irritant or sensitizing taking back in label the time specific of return	8 hours after the treatment, by ventilation of the environment[3]
Irritant products, with risk sentence: R36, R38, R41	24 hours after the treatment, by ventilation of the environment[3]
Sensitizing products, with risk sentence: R42, R43	48 hours after the treatment, by ventilation of the environment[3]
Products with label mentioned re-entry times	Observance of the suggested re-entry times and use of the mentioned PPE

Source: *Ministry of the French Agriculture.*

Materials and methods

Simulated treatment tests were carried out in tunnels over strawberry crops, using a watery solution with a 2% concentration of food colouring (tartrazine). The land was arranged into mulched ridges with plastic black film.

The tests involved 3 types of hand held equipments (Fig.1), connected with a hose to a trailed pressure-driven atomizing sprayer, placed outside at the front opening of the tunnels and powered by the tractor's PTO. The examined machines were:

- a spray gun equipped with one nozzle (Fig. 1A);
- a boom segment with 2 nozzles (even flat spray tips) 25 cm spaced (Fig. 1B);
- an adjustable row application kit equipped with 3 differently positioned nozzles (even flat spray tips) (Fig. 1C).

The delivered volumes varied among 1200 ÷ 2800 l/ha with operating pressures of 1 or 2 MPa (Tab.2).

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[3] The prevention bodies suggest ventilating (forced ventilation) a closed environment (greenhouses) for 2 hours at least, in order to remove the molecules in suspension in the air, before the re-entry of the workers.

Figure 1. Tested hand held equipments: A - Spray gun; B - Boom segment; C - Adjustable row application kit

Table 2. Synoptic table of operating parameters adopted during tests

Description	Operating parameters
Spray gun	• nozzle flow rate: 5,2 l/min • operative pressure: 2 MPa • volume rate: 1633 l/ha
Boom segment	• overall nozzle flow rate: 13,1 l/min • operative pressure: 2 MPa • volume rate: 2785 l/ha
Adjustable row application kit	• nozzle flow rate: 3,84 l/min • operative pressure: 1 MPa • volume rate: 1226 l/ha

The measures regarded:

- the deposits of dyestuff on the PPE (disposable overalls, headwear, mask, gloves and shoe covers) worn by the workers during the tests. The afore-mentioned PPE were split and kept apart at the end of each simulated treatment, in order to evaluate the amount and the placement of the contamination (staining).
- the «off-target » losses, measured by Petri capsules, placed on the ground, along the lanes where the workers walked.

The deposits of dyestuff on the PPE and those relating to «off-target » losses were determined in the laboratory using a spectrophotometer.

Results and discussion

The hourly deposits mean values and the percentage ones of contamination measured at the different parts of the overalls and the other components of the PPE worn by the workers are reported in the Tab.3.

As expected, for all the tested equipments, the deposits registered on the PPE sensitively increase from the head, to the thorax, to the lower limbs, because of the "prostrated" vegetative behaviour of the crop, not more than 30 cm from the top of the ridge high.

Tab.3- Contamination on the parts of the overalls and PPE

	Spray gun		Boom segment		Row application kit	
	deposit		deposit		deposit	
	(%)	(ml/h)	(%)	(ml/h)	(%)	(ml/h)
headwear	0,7	0,9	0,5	2,7	0,2	2,5
mask	0,1	0,1	0,1	1,2	0,1	0,7
back	1,0	1,1	0,8	6,2	0,4	3,4
thorax	2,9	3,5	0,9	6,7	0,5	4,1
right arm	1,8	2,2	0,5	2,9	1,6	12,7
left arm	1,1	1,2	0,7	6,1	0,5	4,2
right glove	1,4	1,3	1,5	8,3	0,1	0,5
left glove	1,0	0,9	1,2	7,8	0,1	0,5
right leg	25,1	24,2	33,3	230,9	41,0	333,5
left leg	35,0	36,3	32,7	231,9	23,1	192,2
right foot	13,8	13,9	13,9	91,4	14,7	120,0
left foot	16,1	15,8	13,9	90,0	17,7	145,9
total	100,0	101,4	100,0	686,1	100,0	820,2

The hourly deposit and the percentage values measured at the mask are the lowest (0,1%), so the potential contamination for respiratory tract would turn out negligible. On the contrary the contamination for cutaneous passage, above all at legs and feet level, is by far prevailing (Fig.2): from 90% to 97% for the three tested equipments.

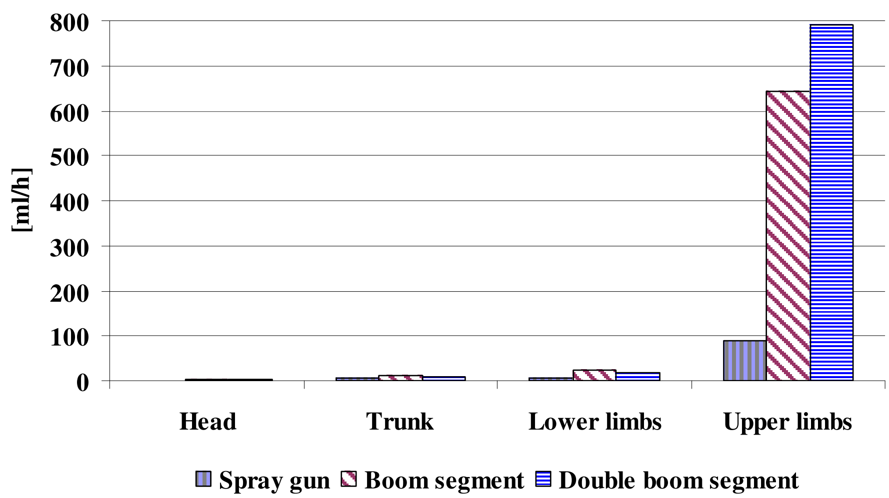

Figure 2. Hourly average deposits registered on the PPE, corresponding to the various parts of the workers' body

The hourly amounts of total deposit on the PPE are very different: about 100 ml/h with the spray gun, 690 ml/h with the boom segment and 820 ml/h with the adjustable row application kit.

There is not a clear correlation between the afore mentioned deposits and the delivered volumes and then the contamination prevalently results from: a) the closeness and direction of the spray as regards the worker's body; b) the manner of using the various equipments, included the way of walking (forwards or backwards) in the lanes during the treatments.

Such reasons explain the asymmetrical deposits of dyestuff registered at the right/left and front/rear parts of the body.

The deposits registered in the lanes have been regarded as "ground losses", but not those ones obtained inside the ridge which can be useful for the product leaning on the mulched film, above all during the ripening.

Although the equipments allow to carry out localized treatments on the ridge, considerable «off-target» losses were registered on the transit lanes: from 1,84 $\mu l/cm^2$ (adjustable row application kit) to 2,80 $\mu l/cm^2$ (spray gun). This last value is higher than the average deposit measured on the leaves of the treated crop.

The amount of the losses along rows turned out unsteady and in inverse relation to the leaves deposits.

Conclusions

The amounts of the «off-target » losses and the staining of the PPE worn by the workers, registered during the simulated treatments over the strawberry crop, prove a common and widespread underestimation of the problem. This also appeared from a recent survey carried out in Italy, concerning the sprayers - more than 60% of the farms use manual lances - and the way of distributing the pesticides over the covered crops: although more than 80% of the interviewees stated to use the PPE during the distribution, only 50% of these PPE were suitable to the protection from the chemical agents (Cerruto *et al.*2007).

There is a prevailing concern in the operating situation of the sector: to assure, in any case, a uniform covering of the crops so that to obtain the best of protection, using the available equipments.

The experiences carried out in Italy and abroad, instead, prove that it is possible to make agree among distribution effectiveness, worker's safe guard from the chemical contaminations and the environmental protection from the punctiform pollutions, through suitable technological and operating choices and, in option, the use of fit machines and protection systems.

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Thermal stress of fruit and vegetables pickers: temporal analysis of the main indexes through "Predict Heat Strain" model

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Abstract
Working in agriculture behaves workers to be exposed to sundries risk factors e.g. chemical agents, noise, posture, loads heading etc. Among these the most peculiar and the least investigated is constituted by microclimatic conditions during the different work steps. Warm and cold thermal stresses are estimated by microclimatic index: in particular, in agriculture range a heat strain condition come strain high temperature presence during horto-fruit harvesting. In particular the variation of environmental parameters during the working day makes the evaluation very difficult. A software for the evaluation of the main indexes has been realized to calculate the "Predict heat strain" (P.H.S.) according to the UNI EN 7933:2005 [2]. The model has been applied to the work environment of fruit and vegetables pickers during august. Analysis factors were: 1) physiologic variation, expressed by body temperature increase, skin moisture, water loss, perspiration; 2) variation of the main indexes of P.H.S. during the working day. Furthermore, the most effective and negative factors that determine thermal stress conditions have been found out. Among them, the most important is the worker acclimation, so it's extremely important to locate proper areas for reducing any exceeding thermal excursions. The paper highlights the importance of acclimation for fruit and vegetables pickers in their work environment.

Keywords: analytic determination, mean skin temperature, hot environment, total water loss.

Introduction

The job in agriculture involves the exposure of workers to different factors of risk, like chemical agents, noise, the postures, the loads moving, etc.

Among these, one of the most peculiar and less investigated risk is constituted by the micro-climatic conditions, during the different phases of work (in the field, in greenhouses, etc.). The thermal (heat and cold) stresses are evaluated through the micro-climatic indexes: particularly, in agricultural environments, a condition of thermal stress for the presence of high temperatures is had during the fruit harvest in the orchard.

In fact this mainly takes effects in the summer periods with the presence of high temperatures (> 30°C) and it lasts for a lot of time during the day.

The micro-climatic conditions outdoors, as for the operators addicted to fruit harvesting, result also to be varying and standard conditions are not always introduced within the cycle of work and in the following days. It is therefore necessary to also consider the physiological aspects that can describe in a better detailed way the evolution of the thermal stress due to activity in severely warm environments. The standard ISO 7933: 2005 "Analytical Determination and Interpretation of heat stress using calculation of the predict heat strain" comparisons a particular set of data, concerned:

- the prediction of the skin temperature (ISO 9886) [5]
- the influence of clothing on convection, radiation and evaporation;
- the combined effect of clothing and movements;

- the increase in core temperature related to activity;
- the exposure limit criteria and in particular the alarms and danger levels;
- the allowed maximum water loss.

The points requiring a concerted research were consequently identified as being:

- the coefficients of heat exchange by convection, radiation and evaporation in extreme conditions;
- the modelling of the physiological behavior during work to heat and, in particular, of the average skin temperature, the core temperature (rectal) and sweat rate [2].

The criteria for the determination of the exposure duration limit take account of the interindividual differences between the workers.

The goal of this paper is to describe the evolution of the thermal uneasiness, in a context of "predict heat strain", to evaluate the thermal discomfort for the operators employed to the fruit harvest. Particularly we want to foresee the response of the operators to the possible temperatures, considering a range that could be present during the harvest season, through physiological indexes as the skin temperature (t_{sk}) e Body mass loss measurement, $D_{limloss50}$, $D_{limloss95}$, D_{max50} [grams] (maximum water loss to protect a mean subject), D_{max95} (maximum water loss to protect 95% of the working population [grams] [4].

Matherial and methods

Influence of Clothing on the Heat Transfers by Convection and Evaporation

The heat loss by convection is a main part of the heat loss of the human body, particularly in moderate climates. In hotter environments, the heat loss depends more on evaporation, itself function of the characteristics of clothing. An important aspect of the transfers of heat to convection and evaporation is the effect wind velocity and movements on the transfer coefficients on the surface layer of the clothes. A factor played by clothing in the heat transfer is that it increases the heat transfer surface between the body and the environment. This increase is larger as the clothing is thicker and more insulating. The relation between the average t_{sk}, the primary climatic parameters, the metabolic rate and the rectal temperature was represented by an additive model. For the subset of data relating to the naked subjects, a model of prediction excluding the non significant variable metabolic rate was obtained [4]:

$$t_{sk} = 7{,}19 + 0{,}064 + 0{,}061 t_r + 0{,}198 p_a - 0{,}348 V_a + 0{,}616 t_{re}$$

were: t_{sk} = temperature of the surface of the clothes; t_r = mean radiant temperature ; p_a = partial vapour pressure; V_a = air velocity; t_{re} = rectal temperature.
The multiple coefficient of correlation between the observed values and predicted was equal to 0,86 and 83,3% of the predicted skin temperatures were in the range of = 1 °C from the observed values.
The following model was obtained for the clothed subjects:

$$t_{sk} = 12{,}17 + 0{,}020 t_a + 0{,}044 t_r + 0{,}194 p_a - 0{,}253 V_a + 0{,}0297 M + 0{,}153 t_{re}$$

with M = the metabolic rate (Wm^{-2}).
The coefficient of correlation (0,77) was lower than for naked subjects, but 81,8% of the predicted values were in the range of ± 1 °C from the observed values.
While the *temperature of the clothing t_{cl}* is given from:

$$t_{cl} = t_{sk} - I_{cl} \left\{ f_{cl} * h_c (t_{cl} - t_a) + 3{,}96 * 10^{-8} f_{cl} \left[(t_{cl} + 273)^4 - (t_r + 273)^4 \right] \right\}$$

where: I_{cl} = clothing insulation , f_{cl} = clothing area factor, There are two different types of temperatures that influence the heat exchanges from the operator to the outside; one is the temperature of the skin and the other one it is the temperature of the external surface of the clothing. It is also possible to identify a layer of air and a layer constituted by the fabric of the same clothing between the surface of the skin and the external surface of the clothing (figure 2). The two layers oppose a resistance to the transfer of the sensitive heat coming from the body (H) measured in [m^2 k/W]. In situations of rest it can be hypothesized that the thermal sensitive exchange through clothing, H, equalizes the general thermal exchange for convection, C, and for radiation, R, that leaves the surface of the covered body.

$$H = C + R; \quad H = (t_{sk} - t_{cl}) / I_{cl}$$

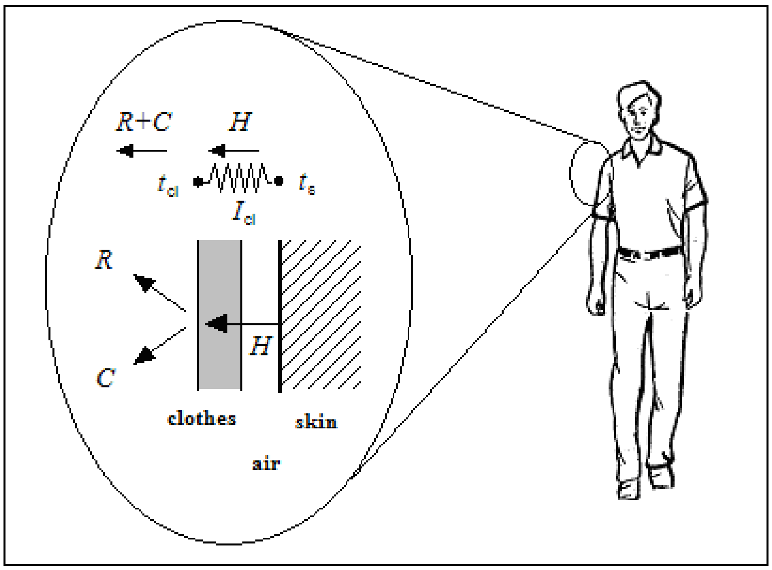

Figure 2: representation of the thermal sensitive exchange [2]

<u>Instruments</u>

To survey environment parameters, the unit LSI BABUC M with six inputs was used connected to 3 probes: a psychometric probe BSU102 with forced ventilation and a distilled water tank, used for measuring the air temperature (t_a) and the temperature of the damp bulb (t_w); an anemometric probe with hot wire BSV101, to measure the speed of the air (V_a); a global thermometric probe BST131 in black opaque copper (reflexion < 2% ASTM 97-55) for measuring the average radiating temperature (try) (probes in compliance with regulation ISO 7726) [1].
A farm situated on the Latium coastline was monitored, evaluating with the P.H.S. model the risk of excessive thermal load for workers harvesting fruit and vegetables in the fields. Monitoring have been done from July to August, during the whole day (a work day), during the harvest period.

<u>PHS Model (Predict Heat Strain) and software realized</u>

The P.H.S. "Predict Heat Strain", takes as input environmental parameters as air temperature t_a, the average radiating temperature t_r and the air velocity V_a.
Besides subjective parameters which are related to the operators, are considered: metabolic rate (Met), clothing insulation (I_{cl}), the duration of activity, weight and height of the operator, the speed with which the work is carried out in relation to the direction of the wind, and the acclimatization of the worker.

In exchange the P.H.S. model supplies us with some output which enable us to evaluate the probability of thermal collapse due to the environmental and personal conditions of operators working in severely hot environments.
The P.H.S. calculation is arduous; we can make it easy using a software Microsoft© Excel and Macro in Visual Basic programming language, inserting and modifying the analytic processes and the algorithm fixed by UNI EN ISO 7933:2005 [2].
In figure 2 you can see a data form, as well as the various instruments used for the experiment.
The software was developed by the department GEMINI – Laboratory of Ergonomics and Occupational Safety and Health– of the University of Tuscia - Viterbo, by Andrea Colantoni and Massimiliano Bernini.

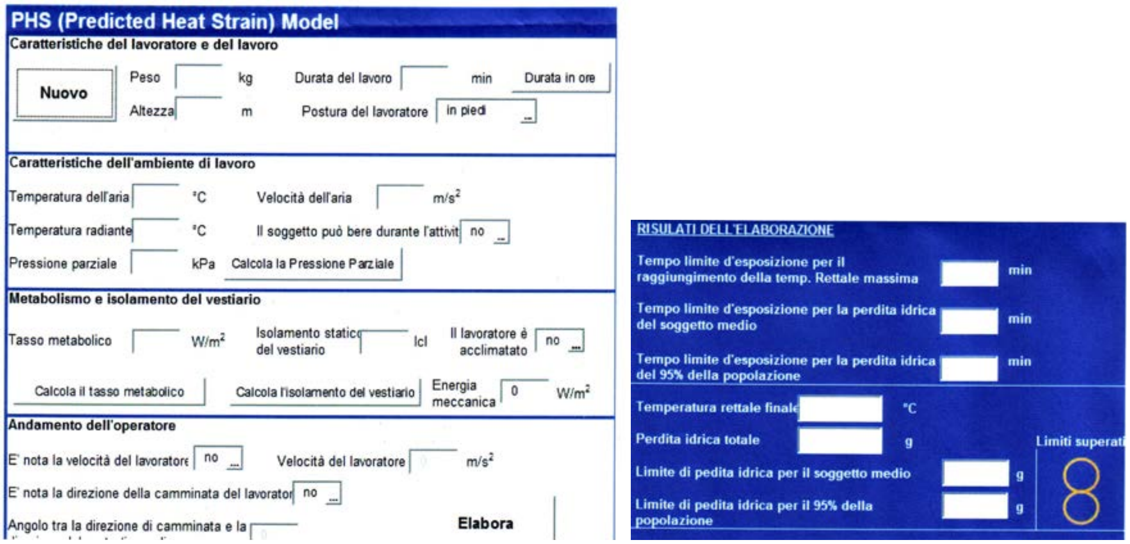

Figure 2. Software realized with Microsoft© Excel and Visual Basic's Macro

Results

Risk valued through P.H.S. method during harvest period on field

The tests were carried out on 6 workers taking into consideration their weight, height, type of work, insulation from clothes, their metabolic expenditure in relation to their work and lastly the state of acclimatization in relation to the environmental parameters.
The average values of environmental parameters, measured near workplaces, have been:
t_a = 30 °C (air temperature); t_r = 42,3 °C (mean radiative temperature); p_a = 3,48 kPa (partial vapor pressure), V_a = 3,0 m/s (air velocity); M = 150 met (metabolic rate); I_{cl} (clothing insulation) = 0,5 clo, on fields during the harvest [3-4].
The above described values, derive from the average of surveys made within a day; the environmental characteristics result notably variable and they negatively influence the micro-climatic evaluation. In the following tables is shown the response of these operators to a range of temperatures (28 - 38°C) that can be present within the same day, but also during different days of harvest. The evaluation in outdoor systems results to be complicated by the variability of the environmental parameters: therefore is useful to the goals to prevent the risks from heat stress to define a previsional model of the physiological response to the different and possible situations of thermal discomfort, caused by variations of temperature for severely warm environments.

Worker[1]	Personal information		A_{Du}	Acclima-tization	Work position	I_{cl}	Met	Work
	weight	height						
A	[kg]	[m]	[m^2]	[%]	Standing	[clo]	[W/m^2]	Harvesting peppers
	58	1,70	1,67	0		0,5	150	

([1]) no drink

t_a °C	t_{sk} °C	t_{cl} °C	SW $_{tot}$ [g]	$D_{limloss\ 50}$ [minutes]	$D_{limloss\ 50\ (*)}$ [minutes]	$D_{limloss\ 95}$ [minutes]	*H* m^2 k/W
28	33,89	32,30	2290,00	480	288	480	3,2
29	34,59	33,21	2474,55	480	288	480	2,8
30	34,69	34,10	2873,40	480	288	480	1,2
31	34,70	34,45	2890,05	480	288	455	0,5
32	34,73	34,55	3080,35	480	272	427	0,4
33	34,75	35,10	3292,50	480	255	410	-0,7
34	34,86	35,89	3510,00	480	239	400	-2,1
35	34,86	35,89	3735,50	480	226	377	-2,1
36	34,91	36,33	3967,00	480	213	356	-2,8
37	35,01	36,78	4205,00	480	201	336	-3,5
38	35,10	37,22	4451,00	470	190	318	-4,2

Table 1 course of the physiological indexes in the range of temperature 28 ÷s 38° Cs for the operator A (limit values D_{max50} = 4350 grams; D_{max95} = 2900 grams)

Worker[1]	Personal information		A_{Du}	Acclima-tization	Work position	I_{cl}	Met	Work
	weight	height						
B	[kg]	[m]	[m^2]	[%]	Standing	[clo]	[W/m^2]	Harvesting peppers
	80	1,75	1,95	0		0,5	150	

([1]) no drink

t_a °C	t_{sk} °C	t_{cl} °C	SW $_{tot}$ [g]	$D_{limloss\ 50}$ [minutes]	$D_{limloss\ 50\ (*)}$ [minutes]	$D_{limloss\ 95}$ [minutes]	*H* m^2 k/W
28	34,51	32,30	2679,0	480	288	480	4,4
29	34,60	32,55	3000,0	480	288	480	4,1
30	34,63	33,64	3139,0	480	288	480	2,0
31	34,65	34,08	3377,0	480	288	480	1,1
32	34,70	34,53	3621,2	480	272	427	0,3
33	34,73	34,90	3872,7	480	255	410	-0,3
34	34,77	35,42	4131,3	480	280	466	-1,3
35	34,81	35,86	4397,0	480	262	438	-2,1
36	34,85	36,31	4671,2	480	247	413	-2,9
37	34,90	36,75	4954,2	480	234	390	-3,7
38	34,94	37,20	5246,6	470	221	369	-4,5

Table 2 course of the physiological indexes in the range of temperature 28 ÷s 38° Cs for the operator B (limit values D_{max50} = 6000 grams; D_{max95} = 4000 grams)

Worker[1]	Personal information		A_{Du}	Acclima-tization	Work position	I_{cl}	Met	Work
	weight	height						
C	[kg]	[m]	[m²]	[%]	Standing	[clo]	[W/m²]	Harvesting peppers
	78	1,80	1,97	0		0,5	150	

([1]) no drink

t_a °C	t_{sk} °C	t_{cl} °C	SW_{tot} [g]	$D_{limloss\ 50}$ [minutes]	$D_{limloss\ 50\ (*)}$ [minutes]	$D_{limloss\ 95}$ [minutes]	*H* m² k/W
28	34,54	32,76	2339,60	480	288	480	3,6
29	34,57	32,94	2560,20	480	288	480	3,3
30	34,63	33,65	2739,40	480	288	480	2,0
31	34,67	34,1	2946,70	480	288	480	1,1
32	34,73	34,54	3159,20	480	288	480	0,4
33	34,76	34,99	3377,09	480	288	480	-0,5
34	34,81	35,44	3601,40	480	270	451	-1,3
35	34,85	35,88	3832,24	480	254	424	-2,1
36	34,90	36,33	3890,58	480	240	400	-2,9
37	35,01	36,77	4315,34	480	226	378	-3,5
38	35,10	37,66	4830,49	470	214	357	-5,1

Table 3 course of the physiological indexes in the range of temperature 28 ÷ 38° C for the operator C (limit values D_{max50} = 5850 grams; D_{max95} = 3900 grams)

Worker[1]	Personal information		A_{Du}	Acclima-tization	Work position	I_{cl}	Met	Work
	weight	height						
D	[kg]	[m]	[m²]	[%]	Standing	[clo]	[W/m²]	Harvesting peppers
	63	1,75	1,76	0		0,5	150	

([1]) no drink

t_a °C	t_{sk} °C	t_{cl} °C	SW_{tot} [g]	$D_{limloss\ 50}$ [minutes]	$D_{limloss\ 50\ (*)}$ [minutes]	$D_{limloss\ 95}$ [minutes]	*H* m² k/W
28	34,52	32,75	2704,26	480	288	480	3,5
29	34,56	33,20	2933,19	480	288	480	2,7
30	34,61	33,64	3167,53	480	288	480	1,9
31	34,65	34,09	3407,67	480	288	480	1,1
32	34,70	34,53	3654,07	480	279	465	0,3
33	34,74	35,01	3906,80	480	261	435	-0,5
34	34,78	35,42	4167,08	480	245	403	-1,3
35	34,82	35,87	4435,05	480	231	385	-2,1
36	34,87	36,31	4711,24	480	217	363	-2,9
37	34,91	36,76	4996,23	480	205	343	-3,7
38	34,95	37,20	5290,66	470	195	325	-4,5

Table 4 course of the physiological indexes in the range of temperature 28 ÷ 38° C for the operator D (limit values D_{max50} = 4725 grams; D_{max95} = 3150 grams)

Worker[1]	Personal information		A_{Du}	Acclima-tization	Work position	I_{cl}	Met	Work
	weight	height						
E	[kg]	[m]	[m²]	[%]	Standing	[clo]	[W/m²]	Harvesting peppers
	90	1,70	2,00	0		0,5	150	

([1]) no drink

t_a °C	t_{sk} °C	t_{cl} °C	SW_{tot} [g]	$D_{limloss\ 50}$ [minutes]	$D_{limloss\ 50\ (*)}$ [minutes]	$D_{limloss\ 95}$ [minutes]	*H* m² k/W
28	34,49	32,74	2762,11	480	288	480	3,5
29	34,54	33,18	2996,63	480	288	480	2,7
30	34,58	33,63	3236,80	480	288	480	1,9
31	34,62	34,1	3483,02	480	288	480	1,0
32	34,66	34,52	3735,77	480	288	480	0,3
33	34,71	34,97	3995,15	480	288	480	-0,5
34	34,75	45,41	4262,42	480	288	480	-1,3
35	34,80	35,85	4537,75	480	286	477	-2,1
36	34,83	36,30	4821,69	480	270	450	-2,9
37	34,87	36,74	5114,86	480	254	424	-3,7
38	34,91	37,18	5417,93	480	240	400	-4,5

Table 5 course of the physiological indexes in the range of temperature 28 ÷ 38° C for the operator E (limit values D_{max50} = 6750 grams; D_{max95} = 4500 grams)

Worker[1]	Personal information		A_{Du}	Acclima-tization	Work position	I_{cl}	Met	Work
	weight	height						
F	[kg]	[m]	[m²]	[%]	Standing	[clo]	[W/m²]	Harvesting peppers
	85	1,75	2,00	0		0,5	150	

([1]) no drink

t_a °C	t_{sk} °C	t_{cl} °C	SW_{tot} [g]	$D_{limloss\ 50}$ [minutes]	$D_{limloss\ 50\ (*)}$ [minutes]	$D_{limloss\ 95}$ [minutes]	*H* m² k/W
28	34,49	32,74	2751,11	480	288	480	3,5
29	34,54	33,18	2984,40	480	288	480	2,7
30	34,58	33,63	3223,25	480	288	480	1,9
31	34,62	34,1	3468,1	480	288	480	1,1
32	34,66	34,52	3719,37	480	288	480	0,3
33	34,71	34,97	3977,18	480	288	480	-0,5
34	34,75	35,41	4242,78	480	288	480	-1,3
35	34,80	35,85	4516,31	480	271	453	-2,1
36	34,83	36,30	4798,33	480	270	450	-2,9
37	34,87	36,74	5150,50	480	256	427	-4,4
38	34,91	37,18	5390,30	480	292	382	-4,5

Table 6 course of the physiological indexes in the range of temperature 28 ÷ 38° C for the operator F (limit values D_{max50} = 6350 grams; D_{max95} = 4250 grams)

Conclusions

The analyzed data in the charts, show the principal physiological indexes defined by the P.H.S. *predict heat strain model* in agreement to the ISO 7933:2005. The variations of the total loss water, reaching dangerous levels for the workers, have been analyzed particularly, considering a range of temperatures, that can be present during the season of harvest and mainly in the warmest hours (from 12.00 a.m. to 4.00 p.m.), and the minutes needed to arrive to possible critical situations, expressed in terms of:

- $D_{limloss50}$ (minutes): this is the maximum allowable exposure time for water loss, for a mean subject (weight 75 kg and height 1,80 m);
- $D_{limloss50}$(*) in water absence;
- $D_{limloss95}$ (minutes): this is the maximum allowable exposure time for water loss, for 95% of the working population.

Analyses have been developed considering the maximum values of air speed (3 m/s) and the partial pressure of vapor (3,8 kPa), as defined by the limits of applicability of the P.H.S. and only increasing the temperature of the air. It is possible to deduce from the tables that there are no risks to arrive to the total water loss if the worker can reinstate the lost liquids through an availability of water, versus the analysis in absence of water availability (Dlimloss50 $^{(*)}$) shows the attainments of critical levels, expressed in minutes, for all the workers in one determined temperature; these levels vary in operation of the subjective parameters of the works and particularly of weight and height (used for the calculation of the bodily surface A*Du* in m^2). The results are synthesized in table 7.

Worker	A	B	C	D	E	F
Dlimloss50(*) [min.]	288					
Dlimloss95 [min.]	455	427	451	465	477	453
SW tot [g]	3080,35	3621,2	3601,40	3654,07	4537,75	4516,31
t. criticism [°C]	**31**	**32**	**34**	**32**	**35**	**35**
ADu [m2]	**1,67**	1,95	1,97	1,76	**2,00**	**2,00**

Table 7 comparison among the total SW and the ADu and measure of the times for the attainment of critical levels and determination of the temperature limit

Also the Dlimloss50 $^{(*)}$ in absence of water availability has been valued: in fact in some cases there is no possibility for workers to access water because the harvest's areas are mostly isolated. An important aspect, is deduced by the comparison between ADu (Du Bois surface area) and the total water loss, for from table 7 is deduced that the greater is the bodily mass of the subject, the greater the critical temperature in which phenomena of excessive loss of perspiration are introduced. The results of the present work, therefore, seem to bring to the conclusion that, besides the evaluation of the risk founded on the P.H.S. model, it would be opportune to deepen the investigation with evaluations of the fatigue through, for instance, measurement of the cardiac frequency of the workers.

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The contribution to the programming and executing of this research must be equally divided by the authors.

Analysis of work time and workers capacities in "culurgione's" production

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Abstract

In the alimentary tradition of the Sardinia a few types of pasta production reached a international notoriety, i.e. malloreddus, sebadas and culurgiones produced exclusively by hand. Unfortunately the production is not able to satisfy all the demand of the modern commercial distribution which often, orients towards other markets and products. The study, was carried out in one of the most important plant for the production of "culurgiones" and were compared two work cycles: traditional and partially mechanized. The last five phases of production (rolling, breaking, moulding, forming and cutting) are in total over the 77% of the working time and furthermore reduce considerably the number of workers in use in the product closing phase forcing the producer to destine two of this in the lengthening and in the foil cut by hand. With the introduction of this equipment, the incidence of the last two phases was reduced on the operating time of 5% and was increased the number of the workers, from four to six, employed in the final phase (close) of "culurgiones" productions and the working time of this phase increased. The work capacity increased in term of journey production and in term to worker capacity per hour of work.

Keywords: fresh pasta, "culurgiones", time analysis, workers capacities.

Introduction

In the pasta tradition of Sardinia (for instance Malloreddus) issue a few types of international notoriety pasta, as pure other typologies of pastries elaborated with the use of local traditional ingredients, as for instance Sebadas and Culurgiones (fig.1) produced exclusively to hand. Above all this last format makes use of preparation modes rigidly based on the manual dexterity, modes which determine the characterization and the originality of product form. This very manual dexterity, deeply codified in the Sardinian popular culture, some foil about the stuffing gives Culurgiones a few important properties also of technological, especially as regards the operations of folding and envelopment nature, with a sequence of movements of the fingers which allow to obtain a longitudinal closing with the replicate foil margins inward the format; under the point of view specifically technical that allows to obtain a strong structural resistance of culurgiones during the cooking phase, in practice the stuffing avoiding the risk which because of the thermal and mechanical solicitations caused by the water boil, the format can open and therefore disperse in water of cooking itself, besides, obviously, getting deformed changing his original form to completed cooking. The both national and international diffusion of this Sardinian typical pasta is subject to the necessity of producing culurgiones in quantities and

Figure 1. The "culurgiones" are formed by fresh pasta with inside, potato, recotta cheese, and other ingredients

would be incompatible with the manual product preparation, not only for the high costs would and would carve in an excessive way on his commercial to price, but also give the product itself the microbiologic and biochemical stability necessary for extending shelf life, in a way compatible with the times and the rhythms of the modern commercial distribution and the dilated with respect to the current one diffusion in the market worlds.

Material and method

The study was carried out in one of the most important plant for the production of "culurgiones" and were compared two work cycles: traditional and partially mechanized. The first, where all the phases of production was completed by hand and a another one where two types of machinery was inserted and used: moulder and a hand formed. The working capacity of the plant, the efficiency of the workers, and the electricity consumed per unit of production were calculated by measuring the following parameters: the theoretical working capacity of all the machines used according to the manufacturer's specifications, the total work time in each phase of production, the real total production, the number of workers, the energy consumed, and the quantity of electricity used in each phase of production. In order to reach their daily production targets, two productive cycles were necessary in the traditional plant and three in the semi-industrial plant. Each cycle included all the phases of the production process. In the traditional plant there was a further work cycle so that the samples used in the statistical analysis were uniform. The work capacity of the individual workers was calculated as: Work capacity per worker (kg/h) = Operational Capacity (OC)/number of worker in the phase where OC (operational capacity in the single phase) was calculated as a function of OT (Operational Time) and AT (Additional Time). OT is the working time of the worker and was calculated as the sum of the effective time (ET) and the additional time (AT). Both of these were taken analytically. AT was equal to 5% to 10% of OT and was the range of variations of extra time for each single phase. Daily consumption or (Dc) was determined on the basis of the Electrical Power Installed (EPI = kW) and the operating time (OT) for each single phase $Dc = EPI$ (kW) $\times$ OT. The energy used for the daily production (Wh/kg) was calculated by dividing the daily consumption (kWh/day) by the quantity of product produced. The incidence (I) was calculated as the relationship between the energy for unit production (EUP) in each single phase and the total consumption of energy $I = \frac{EUP}{Eenergy(total)}$.

Results and discussion

<u>*Labour Used*</u>

The number of labours used (table 1) was different and in each phase depended on the operational capacity of the production line, even though 16 workers were used in each plant. In the traditional plant, daily production was 50.0 kg and the workers were employed equally in all phases of production, with the exception of closing, where only 4 worker was used. In the semi-industrial plant the work force was mainly employed in closing of the "culurgiones" (6 workers), so the planned daily production was 250 kg/day.

Table 1. Production phases, number of workers, work time and incidence percentage of the phases in the two work cycles

Phases of production	Workers used in the phases traditional (A)	Workers used in the phases semi-industrial (B)	Work time (A)	Work time (B)	Incidence (A)	Incidence (B)
	(n)	(n)	(h)	(h)	(%)	(%)
ingredients preparation	4	4	0,28	0,28	3,21	3,21
kneading	1	1	0,33	0,33	3,78	3,78
stuffing preparation	3	3	0,83	0,83	9,51	9,51
rest	-	-	0,50	0,50	5,73	5,73
rolling	-	-	0,67	0,67	7,67	7,67
breaking	1	1	0,50	0,50	5,73	5,73
moulding	2	-	0,83	-	9,51	-
forming	1	1	1,42	1,00	16,27	11,45
closing	4	6	3,37	4,62	38,60	52,92
total	16	16	8,73	8,73	100,00	100,00

Work Time and Working Capacity

The total time for each single operation (table 1) shows that there were substantial differences in the time used for each operation in the two types of plants. Daily capacity in the traditional and in the semi-industrial was reached after 8.73 h, even though the amount of "culurgiones" produced was almost five times as great. Looking, in more detail, at the time taken for each single operation, it becomes clear that moulding and closing were the two most important and most time consuming operations in both types of plants. In the traditional plant 16.27% and the 38.60% of the total time was used for this, while in the semi-industrial this figure rose to 11.45% and 52.92%. The preparation of the ingredients was the most rapid part of the operation: 3.21% of the total time. Moulding in the traditional and in the semi-industrial plant, took 3.73 h per day when maximum daily capacity was reached. In other words, 75,0% and 62,5% of the work power was employed in the first seven phases of the production but it use only the 45.15% of the total work time in the traditional and the 36.35% in the semi-industrial one. Forming and closing took 1.00 h in the semi-industrial plant and 1.42 h in the traditional. In this case the number of workers employed certainly made a difference: seven in the semi-industrial plant and five in the traditional one because the 54.85% and the 63.65% of the total work time was used in these two phases. There was a significant difference between the two plants in the operating capacity for the single operations. Preparation of ingredients took place at 40 kg/h in the semi-industrial plant and at 30 kg/h in the traditional plant and mixture at 100 kg/h in the semi-industrial plant and at 50 kg/h in the traditional one (table 2). Mouding, forming and closing of the "culurgiones" in the traditional plant also took place at 12.00 kg/h, 3.00 kg/h and 7.00 kg/h. Hourly production of the workers was: 7.5 kg/h for the preparation of ingredients, 50.0 kg/h for the kneader, 25.5 kg/h for preparation of the stiff, 40.0 kg/h for moulding, 12.0 kg/h in the braking and forming and 3.0 kg/h and 8 kg/h for printing and closing (table 2). The hourly production per worker during moulding were also lower in the traditional plant than in the semi-industrial one (7.50 kg/h vs 10.00 kg/h).

Table 2. Total time, and working capacity in the two plants

Work phases	Plant	Total time (h)	Capacity Operating (kg/h)	Capacity per worker (kg/h)
ingredients preparation	Traditional	0,28	30,00	7,50
	Semi-industrial	0,28	40,00	10,00
kneading	Traditional	0,33	50,00	50,00
	Semi-industrial	0,33	100,00	100,00
stuffing preparation	Traditional	0,83	25,00	8,33
	Semi-industrial	0,83	50,00	16,67
rest	Traditional	0,50	-	-
	Semi-industrial	0,50	-	-
rolling	Traditional	0,67	40,00	40,00
	Semi-industrial	0,67	75,00	75,00
breaking	Traditional	0,50	12,00	12,00
	Semi-industrial	0,50	22,00	22,00
moulding	Traditional	0,83	12,00	12,00
	Semi-industrial	-	22,00	22,00
forming	Traditional	1,42	3,00	3,00
	Semi-industrial	1,00	7,00	7,00
closing	Traditional	4,62	8,00	2,00
	Semi-industrial	3,37	18,00	3,00

Energy consumption

Energy consumption varied greatly from machine to machine (table 3). Greatest consumption was by the moulders, which consumed 4.75 kW in the traditional plant and 4.50 kW in the semi-industrial one, and lowest by the rolling and small mixers for ingredients, which consumed 0.37 kW in the traditional plant and 0.45 kW in the semi-industrial plant. Daily energy consumption was linked to how long the machines worked and how much energy they consumed. In the traditional plant it varied from 0.25 kWh/day for the small mixer to 3.19 kWh/day for the forming. Similar results were found for the semi-industrial plant. The rolling consumed the least energy (300.00 Wh/day) and the used the most energy (970.90 Wh/day). The energy consumption per unit of production was as follows: from a minimum of 6.25 Wh/kg for the rolling to 256.83 Wh/kg for the forming in the traditional plant, and from 4.00 Wh/kg for the rolling to 125.0 Wh/kg for the moulding in the semi-industrial plant. Thus the moulding consumed most energy in both plants. The next highest consumer was the small mixer used for the preparation of the ingredients (32.67 Wh/kg) and the moulder in the traditional plant (31.35 Wh/kg) and the small mixer in the semi-industrial plant (15.50 Wh/kg.).

Table 3. Electrical Power Installed (EPI), daily energy consumption (Dc) per machine, and energy used per unit of production (EUP), for each phase in the two plants

Machine	Plant	Electrical Power Installed (kW)	Dc (kWh/day)	EUP (Wh/kg)
ingredients preparation	Traditional	3.50	0. 98	32.67
	Semi-industrial	2.20	6.20	15,50
kneading	Traditional	4.75	1.56	31.35
	Semi-industrial	4.50	1.49	14.90
stuffing preparation	Traditional	0.45	0.38	15.20
	Semi-industrial	0.45	0.38	7.60
rest	Traditional	-	-	-
	Semi-industrial	-	-	-
rolling	Traditional	0.37	0.25	6,25
	Semi-industrial	0.45	0.30	4.00
breaking	Traditional	a mano	-	-
	Semi-industrial	a mano	-	-
moulding	Traditional	2.20	3.19	256.83
	Semi-industrial	2.75	2.75	125.00
forming	Traditional	-	-	-
	Semi-industrial	-	-	-
closing	Traditional	-	-	-
	Semi-industrial	-	-	-

Conclusions

The machinery and plant that are used at present in small- and medium-enterprises cause discontinuities in the process. These affect the work capacity and thus also the productivity of the workers. Thus introducing plant and processing systems which can incorporate different phases of the production process would result in concrete rationalisation of working capacity, of productivity of the workforce and of electricity consumption. The introduction of the correct criteria when deciding which machines to use would resolve the problems linked to increasing hourly productivity of the plant and the workforce. Actually, the last five phases of production (rolling, breaking, moulding, forming and cutting) are in total over the 77% of the working time and furthermore reduce considerably the number of workers in use in the product closing phase forcing the producer to destine two of this in the closing. With the introduction of the equipment, the incidence of the phase to forming was reduced on the operating time of 5% and the phase of closing was increased respect to the traditional plant to the 9.5% with a number of the workers, from four to six, employed in the final phase (closing) of "culurgione's". The productions for worker in the phase of forming increased from 3kg/h in the traditional plant to 7kg/h in the semi-industrial and for the final phase from 2kg/h in the traditional to 3kg/h in the semi-industrial one.

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Investigation of the vibrations transmitted by agricultural tractor to the driver under operative conditions

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Abstract

Professional risk from mechanical vibrations is contemplated, in the national legislation, by the Legislative Decree 187/05, receiving the 2002/44/CE Directive that indicates the minimum prescriptions, in safety and health matter, concerning workers' exposure to the risk from vibrations.
From an health point of view, the vibrations transmitted to the workers are traditionally classified as whole body vibrations or hand harm system vibrations.
The present paper took into consideration the levels of the whole body vibrations transmitted to the drivers by a series of agricultural tractors of different dimensions and power, under typical conditions of utilisation. The tests have been conducted according to the ISO 2631-1:1997 standard concerning the measurement of vibration levels at the driver seat.
Each tractor has been used in two operations typical for its characteristics, using proper operating machines, with the aim of characterizing the level of vibrations produced by each operation, in terms of total acceleration, axial acceleration and time of exposure, calculated by means of a suitable Excel data-sheet, providing both the "limit value" and the "safety value".

Keywords: work, vibrations, tractor, safety.

Introduction

Professional risk from mechanical vibrations is contemplated, in the Italian legislation, by the Legislative Decree 187/05 [1], receiving the 2002/44/CE Directive [2] that indicates the minimum prescriptions, in safety and health matters, concerning workers' exposure to the risk from vibrations.

As they represent, in Italy, one of the most diffused and unknown causes of pathologies, a specific policy of prevention has been started against them.

Considering the exposure of the workers to the vibrations, these are traditionally classified as whole-body vibrations and hand-arm system vibrations. As regards to the whole-body vibrations, it is estimated that, in Europe, 4% up 6% of the craftwork is regularly exposed to high intensity vibrations, capable to determine health damages, particularly on the lumbar rachis [3].

The decree of above reports two time values for the exposure to the whole-body vibrations, the "limit value" and the "action value" (table 1), determining some obligations.

From a technical point of view, the test procedures for the measurement and evaluation of whole-body vibrations are reported in the ISO 2631-1:1997 standard [4]. It allows to estimate the effects of the vibrations on health and comfort.

Table 1. Daily exposure to vibrations: limit and action values according to the Lgs. D. 187/05

	Limit value (ms^{-2})	Action value (ms^{-2})
Whole body	1,15	0,50

In such a picture, a study has been started with the aim of investigating the levels of whole-body vibrations generated by using tractors in agricultural works. The study regarded a series of tractors with different characteristics of dimensions, power and use. The sample of tractors has been chosen with the purpose of being representative of the wide range of possibilities offered by the market. Each tractor has been observed in field, during the execution of operations typical for it.

Materials and methods

<u>Measured parameters, data processing and reference parameters</u>

The basic parameter to measure, in the evaluation of the level of vibrations, is the acceleration, *a,* expressed in ms^{-2}.

As the effects of the vibrations depend on the frequency of the accelerations, these must be weighted by means of suitable filters, according to the standards [4].

The weighting filters are calculated as a function of the human body sensitiveness to the acceleration in the different sampling frequencies and provide an acceleration value called frequency weighted acceleration, a_w,

$$a_W = \left[\frac{1}{T}\int_0^T a_w^2(t)dt\right]^{\frac{1}{2}}$$

where:
$a_W(t)$ is the measured value of the acceleration;
T is the acquisition time interval in seconds.

The three components of the acceleration along the x, y and z axes are measured and the resulting total acceleration a_v is provided by the relation:

$$a_v = (k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2)^{\frac{1}{2}}$$

where:
a_{wx}, a_{wy}, a_{wz} are the weighted r.m.s. accelerations along the x, y and z axes;
k_x, k_y, k_z are indices the values of which has been determined depending of the effects of the relative components of the acceleration on the health: fir k_x e k_y a value of 1.4 is applied in the case of sitting positions as they are equal to 1 for the upright position; k_z is equal to 1 in both positions.

<u>Determination of the acceleration level referring to the daily exposure time</u>

In general, the total value of the acceleration a_v, measured during the daily exposure time (T_e), must be normalized referring to the 8 hours time interval, according to the principle of "equal energy". The normalized value of acceleration, *A(8)*, is calculated by means of the formula:

$$A(8) = a_v \sqrt{\frac{T_e}{8}}$$

By means of this formula, basing on the comparison between A(8) and the standard limits values given for the 8 hours time, the time of exposure to a_v can be determined. The values of A(8) are: the "daily action value" and the "limit value" of tab 1, providing, respectively, the "safety time" and the "limit time". If the safety time is not exceeded, the exposure to vibrations does not determines the occurrence of pathologies on an operator in normal health conditions. In the case of whole-body vibrations, the determination of A(8) is made using, instead of a_v, the highest axial component, among a_{wx}, a_{wy}, a_{wz} , multiplied by the relative index k (1.4 for the x and y axes and 1 for the z axis).

<u>*Instruments*</u>

The figure 1 shows the instrumental chain use in the tests. It was composed by:

- a tri-axial accelerometer for driver seat Brüel & Kjær, type 4322;
- an 8-channel digital recorder DAT-Herm;
- two signal conditioners Brüel & Kjær mod. 'Nexus';
- a signal acquisition and processing system Brüel & Kjær, mod. Pulse;
- a calibrator for accelerometers Brüel & Kjær, tipo 4294.

Figure 1. Instrumental chain A) triaxial accelerometer for driver seat; B) 8-channels digital recorder; C) 6-channell signal conditioners; D) "Pulse" data processing system

<u>*Characteristics of the machines*</u>

The tests have been conducted on 10 tractors with different power, mass and utilization (Tab. 2). The tractor have been tested during the execution of two operations typical for each of them (fig. 2), under the usually adopted conditions of velocity, power-take-off speed. etc., also depending on the type of operating machine used.

Table 2. Main characteristics of the tested tractors and test conditions

Tractor No.	Power (kW)	Mass (Kg)	Operation	Velocity (Km/h)
1	51,5	2280	Chopping Distribution of chemicals	4,0 5,7
2	54,5	2270	Chopping Distribution of chemicals	6,2 7,2
3	58,8	2955	Harrowing Chopping	
4	70,5	3150	Ploughing Hay harvest	4,0 7,9
5	70,5	4055	Ploughing Sowing Earthworks	4,0 8,0 --
6	70,0	4150	Ploughing Harrowing	5,4 7,2

7	87,0	4850	Ploughing Harrowing	5,1 5,4
8	103,0	6420	Ploughing Harrowing	
9	157,0	7520	Ploughing Harrowing	3,8 5,2
10	205,0	11000	Ploughing Harrowing	6,0 8,0

The tractor No. 1 is characterized by low seat, high manoeuvrability and compact frame that make it suitable for the use in row cultivations (fructiculture and horticulture), in small farms and in works requiring the p.t.o. as a power source.

No. 2 is fitted up with some advanced technical solution increasing the level of comfort and performances. Because of a good mass/power ratio, it cab be conveniently used on soils sensitive to compaction, as the front axle with a 55°steering angle makes it suitable for manoeuvres in narrow spaces. It can be used in a wide range of operations, from soil refinement to crop protection, from hay harvest to farm works and road transport.

No. 3 is a 4WD tractor for universal use. In the tests, the engine speed has been adjusted on the value of 2067 min^{-1} corresponding to a p.t.o. speed of 540 min^{-1}, for driving a chopper.

No. 4 is a simple tractor, easy to use and suitable for field works in small and medium farms.

No. 5 with a power similar to the previous one, is a modern tractor with high performances equipped with a drooping cowling that increases la visibility, a power-shift gear box, an electronic lift and an automatic system that electronically controls the traction.

No. 6 is a robust and reliable tracked tractor suitable for works in hard soils and under high slope conditions. The function of dumping of the vibrations is operated by the platform supporting the seat, that is suspended on silent-block.

No. 7 is a medium power, modern tractor characterized by high versatility in the different operative situation, from the field to the road transfer, guarantying a good level of comfort and ergonomics to the driver. It is equipped with a self- front axle and with both front and rear p.t.o. electro-hydraulically controlled.

No. 8 is a 4WD, medium power tractor of universal use.

No. 9 is a medium power tractor equipped with a hydraulic suspension at the front axle. Moreover, an automatic electro-hydraulic system operates the self-levelling of the cab under slope conditions, increasing the comfort for the driver.

N. 10 is an high power modern tractor largely used in field works and transport operations.

Figure 2. Some of the tested tractor during field works: Left: Tractor No. 9 in harrowing; right: tractor No. 10 in ploughing

The driver seat represents the element through which most of the vibrations generated by the interaction among soil, tractor and operating machine are transmitted to the driver's body.

In the tractors no. 1, 2, 3, 4 and 6 the suspension of the driver seat is based on a four-bar linkage with a central hydraulic cylinder and on a system of springs for the damping of the vertical accelerations. The stiffness of the springs is adjusted by rotating a knob in the lower part of the seat. In the tractors no. 5, 7, 8, 9, e 10 the adjustment of the driver seat suspension is operated by means of a pneumatic device that controlling the air pressure basing on the mass of the driver.

During the tests, the inflation pressure for both front and rear tyres has always been set on the values indicated in the ETRTO standard.

Methodology test

The measurements have been made according to the methodology reported in the ISO 2631-1:1997 standard [4]. The tri-axial accelerometer at the driver seat has been oriented as shown in fig. 3. The values of a_{wx}, a_{wy} e a_{wz} have been simultaneously collected and calculated in the frequency interval 0.5 to 80 Hz.

The acquisition time has been 240 s and is considered significant for the characterization of the level of vibrations typical for each operation. Five replications have been made in each test condition.

The values of A(8) and of the resulting safety and limit time values have been calculated by means of a Microsoft-Excel work-sheet for the "calculation of the exposure to vibrations", available in the Website of the ENAMA (National Body for Agricultural Mechanization).

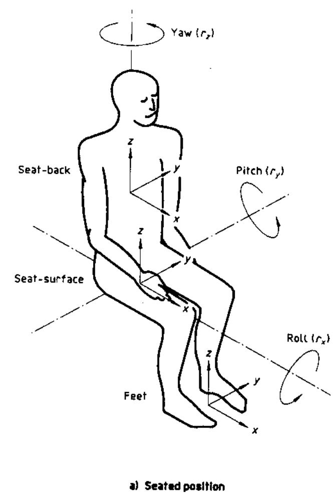

Figure 3. Systems to coordinate the relief vibration body defined by ISO 2631-1:1997

Results

The table 3 shows the values of the mean axial accelerations, a_{wx}, a_{wy}, a_{wz} , the values and the standard deviation of the resultant of the acceleration, a_v, the "safety time" and the "limit time". As said above, the times of exposure have been calculated on the basis of the highest axial value among a_{wx}, a_{wy}, a_{wz} , multiplied by 1.4 for the x and y axes and by 1 for the z axis [5] [6].

It can be noticed that in the tillage tests (ploughing and harrowing) the vector a_v always resulted higher than the daily limit value of 1.15 ms^{-2} fixed in the Directive.

Ploughing is the heaviest operation because of the shocks caused by the interaction among the force of traction, the characteristics of the plough, the coupling system and the characteristics of the soil, that determine severe work conditions from the point of view of the exposure to vibrations. As to the harrowing, aimed to the refinement of soil previously ploughed, the measured high vibration levels are mainly due to the high unevenness and cloddiness of the soil.

Table 3. Mean axial accelerations, a_{wx}, a_{wy}, a_{wz}, the values and the standard deviation of the resultant of the acceleration, av, found body during the main processing. - Time maximum daily use not to exceed the value of safety and the limit value

Test No.	Operation	a_{wx} (ms^{-2})	a_{wy} (ms^{-2})	a_{wz} (ms^{-2})	a_v (ms^{-2})	Standard Dev.	a_w (ms^{-2})	Safety time (a_v < 0,5) (h:min)	Limit time (a_v < 1,15) (h:min)
1	Chopping	0.280	0.333	0.541	0.833	0.241	0,541 (z)	6.18	> 12.00
	Distribution of chemicals	0.211	0.383	0.482	0.780	0.114	0,383 (y)	6.25	> 12.00
2	Chopping	0.241	0.414	0.771	1.02	0.052	0,771 (z)	3.06	> 12.00
	Distribution of chemicals	0.303	0.567	0.847	1.24	0.269	0,847 (z)	2.34	> 12.00
3	Harrowing	0.356	0.632	0.604	1.18	0.032	0,632 (y)	2.21	> 12.00
	Chopping	0.506	0.637	1.03	1.51	0.278	1,03 (z)	1.44	9.58
4	Ploughing	0.671	0.425	0.863	1.41	0.312	0,671 (x)	2.05	11.59
	Hay harvest	0.747	0.561	0.407	1.38	0.331	0,747 (x)	1.41	9.40
5	Ploughing	0.702	0.433	0.453	1.24	0.147	0,702 (x)	1.54	10.57
	Sowing	0.502	0.372	0.312	0.930	0.091	0,502 (x)	3.44	> 12.00
	Earthworks	0.494	0.361	0.328	0.918	0.181	0,494 (x)	3.51	> 12.00
6	Ploughing	0.523	0.661	0.800	1.43	0.052	0,661 (y)	2.09	> 12.00
	Harrowing	0.395	0.616	0.466	1.13	0.330	0,616 (y)	2.29	> 12.00
7	Ploughing	0.490	0.612	0.343	1.15	0.162	0,612 (y)	2.31	> 12.00
	Harrowing	0.527	0.835	0.356	1.43	0.127	0,835 (y)	1.21	7.45
8	Ploughing	0.410	0.374	0.427	0.888	0.070	0,410 (x)	5.36	> 12.00
	Harrowing	0.668	0.696	0.741	1.55	0.124	0,696 (y)	1.56	11.09
	Sowing	0.488	0.643	0.669	1.28	0.109	0,643 (y)	2.16	> 12.00
9	Ploughing	0.380	0.360	0.280	0.791	0.036	0,380 (x)	6.31	> 12.00
	Harrowing	0.370	0.350	0.190	0.738	0.196	0,370 (x)	6.52	> 12.00
10	Ploughing	0.412	0.604	0.541	1.16	0.072	0,604 (y)	2.35	> 12.00
	Harrowing	0.753	1.16	1.08	2.21	0.092	1,16 (y)	0.42	4.02

In the remaining operations a_v varies between the daily action value (0.5 ms^{-2}) the limit value (1.15 ms^{-2}). In particular, observing the data of the tractors No. 1, as the chopping and the distribution of chemicals do not require high traction performances and are usually made on more even surfaces, low values of the horizontal components, a_{wx} and a_{wy}, can be noticed, as the vertical, a_{wz}, resulted the most significant component and has been used in the calculation of the two exposure times that, at any rate, have been the highest together with the exposure times of the tractor No. 9. This was equipped with two special devices: an hydraulic self-levelling system of the cab and an hydraulic suspension at the front axle. The latter device is automatically excluded by locking the differential and it has not been used in the ploughing and harrowing tests, as the cab self-levelling system normally worked. The most severe solicitations occurred along the x-axis (travel direction), as the vertical component resulted the lowest testifying of a good performance of the seat suspension.

Considering the safety time, the values obtained from all the other tractors, would allow to work two to three hours a day. The things substantially change referring to the limit time, because the resulting exposure times always are higher than 8 hours except for the tractor No. 10 in harrowing.

Conclusions

From the test results of the present paper emerged the great complexity of the agricultural work conditions from the point of view of the exposure to the vibrations, confirming the data observed in previous experiences. In this context it is often very difficult to operate a generalization, applying models developed for different operative situations.

Basing on the correctness of the methodological approach aimed at measuring the fundamental parameters, the discussion should involve the determination of the exposure times. Notwithstanding the transformations and the undoubted evolution of the agricultural work, it still keeps characteristics different from any other sector, that necessarily are reflected on the aspects of worker's safety and health.

The main peculiarity of agricultural work from the point of view of the exposure to vibrations is represented by the high variability of their level as a consequence of environmental factors (seasonality of the productions, meteorology, soil characteristics, etc.) and management choices (involving, for instance, the production lines, the organization of the work, the kinds of machines etc). This variability is referred both to the year and to the single working day and often causes the occurrence of heavy working loads in brief periods (in the year and in day) in which the levels of vibrations, determined by different equipments, assume different values and characteristics.

It is difficult to apply a model developed for evaluating the exposition to vibration in industrial working environments to such a situation. The combined effects of the vibration level and of the exposure time should be reconsidered referring to the above mentioned factors typical of agricultural works and, in addition, to the different kinds of agricultural worker: a farmer will undergo minor solicitations, for instance in tilling its fields in a few days, than a farm-contractor that, in order to maximize its profits, has to make the same operations in large extensions for longer periods.

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Control tests of main safety requirements of a flail mower, according to EN standards

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Abstract

The manufacturers of agricultural machines must accurately evaluate the risks associated to their utilization and equip them with safety devices. By applying the norms and technical specifications of the Directive 98/37/EC it is possible to obtain the presumption of CE conformity that allows the free trading of said products. The standardization bodies (ISO, EN) issued a series of norms fixing the minimum safety requirements and the relative control tests for the main categories of agricultural machinery.

This paper reports the results of tests on a flail-mower aimed at verifying the sound pressure and sound power levels, the parking stability and the guards effectiveness against accidental ejection of materials according to the reference standards.

The flail-mower was driven by a 58,8 kW tractor that represented an external source of noise. The measurements of A-weighted sound pressure levels (L_{pA}) and of C-weighted sound peak levels ($L_{pC,peak}$), showed values higher than 85 dB(A). Consequently, the sound power levels have been measured in a fictitious hemispheric zone, comprising the tested machine, showing a maximum value of 104,6 dB(A).

The guards against the accidental ejection of materials have been tested into an "eject-chamber" delimited by Kraft paper target-panels. The number of outward perforations determined by the impacts of test materials, used as projectile on the target-panels, indicated the guards suitability. The results showed that the guards resulted in compliance with the standard.

Finally, the flail-mower has been placed on a 13° inclined plane, showing to be stable in parking, independently from its orientation.

Keywords: agricultural machinery, sound pressure, sound power, stone ejection, parking stability.

Introduction

The manufacturers of agricultural machines, during the development of their products, must accurately evaluate the risks associated to their utilization and equip them with safety devices. By applying the norms and technical specifications of the Directive 98/37/EC it is possible to obtain the presumption of CE conformity that allows the free trading of said products. The standardization bodies (ISO, EN) issued a series of norms fixing the minimum safety requirements and the relative control tests for the main categories of agricultural machinery.

At CRA-ING it has been constituted the CPMA (Agricultural Machinery Testing Centre), a work-group fitted up with specific equipments, test areas and updated instrumentations aimed at verifying the compliance of the machines with the standards in force and at studying proper solutions for improving the safety conditions and solving eventual non-conformity problems. As example of CPMA test activity, this paper reports the results of tests on a flail-mower (from the normal production line), aimed at verifying: the levels of sound pressure and sound power; the parking stability (according to EN ISO 4254-1:2005); the effectiveness of the guards against the accidental ejection of materials (according to EN 745:1999).

Materials and methods

Characteristics of the machine

The tested flail mower is an operating machine mounted on the tractor's three point linkage and driven by the tractor's power take off (fig. 1). It is used in the shredding of shrubby and/or grassy soil covering, straw and pruning residues with diameter up to 30 mm. The steel mainframe has been designed for resisting to the severe shocks and vibrations typical of this kind of machine; a second bowed frame has the function of connecting the machine to the three point linkage and can move sideways, when, for instance, a trunk is met along the row. The movement from the p.t.o. to the tool holder rotor is transmitted by means of a system consisting of a drive shaft (transversal referring to the advancing direction) that ends in a drive pulley; this is connected, by means of 4 V-belts, to the driven pulley at the tip of the tool holder rotor, where the tools are radially bolted. These are represented by "double L" blades with a sharpened edge. The tested flail mower had a working width of 1.40 m and a total mass of 620 kg.

Figure 1. The tested flail mower

Sound pressure levels tests

As to the sound pressure, according to the EN ISO 4254-1:2005 standard, the basic parameters to measure were: the level of the A-weighted sound pressure, L_{pA}, and the level of the C-weighted peak, $L_{pC,peak}$. The reference standard specifies the point in which the instruments must be placed; the measurements must be done on a reflecting surface, under free sound field conditions.

The sound pressure levels have been measured for frequency bands in $^1/_3$-octaves in the range 12.5 Hz to 20 kHz, by means of a B&K instrumental chain that consisted of a real-time frequency analyzer (mod. 2260), a microphone (mod. 4810), a sound level calibrator (mod. 4231) and a reference sound source (mod. 4204) (fig. 2). Such instruments are in compliance with the standards (respectively: IEC 651/1979, IEC 804/1985, IEC 1260/1995, IEC 942/1988 class 1) and underwent calibration in a SIT centre (Italian Calibration Service). Before and after the tests, the deviations from the initial calibration value have been verified by means of the calibrator.

The source of power used in the tests was represented by a 58.8 kW tractor. The power-take-off speed has been measured by means of an optical revolution counter (accuracy: 1%). The tractor-flail mower connection has been realized through interposing a special single-axle trolley equipped with a three point linkage and an extended drive-shaft transmission, with the aim of increasing the distance between the tested machine and the external source of noise (the tractor). After a preliminary heating phase, the measurements have been made under optimum temperature conditions of the organs of both tractor and operating machine.

Figure 2. The real-time frequency analyzer, the microphone and the sound level calibrator (left); the reference sound source (right)

For the machines driven by tractor's PTO, the background noise (K_{1A}) is measured in the micro-phonic place predisposed for the test, while the tractor works with PTO disconnected, at an engine speed corresponding to the speed chosen for normal operating machine working. The background noise (also including the wind noise), expressed as weighted sound pressure level, resulted at least 6 dB(A) lower than the level required by the standard for the tested flail mower.

The following formula has been used in order to obtain the A-weighted sound pressure level of background noise:

$$\mathbf{K_{1A} = - 10 \log10 (1\text{-}10^{-0,1\,\Delta L})} \quad \mathbf{[dB(A)]}$$

where ΔL is the difference between the different sound pressure levels measured in a specific position of the external power source (the tractor), respectively working and not working. The formula is valid in the interval $6 < \Delta L < 15$ dB(A); for $\Delta L > 15$ dB(A) K_{1A} is equal to 0 and for $\Delta L < 6$ dB(A) the measurement is considered invalid.

The environmental correction (K_{2A}) has been determined using a sample sound source having the characteristics required by the ISO 6926:1999 standard, that was positioned in the same place of the tested machine. According to the EN ISO 3744:1995 standard, the sound power levels of the sample source have been calculated with the following formula:

$$\mathbf{K_{2A} = L^{*}_{w} - L_{wr}}$$

where:
L^{*}_{w} = sound power level determined by the reference sound source, without environmental correction;
L_{wr} = certified sound power level for the reference source.

According to these considerations, the following tests have been conducted:

- Measurement of the environmental background noise;
- Determination of the sound pressure level produced by the reference sound source (working at a speed of 2282 min^{-1});
- Determination of the background noise produced by the external power source, represented by the tractor and the trolley, working at a P.T.O. speed of 540 min^{-1} without load;
- Determination of the sound pressure produced by the system tractor-trolley-operating machine working at a P.T.O. speed of 540 min^{-1} without load.

The measurements of the sound pressure have been made without driver. The position of the microphone has been determined depending on characteristics of the three point linkage of the tractor as required by standard (appendix B, point B.2 6a) for the machines driven by an external source of power.

The data acquisition started immediately after having observed a deviation lower than 2 dB(A) in three, consecutive measurements: five replications have been made with a sampling time of 60 s. The sound pressure level has been calculated by means of the formula:

$$\mathbf{L_{pA} = L'_{pA} - K_{1A} - K_{2A} \quad [dB(A)]}$$

(the presence of the apex indicates measured values; the remaining are the emission values).

The adopted uncertainty for the A-weighted sound pressure has been that defined in the EN ISO 12001:1997 standard (reproducibility standard deviation), resulting equal to 2.5 dB(A).

Sound power level tests

The EN ISO 4254-1:2005 standard allows to estimate the level of sound pressure generated by a sound source on a test surface under free sound-field conditions, from measurements made in proximity of one or more reflecting planes, so that it is possible to calculate the corresponding sound power. In this case the parameters that must be measured are the sound pressure mean level (L'_p) with tested sound source working and the background sound pressure mean level (L''_p), both referred to the same test surface. From them it is possible to calculate the superficial sound pressure level by applying the correction factors, K_{1A} and K_{2A}, respectively for the effects of the background noise and of the reflected sound. The level of the sound power, L_w, is finally determined by means of the formula:

$$\mathbf{L_w = L_{pf} + 10 \lg \frac{S}{S_0} \quad [dB(A)]}$$

The standard requires 10 micro-phonic positions dislocated on an hemispheric surface, $S = 2 \Pi r^2$, that includes the sound source and is delimited by the reflecting plane. The test surface and the 10 points are schematically shown in fig. 3 and their coordinates are reported in the table 1.

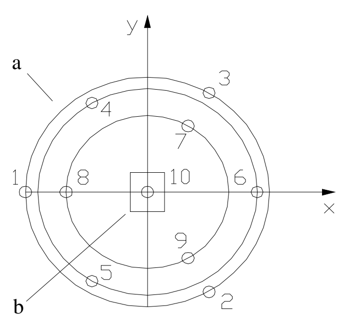

Figure 3. Top view of the hemispheric surface (a) surrounding the sound source (b) and of the 10 micro-phonic positions

Table 1. Coordinates of the 10 micro-phonic positions

Micro-phonic position	X (m)	Y (m)	Z (m)
1	- 3,96	0	0,60
2	2,00	- 3,44	0,60
3	2,00	3,44	0,60
4	- 1,80	3,08	1,80
5	- 1,80	- 3,08	1,80
6	3,56	0	1,80
7	- 1,32	2,28	3,00
8	- 2,64	0	3,00
9	1,32	- 2,28	3,00
10	0	0	4,00

Parking stability

The EN ISO 4254-1:2005 reports the test procedure aimed at verifying the parking stability of the operating machines on hard surfaces having an inclination angle up to 8.5°, in all directions. Such a test has been performed on a plane with an inclination of 13° ± 0,5° (fig. 4) higher than 8,5° required by the standard.

Figure 4. The machine on a tilted plan

Accidental ejection of materials

The wide diffusion of flail mowers determined, from the point of view of safety, an increase of the risk of accidents determined by the ejection of materials as stones, pebbles and/or fragments of tool crashed for the impact with rocks. Such an issue is the subject of the EN 745:1999 standard that reports the minimum safety and control requirements for both the phases of project design and realization of machines, together with the criteria to be followed in the tests aimed at verifying said requirements.

The tested flail mower was equipped with a couple of self-steering rear wheels used for adjusting the cutting height. The protections are represented by two rubber strip covers (fig. 1). The upper cover is fixed on the frame of the cutting chamber, as the lower cover is bolted to the beam supporting the wheels.

The tests have been made inside an "eject-chamber" that consists of five target panels surrounding the tractor-operating machine system. This must move forward on an horizontal surface (in asphalt) with a velocity between 2 and 4 km h^{-1} and meets a mixture of sand and stones. The P.T.O. speed is set on the value indicated by the manufacturer. A further panel is applied on the rear window of the tractor's cab, representing the target referred to the zone of the driver. The effectiveness of the protection of the flail mower is evaluated by observing the number and the entity of the impacts of the material against the targets. The target panels are represented by 2 m high, vertical wood frames, supporting Kraft paper sheets with a grain of 120 g m^{-2}. Two reference lines must be drawn on each panel: one at 200 mm and the other at 600 mm from the soil surface, in order to define three zones on the target (lower, medium and higher) as a reference for the evaluation of the impacts. The target are also divided, by vertical lines, in numbered sectors with a width of 1000 mm. The mixture used consists of a fraction of sand (50%) and two fractions of gravel respectively characterized by diameter between 8 and 16 mm (25%) and between 16 and 31.5 mm (25%).

Figure 5. The test material

The mixture, with moisture contents corresponding to the saturation point, must be positioned in conic piles with a volume of 10 l and a height of 150 ± 5 mm (fig. 5). The piles must be disposed on a line perpendicular to the advancing direction, behind the tested machine, at a distance of 2000 mm from the rear wall of the chamber. The reference standard defines the disposition and the number of target panels and of the piles of mixture, depending on the characteristics of the flail mower.

Two tests have been executed, with blades working height set at 50 mm from the soil. Each test consisted of two replications, always made on a new series of piles. After each replication, the impacts on the target panels have been observed and all the residues of the mixture accurately eliminated from the test surface.

Every perforation or tear outward observed on the targets Kraft paper is considered an "impact". The test is passed if the following conditions occur:

- the number of impacts does not exceed 2 in the medium zone (200 to 600 mm) of each numbered sector;
- no impacts occur in the higher zone of the eject chamber and on the target positioned on the cab's rear window.

In the case in which the results of two tests are uncertain, the conformity of the machine to the standard is decided on the basis of the results of a third test.

Results

The results of the tests for the measurements of the sound pressure levels generated by the flail mower are reported in the table 2.

Table 2. Results of the sound pressure level measurements

	Test	$L_{pC,peak}$ dB(C)	L'_{pA} dB(A)	Pto speed (min^{-1})	Δ□L dB(A)	K_1 correction dB(A)	K_2 correction dB(A)	L_{pA} dB(A)
1	Background noise with tractor and trolley	100.9	80.9	542	-	-	-	-
	Noise under working conditions without load	106.5	88.5	543	7.57	0.84	0.63	87.04
2	Background noise with tractor and trolley	101.4	80.8	542	-	-	-	-
	Noise under working condition without load	107.7	88.6	543	7.82	0.78	0.65	87.19
3	Background noise with tractor and trolley	100.9	80.9	542	-	-	-	-
	Noise under working conditions without load	106.5	88.7	543	7.81	0.79	0.64	87.24
4	Background noise with tractor and trolley	100.7	81.1	542	-	-	-	-
	Noise under working conditions without load	106.8	88.8	543	7.69	0.81	0.67	87.32
5	Background noise with tractor and trolley	101.0	81.1	542	-	-	-	-
	Noise under working conditions without load	107.3	89.0	543	7.94	0.76	0.64	87.60

It can be noticed that the L_{pA} values are always higher than the reference value of 85 dB(A). As consequence, the maximum L_{pA} value, equal to 87.6 dB(A) and its associated uncertainty must be indicated on the user manual of the machine and it has been necessary to determine the corresponding sound power. The results of the measurements of the sound power level are reported in the table 3, showing a maximum sound power of 104.58 dB(A). Such a value and its associated uncertainty must be reported in the user manual as well.

The presence of the tractor affected the measurements of both sound pressure and power generated by the flail mower, as testified by the high values of the corresponding correction coefficient (the maximum K_1 values are, respectively, 0.84 and 0.70 dB(A) for the sound pressure and the sound power). On the other hand, as the tests have been executed under free noise field conditions, the background coefficient of correction, K_2, resulted below the standard's limit (respectively, 0.67 e 0.66 dB(A) for the sound pressure and the sound power).

Table 3. Measured levels of the sound power

Replication	L_p' dB(A)	Pto speed (min^{-1})	Correction (K_1) dB(A)	Correction (K_2) dB(A)	Surface (m^2)	L_w dB(A)
1	85.57	540	0.70	0.63	100.48	104.27
2	85.71	543	0.67	0.66	100.48	104.41
3	85.74	540	0.66	0.63	100.48	104.48
4	85.84	542	0.65	0.66	100.48	104.56
5	85.86	542	0.65	0.66	100.48	104.58

Finally, the data collected during the tests for the determination of the sound pressure underwent frequency analysis in $^{1}/_{3}$ –octaves that provided the behaviour of fig. 6: the contribution of flail mower to the sound pressure level is given by the difference between green and blue bars. It is more significant within the interval 200 to 630 Hz and shows a typical peak at 63 Hz, as, at 125 Hz, it could be determined by the resonance effect of the 63 Hz frequency.

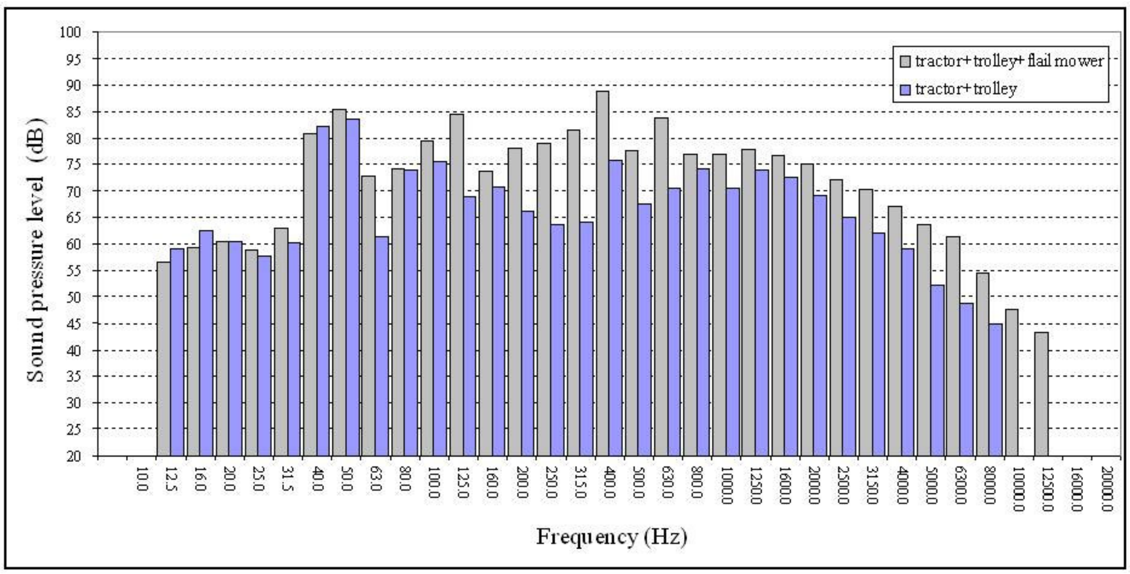

Figure 6. Frequency analysis in $^{1}/_{3}$ –octaves

As regards the suitability of the safety protections against the ejection of materials during the work, the results of both the tests showed that no impacts occurred on the higher zone of the target and on the panel on the rear window of the car, as the medium zone never evidenced more than two impacts in each numbered sector of the eject chamber. As consequence of these results, the protections are in conformity with the safety requirements of the EN 745:1999 standard and the flail mower passed the test.

The parking stability has been verified on the tilted plane described above: the flail mower has been parked on the tilted plane in the four different orientations, by progressively rotating it of 90° (in the horizontal plane) and, as no movement has been observed, the test has been passed.

Conclusions

The present paper reports an example of the application of the standards requirements to the tests aimed at evaluating the operating machines from the point of view of safety. The tested flail mower resulted in conformity with the standards for the protection against the accidental ejection of materials (EN 745:1999) and for the parking stability (EN ISO 4254-1:2005). As to the sound pressure, the measured values exceeded the reference value of 85 dB(A) (EN ISO 4254-1:2005) and had to be reported on the user manual together with the corresponding sound power level.

As a consequence of the relevance assumed by the aspects of safety and prevention of accident in the work environment, the importance of such an activity is continuously increasing. In particular, when it is conducted in an official testing centre, it represents a guaranty for both the users (that can orientate their choices towards the most safe machines) and the manufacturers (often small manufacturers that could find, in the test results, suggestions for modifications and adaptations aimed at improving the quality of the machines). For instance, considering the observed dislocation of the impacts in the different sectors of the eject chamber, the presence of perforations in the front and side panels suggests some modifications in the design of the flail mower sides and of the lateral sledges, aiming at avoiding the presence of unprotected zones.

Furthermore, the high values of sound pressure and sound power generated by the flail mower seem to be mainly due to the blades bolted on the horizontal rotor and to their high rotation speed (1790 min^{-1}). Probably, such levels of noise could be significantly reduced if the tool-holder rotor, before its mounting on the machine, undergoes an electronic balancing aimed at reducing the level of vibration.

References

EN 745:1999. Agricultural machinery - Rotary mowers and flail-mowers – Safety.

EN ISO 3744:1995. Acoustics - Determination of sound power levels of noise sources using sound pressure - Engineering method in an essentially free field over a reflecting plane.

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ISO 6926:1999. Acoustics - Requirements for the performance and calibration of reference sound sources used for the determination of sound power levels.

Identifying physical hazard for intensive pig and cattle breeding operators and defining prevention measures

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Abstract

This paper describes the results deriving from a survey, carried out at regional level about the implementation of safety prevention in agriculture. The main physical, chemical, and biological hazards connected to cattle and pig breeding, important zootechnical activities in Lombardy, were detected and quantified. In particular, the results related to the quantification of risks due to noise, lighting, and microclimate are considered here. The overall situation emerging from the study did not appear to be much critical.

Noise levels were generally lower than 80 decibels in dairy cattle farming, but they could increase on account of mechanized operations, a case where the quantification of the risk depended on the type of machinery implied (with or without cabin). During milking, noise values might range between 70 and 75 decibels. Exposure to noise in pig farms derived from the use of machinery and from stressed animals.

Lighting conditions showed very different in both types of breeding. Lighting levels were usually lower than the values in UNI EN 12464 standard; in some cases over measured lighting systems were found. Neither maintenance nor cleaning of bulbs resulted to be carried out on a regular basis, which decreased lighting levels.

Uncomfortable thermal conditions for milkers were found in dairy cattle farms in winter as all milking premises were not heated. In pig farms, the microclimate hazard concerned operators working in a very hot environment and having to withstand strong thermal shock in winter.

Keywords: animal husbandry, microclimate, lighting, noise.

Introduction

The aim of this paper is to highlight the main objectives and achievements of the survey: "*Identifying chemical, physical and biological hazards for intensive pig and cattle breeding operators and defining prevention measures*", carried out by Lombardy Region with the scope of enhancing the effects of a programme called "preventive interventions in agriculture". This survey was perfectly in tune with a broader context of activities, providing essential information and contributing to the drafting of the guidelines on hygiene and safety in rural buildings (BURL of 10/02/2006, 3° special issue) and to the promotion of farm management systems taking into account prevention measures.

The project activities analysed all preliminary aspects necessary to describe the production, to provide a framework defining risk factors, and to identify a representative sample of the major breeding and production techniques with the final object of assessing, even by quantitative measures, chemical, physical, and biological risk factors. In particular, and to be concise, this work quantifies the main physical hazards (microclimate, lighting, noise) through detailed measurements and explains the main prevention measures put forward for intensive dairy cattle and pig farming.

Material and methods

Sample premises were identified according to their being representative of animal productions and main breeding techniques in Lombardy region; productions and techniques whose physical, chemical, and biological risk factors were assessed even through quantitative measures. Zootechny is highly developed in Lombardy and among the various agricultural productions it excels economically with cattle and pig farming. Thus, this study focused on these two zootechnical productions. Cattle farms were chosen according to their milking parlour typology (stanchion barn, herringbone, parallel, robotic milking); while pig farms were chosen according to their breeding typology (farrow to finish, farrowing and fattening or farrowing only or fattening only).

The main features of the farms considered are shown in table 1.

Table 1. Farms considered for quantitative analysis of physical risks

Dairy cattle breeding			**Pig breeding**		
Farms	**Typology**	**Nr. cow**	**Farms**	**Typology**	**Nr. pig**
A	stanchion barn	30	A	farrow to finish	250
B	stanchion barn	70	B	farrow to finish	200
C	parallel 24+24	400	C	farrow to finish	250
D	herringbone 4+4	70	D	farrow to finish	250
E	herringbone 12+12	140	E	farrowing	350
F	herringbone 12+12	350	F	farrowing	400
G	robot	200	G	fattening	8.000

<u>Microclimate</u>

Parameters related to microclimate were obtained by a microclimate recording instrument (Lambda Scientifica, mod. Helios), having a data logger permanently recording data and probes for environmental parameters (dry bulb temperature, wet bulb temperature, radiant temperature, relative humidity and air speed). Sampling was carried out seasonally, each session lasting at least a week for each farm; climate parameters were obtained according to a frequency of one data every ten minutes. The probes were placed at 1.5 metres above the floor (man-high). Obtained data were compared with standard animal welfare reported in literature and with technical standards UNI ISO 7730, 1997 and ASHRAE 55, 1992 about human microclimatic welfare.

As to cattle farms, milking was specifically monitored; in fact, a worker here occupies a fixed area for several hours a day. Instruments were placed in the centre of the milkers' pit.

As to pig farms, the following production units were monitored: farrowing, weaning, storing and fattening rooms; the worker, in fact, continuously moves when on duty for animal inspection, animal feed or animal cleaning. Where possible, the probe was located in the centre of the farrowing room and of the weaning rooms. In the storing and fattening units, giving their large dimensions, additional portable microclimate probes (Delta Ohm, mod. HD 226-1) were placed in different spots of the units.

<u>Lighting</u>

Lighting level was measured by a luxmetre (Minolta, mod. T-10), adapted to catch both natural and artificial light. Accurate measures of horizontal lighting were taken at 80 cm above the floor or at a visual field corresponding to the working location. In the milking parlour, lighting level was measured near the small ladder leading to the milkers' pit, near the control board, and at the height of cows' teats.

In pig farms measures were taken in different points of the units (farrowing, weaning, storing and fattening rooms) as indicated in UNI EN 12464 standard (Fig. 1); measurements took place in autumn/winter and spring/summer as well as in different periods of a day, under natural or artificial lighting. Then, obtained figures were compared to what recommended both in UNI EN 12464 standard - that is an average lighting of 200 lux in farrowing areas, and 50 lux in animal shelters - and in decree 53/2004 concerning pig welfare, estimating as necessary at least 40 lux for eight hours a day.

Lighting homogeneity, shadowing, lamp and window cleaning were also considered.

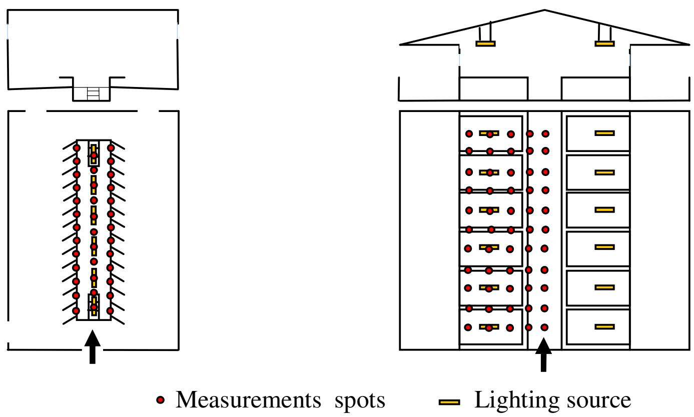


Figure 1. Location of the spots where to measure lighting level inside a herringbone milking parlour 12+12 and within a pen for fattening pigs

Noise

As to noise levels, measures were performed by a class I phonometer integrator (Larson Davis, mod. DSP 82) in keeping with IEC 651 and 804 standards, yearly adjusted and calibrated before and after any survey referring to 114 dB(A) as noise source. Survey methodology is compliant with decree 195/2006, recently included in the act about safety 81/2008, and with UNI 9432 standard concerning good techniques.

As to cattle farms, exposition level by milkers was examined; in pig farms measurements were taken in every production unit where the animals behaved either quietly or stressed (before being fed). Different spots were involved in the measurement as workers can not stay in fixed locations while inspecting animals. Where possible, noise from mills while grinding feedstuff was quantified; the workers' exposure to noise was then compared with the highest values in the regulation.

Results

Dairy cattle farms

None of the temperatures measured in seven sample farms in winter during morning and evening milking (Table 2), were higher than 12°C, in the presence of almost high relative humidity rates offering a stronger subjective feeling of coldness; a situation particularly inconvenient during morning milking, becoming worse as current water was continuously needed by the processing.

Table 2. Average temperature and humidity values obtained during morning and evening milking in winter

Farms	Milking time	T_{ex} (°C)	T_{av} (°C)	Hu_{av} (%)	Milking time	T_{ex} (°C)	T_{av} (°C)	Hu_{av} (%)	s_{air} (m/s)
A	5.30-6.30	-1,7	8,1	70,9	17.30-18.30	4,8	12,0	49,3	0,55
B	4.00-6.30	-1,5	10,8	79,3	16.00-18.30	5,5	12,1	67,8	0,60
C	4.30-7.30	-1,6	6,1	81,8	16.30-19.30	4,6	10,1	59,3	0,45
D	4.00-5.30	-1,5	2,5	84,0	16.00-17.30	6,1	6,0	63,8	0,47
E	4.30-5.30	-1,3	7,6	71,1	16.30-17.30	6,2	9,4	58,8	0,52
F	4.00-7.00	-1,5	4,8	76,7	16.00-19.00	5,7	8,1	50,4	0,44

Measures related to A and B farms (stanchion barns) obviously showed a higher thermal gradient between inside and outside; analogizing, situations C and F (a wide opening communicating with the waiting room) were more influenced by external climate. No heating system was found in the rooms checked contrary to data showing that milking parlour would need it, as anyway stated in the latest policy of Lombardy region dated 29.12.2005, "Hygiene and safety standards in rural building". A system that should be designed in conformity to the structural peculiarities of the room. As data collected in spring time confirmed, its microclimate is strongly affected by external microclimatic conditions. In fact, in recent building typologies processing rooms are as near as possible to the cattle or pig shed, clearly on the basis of organizational reasons that also require wide openings (Fig. 2).

Figure 2. Milking parlour connected to waiting room through a full opening

As given in Fig. 3, optimal lighting, 200 lux as specified in UNI EN 12464 standard, was found in very few cases. This means a greater visual effort and a possible increase of accidents in extreme conditions, even if work is not stopped.

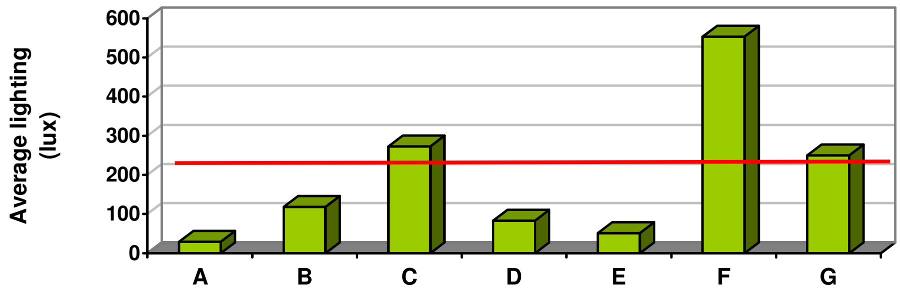


Figure 3. Average lighting (expressed in lux) inside different typologies of milking parlours (recommended lighting level for milking parlour according to UNI EN 12464 standard is given in red)

Cattle-sheds with permanent stalls, reasonably did not guarantee enough lighting where the milker was, as shaded by the cows themselves. At cow's teat level lighting showed to be 10-20 lux (Fig. 4). Notwithstanding such figures, hygienic and health assessment of the teat as well as milking can be easy if the shed is lighted homogenously and when the milker does not shade the body of the cow. Difference in lighting between the two sheds of the same typology are basically due to different heights of the lamps from the floor. In herringbone and parallel milking parlours the average lighting level was not always optimal, which was justified by the building typology. Wide and clean lateral windows, adequate orientation and large openings between the milking parlour and the waiting room permitted a better natural lighting (when there is natural light connected to milking time and to the season). Frequent cleaning and maintenance of the premises (walls painted in light colours) help with reflection from internal surfaces (frequently in raw concrete). When walls are finished, light coloured tiles are preferable and mat to avoid indirect dazzling, mainly occurring during morning milking in winter.

Figure 4. Cow pen with fixed stall for bucket milking

Noise measured during milking was not risky to the worker, less than 80 dB(A) according to the milking duration (according to act 81/2008).

Pig breeding

Pigs are very sensitive to thermal stress, both as exceeding hot or as sudden change in temperature. Therefore, their optimal microclimatic conditions do not match with human requirements. During lactation and weaning, piglets need a warm environment (2-week suckling pigs: 30°C, 4-week: 20°C). During fattening, best temperature conditions for pigs are 18-23°C and 50% of relative humidity.

In summer, working conditions for operators are not particularly hard as the sudden change in temperature between inside/outside is not so high, while in winter the situation gets more critical (Table 3).

Table 3. Average temperature and humidity values obtained in summer-autumn time in the analyzed pigpens

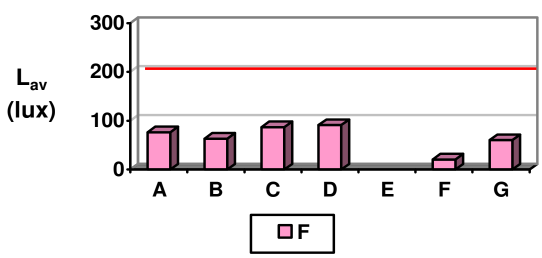
Productive	Average temperature (°C)							Humidity (%)						
sectors	A	B	C	D	E	F	G	A	B	C	D	E	F	G
Farrowing	29,2	27,9	28,9	23,7	26,7	27,5	-	59,3	60,2	60,4	77,2	69,2	66,8	-
Weaning	29,5	28,0	29,3	16,8[a]	26,3	22,2	-	60,9	65,2	58,3	78,0[a]	69,4	77,4	-
Storing	30,2	27,3	27,8	14,6[b]	25,7	22,5	-	59,6	60,7	65,1	75,8[b]	78,4	75,8	-
Fattening	-	-	27,8	21,3	-	-	23,6	-	-	61,9	73,4	-	-	76,9

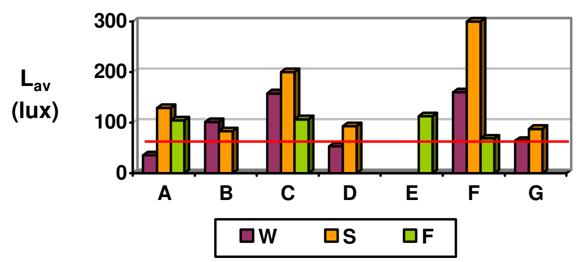
[a] Sheltered stalls with external pens, probe inside
[b] Tunnel with permanent straw litter, probe outside

The working environment can become more comfortable improving ventilation of the shelters just opening and closing the windows, by hand or by automatic systems, in order to keep constant internal temperature. This is needed to change air and avoid dangerous gases (CO_2 e NH_3). Evaporating water from wet floor surface can get cooler air during summer hottest hours, and usually this system is the only one used in farrowing rooms. In winter operators should avoid sudden change in temperature by undergoing an acclimatization period when moving from a shed to another.

All farrowing rooms showed lighting figures inferior to what given in the standard, that is 200 lux (Fig. 5A). Such high value is needed for the operators safety in case they have to help the sow with farrow. Under common conditions, a lower lighting is suggested not to stress sows. Given such considerations, further lights should be placed nearby the farrowing cage, so avoiding strong total lighting.

Other areas, weaning, storing and fattening rooms (Fig. 5B), showed adequate and homogenous lighting with an average level of 50 lux. Considering the typology of the operations performed - i.e. inspection, distribution of feed, environmental control and cleaning – measured levels matched with them. Other procedures, such as vaccinations and gelding, were carried out in other rooms with better lighting or even outside.





F: farrowing W: weaning S: storing F: fattening

A B

Figure 5. Average lighting (L_{av}) in the piggeries (recommended lighting level according to UNI EN 12464 standard is given in red)

Anyway, more care to and more frequent cleaning of the lamps, their due substitution as well as more attention to windows cleaning are suggested. Saving energy would be possible painting stables with light colours and using bulbs with lower power. As also standard highlight, before inspecting animals without stressing them portable devices should be used to light where necessary.

In pig farms, noise risk was mainly due to plant and equipment devoted to feed preparation and unit cleaning, as well as to animal sounds. Where dry feeding was used, a mill could be found; when working it could generate of the lamps noise of 80-85 dB(A) in the environment. An operator was exposed to noise only when operating on the device for on/off phase from a control board enough far from the plant or even inside a soundproof box. When moist feeding was used, the mash was prepared in a special room indicating 75-80 dB(A). The plant here was usually operated from a room soundproof as to the kitchen. The operator could be exposed to high noise levels in units where very stressed animals were to be fed. Cleaning of the units, including faeces removal and manger cleaning, occurred daily using low pressure hydrants or high pressure water cleaners after each pig cycles. According to the environmental reverberation and the impact between water jet and metallic equipment, this phase could generate 80-85 dB(A). The best safety here would be assured by regular use of ear protectors. Pregnant sows and adult swine showed to be the noisiest subjects when under particular conditions, i.e. before being fed or when any disturbing element inside their pen provoked anxiety and stress. Situations inducing sound pressure levels above 85 dB(A), while no risk was estimated in quiet conditions. Animals were particularly quiet in farrowing rooms, in weaning units, where feed was regularly given, and when they were low in number. If they were fed twice a day, they showed higher stress and anxiety just before being given it, which produced sound pressure levels of 85 dB(A). In such cases, operators should be more careful with connected risks by organizing their work:

- with a different conduct and adequate procedures to minimize animal stress;
- with entering their pens only after having fed them;
- with wearing proper ear protectors as suggested.

Sanitary procedures on piglets, i.e. gelding, tail/teeth cutting and vaccinations, exposed the operators to very high sound levels, above 90 decibels, due to the animals' howls, screams and cries. Ear protectors are highly recommended in such cases, as these operations are periodical.

The design of the premises, together with adequate building techniques and soundproof materials can also help with limiting noise propagation and reverberation inside animal pens.

Conclusions

Much more has still to be done, notwithstanding improved conditions of work. Everybody working within public and private prevention institutions must be involved in the prevention measures. In particular, many critical points detected through measurements from this study can be solved thanks to a correct and progressive application of regional policy.

Acknowledgements

The Authors gratefully acknowledge the Local Health Unit of Lodi for coordinating the project, and extend special thanks to breeders for performing experiments and supporting them with useful information.

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Whole Body Vibration (WBV) transmitted to the operator by tractors equipped with radial tires

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Abstract

Other than the tractor components technological development, in the last decennia the interest for the driver comfort increased. Noise and vibration control priority increased too. Especially for vibration the tires quality plays a great role.
Modern tractors are often equipped without any type of suspension and the tires task is to reduce vibration caused by the uneven ground where these machines travel.
When the tractor moves, it is solicited by a vibrational excitation that, through the vehicle, reaches the driver causing to him a stressing and tiring situation.
To verify the vibrational comfort value given by these radial-ply tires, tests have been carried out using a 93 kW tractor. The tests have been executed with two different tractor speeds (12 and 7 km/h) and using both an artificial test track (ISO 5008) and an asphalt road.
Four different types of tires have been used (from three different manufacturers): for each test cycle the inflation pressure has been changed.
The acceleration values have always been revealed over the cabin platform to make irrelevant the running in of the seat.
In this way it was possible to extract the tires parameters which most influence the dynamical behaviour of the tractor and therefore the operator's comfort.
192 test have been conducted, using four different tires at two different pressure, 3 different track type, 2 different speed, and repeating each test three times.

Keywords: vibration, WBV, tractor tires.

Introduction

Low-frequency vibrations, produced by the agricultural vehicles, can be extremely severe, depending upon the terrain that the agricultural vehicle is crossing and the forward speed of the vehicle (Lines et al., 1995, Scarlett et al., 2007). By comparison with the progress achieved over the past decades in improving the performance of agricultural tractors (power, transmission, electronics…), the protection of the driver from vibration remains very inadequate. This is due to the fact that, in general, agricultural tractors do not have chassis suspension and the tires, which are relatively flexible and weakly damped, are the only suspension system (Cutini et al., 2007, Servadio et al., 2007). This explains why the tractor driver is subjected to low frequency, high amplitude vibration that are an important risk factor for low back pain disorder (Bovenzi et al., 1994).

In order to reduce the health risks and the discomfort to the driver and to enable the driver to work at a faster pace, it is important to isolate the driver from the machine vibration as much as possible.

Agricultural machinery construction companies play an important role in the production and implementation of all features that can reduce the WBV driver level: for this reason tyres producers are heavily involved (Stayner 2001, Sherwina et al., 2004) .

Aim of this investigation is to indicate likely variations in WBV from four different types of tires (from three different manufacturers). 192 test have been conducted, using four different tires at two different pressure, 3 different track type, 2 different speed, and repeating each test three times.

Materials and methods

To verify the vibrational comfort value given by the radial-ply tires, tests have been carried out using a 4WD tractor (table 1) equipped with four different types of tires, from three different manufacturers.

Table 1. Main features of tractors

Item	Measure unit	Value
Tractor power	kW	93
Cylinders	n	6
Displacement	cm^3	6720
Wheel base,	mm	2661
Trackwith front	mm	1407
Trackwith rear	mm	1426
Mass front	kg	2044
Mass rear	kg	3066
Cab suspension		silent-blocks
Axles suspension		any
Ballast		any

<u>*Tire characteristic*</u>

Four different types of tires have been tested (table 2). All tires were new. Tires A, C and D were at low aspect ratio.

Table2. Tire characteristics

Tire	A		B		C		D	
	front	rear	front	rear	front	rear	front	rear
Tire size	480/65 R28	600/65 R38	380/85 R28	460/85 R38	480/65 R28	600/65 R38	480/65 R28	600/65 R38
Number of lugs	22	23	20	21	19	20	20	22
Lugs height, mm	41	46	48	52	41	50	42	49
Average area of a lug, cm^2	108	175	77	112	130	213	114	171

Tests have been carried out on three different surfaces:

- The smoother ISO, 100 m track (from standard ISO 5008: 2001), which represents an unmetalled farm roadway, designed to test the fitness for validity of tractor seats. This track provides an acceleration input which, at the cab floor, is dominated by the vertical component (figure 1);

- ISO track and asphalt (1/2 ISO in the following). For this test tractor was driven with two wheels on the track and two on the asphalt. Aim of the test was to improve the lateral force on the tires (figure 2);
- Asphalt. Tractor vibration were tested on a conglomerate bituminous rectilinear plane tract of 400 m length. These type of tests gave us information about the tires behaviour during transfer on the road.

Use of ISO 5008 ride vibration track tests provides a reasonable basis for comparison of tires under tests for the high repeatability and reproducibility of vibration data.

Operative condition

In order to maintain the test programme within reasonable limits we have carried out the test at 12 km/h and 7,5 km/h. Forward speed was monitored by a Peiseler wheel.

For the forward speed of 12 km/h each test was executed with three different tire pressures (1.6, 1.2 and 0.8 bar), while for 7.5 km/h the pressure was only 0.8 bar (table 3).

Three test replicates were performed for each test speed and pressure (192 test have been conducted).

The same driver was used for all tests.

Table 3. Operative conditions

Speed (km/h)	12	12	12	7.5
Pressure (bar)	1.6	1.2	0.8	0.8
Test track	ISO ½ ISO Asphalt	ISO ½ ISO Asphalt	ISO ½ ISO Asphalt	ISO ½ ISO Asphalt

Figure 1. ISO test track

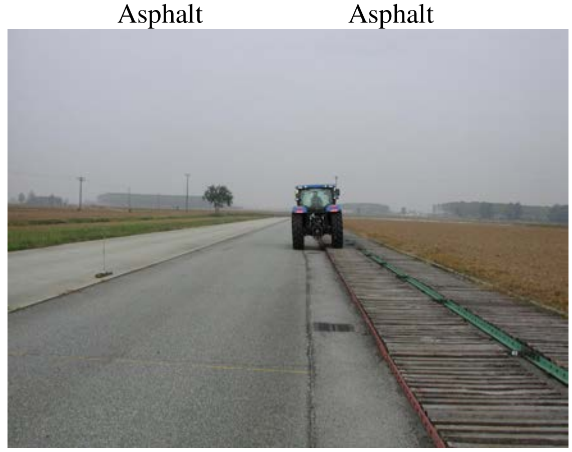

Figure 2. ½ ISO test track

Test instruments

A Larson Davis Human Vibration Meter type HVM100 (serial No 292) was used to condition the cab floor accelerometer. A tri-axial accelerometer ICP® (Integrate Current Preamplifier) from PCB, type SEN020 (serial No. P 51694) with sensitivity of 1mV/g, was connected to the human vibration meter HVM 100. The accelerometer was fixed on the cab floor, close to the seat mounting point.

The acceleration records were frequency-weighted, using the weighting factors *wd* and *wk* specified in ISO 2631-1 for the horizontal and vertical axes respectively, before calculation of root mean- square (r.m.s.) acceleration values. The horizontal (X and Y-axis) components were multiplied by a factor of 1.4, as also specified in ISO 2631-1. Combined (vector-sum) three-axis acceleration values were obtained for the cab floor by calculating the root-sum-of-squares (RSS) of the combined orthogonal axes components.

As the tractor seat was new of factory, in order to avoid any effect of the seat running in, the measurements of vibration were executed only on cab floor.

Test type

Each test has been repeated three times for each configuration. In table 4 the RSS measured and the averages for 7.5 km/h speed at the pressure of 0.8 bar are reported.

Table 4. RSS values (m/s^2) obtained at the speed of 7.5 km/h, 0.8 bar pressure

A		B		C		D	
	RSS		RSS		RSS		RSS
ISO	1.16	ISO	1.07	ISO	1.03	ISO	1.16
ISO	1.15	ISO	1.09	ISO	1.03	ISO	1.14
ISO	1.21	ISO	1.09	ISO	1.03	ISO	1.15
average	**1.17**	**average**	**1.08**	**average**	**1.03**	**average**	**1.15**
1/2 ISO outward	1.03	1/2 ISO outward	0.95	1/2 ISO outward	0.87	1/2 ISO outward	0.88
1/2 ISO back	1.01	1/2 ISO back	1.02	1/2 ISO back	0.88	1/2 ISO back	0.96
1/2 ISO outward	1.00	1/2 ISO outward	0.93	1/2 ISO outward	0.85	1/2 ISO outward	0.91
1/2 ISO back	1.05	1/2 ISO back	1.01	1/2 ISO back	0.84	1/2 ISO back	0.98
1/2 ISO outward	1.02	1/2 ISO outward	0.96	1/2 ISO outward	0.84	1/2 ISO outward	0.92
1/2 ISO back	1.00	1/2 ISO back	1.00	1/2 ISO back	0.87	1/2 ISO back	0.98
average	**1.02**	**average**	**0.98**	**average**	**0.86**	**average**	**0.94**
asphalt	0.15	asphalt	0.16	asphalt	0.13	asphalt	0.21
asphalt	0.16	asphalt	0.15	asphalt	0.14	asphalt	0.19
asphalt	0.14	asphalt	0.16	asphalt	0.16	asphalt	0.21
average	**0.15**	**average**	**0.15**	**average**	**0.14**	**average**	**0.20**

To better understand the possible influence of track type, speed, tire pressure and tire type over the measure vibration, data have been grouped in different ways (by tire type, by speed, etc.). All data have been written in Excel and therefore elaborated using the SPSS software to verify differences among speed, pressure and tire type, using the ANOVA procedure, considering the normality of the data distribution. This has been possible because an high repeatability has been revealed during each test phase: in fact, the obtained result in each test are very homogeneous to demonstrate the high accuracy level used during the test.

Results

First of all, no statistical analysis has been carried out to verify if vibration differences existed among the different test tracks because it was obvious looking at the collected data.

The asphalt registers the lowest values, while the highest accelerations are reported in the ISO track.

Vibration in function of speed and pressure

Considering the speed and the pressure, the different test track have been evaluated. In all the cases, the 0.8 bar pressure registered the lowest vibration values for all the tire type.

12 km/h speed. ISO track

The 12 km/h speed has been initially considered. For the ISO track, the vibration averages at different pressure level at the speed of 12 km/h are reported in figure 3. At the pressure of 1.6 and 1.2 bar the vibrations are between 2 and 2.5 m/s^2, while at 0.8 bar they don't exceed 1.84 m/s^2.

Also if the differences are very low, the highest vibration values are always due to the A and D tires. Because of the high repeatability, the two-way ANOVA (with a confidence level of 95%) reports the main difference factor as the pressure, while a lower difference is for the tire type. In all the cases the tires are different among them.

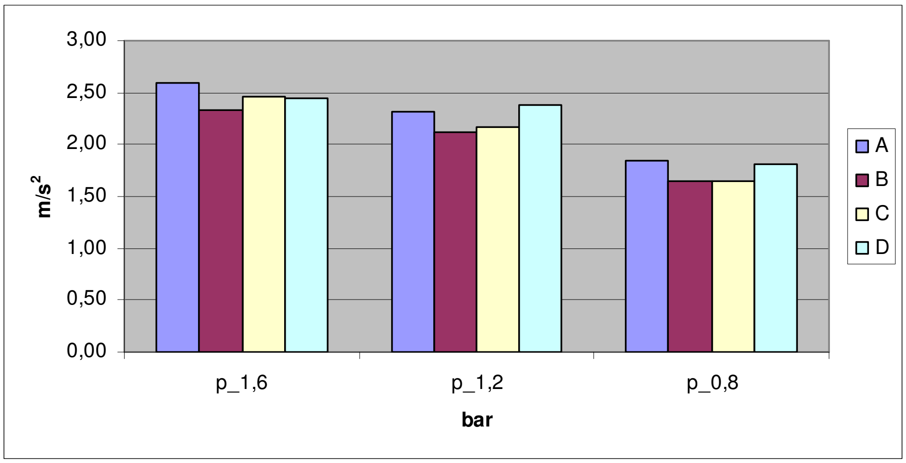

Figure 3. Average vibration values on the ISO track, 12 km/h speed

With a one-way ANOVA analysis ($p<0.05$) it has been possible to better evaluate possible tire statistical homogeneity at the different pressure levels. The results are in table 5.

Table 5. Statistical vibration analysis among tires on the ISO track, speed 12 km/h

1.6 bar	1.2 bar	0.8 bar
C and D have the same vibration behaviour	B and C are statistically equivalent for the WBV	WBV are statistically equal for B and C tyre. The same is for A and D

12 km/h speed. ½ ISO track

Analysing data for this track type (figure 4), we immediately notice that the accelerations are lower than the ISO track (figure 3). Also in this case, the two-way ANOVA ($p<0.05$) reports the highest differences for the pressure and it is not possible to group the tire vibration values. Only the one-way ANOVA permits to couple the vibration obtained by the tires at the different pressure level (table 6). In this case the differences are more underlined, at the point that only at the 1.2 bar it is possible to consider statistically equivalent tires B and C.

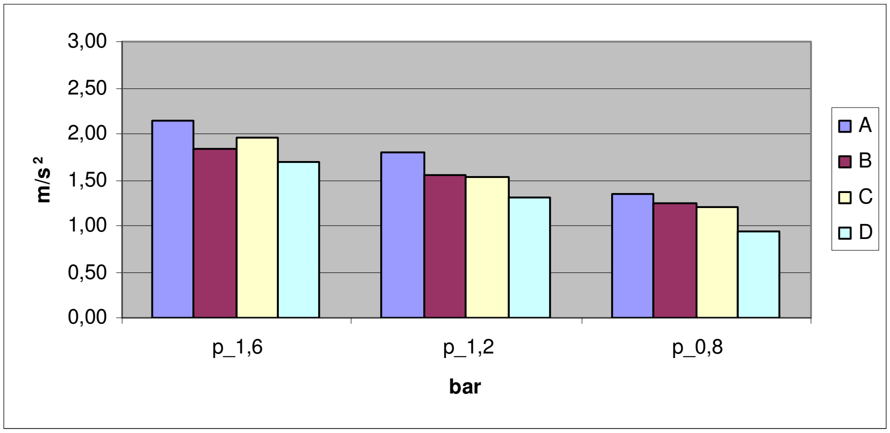

Figure 4. Average vibration values measured on the ½ ISO track, 12 km/h speed

Table 6. Statistical analysis among vibration tires on the ½ ISO track, speed 12 km/h

1.6 bar	1.2 bar	0.8 bar
All tires are different among them	B and C have the same vibration behaviour	B and C are statistically different for $p<0.05$, equal for $p<0.01$

12 km/h speed. Asphalt track

Because the measured vibrations on this track are very low, here it is not possible to represent the averages with the same scale of the other tracks (figure 5): in fact the highest vibration value in this case is 0.42 m/s^2 for the C tire. It is also curious that in the asphalt the tire A registers the lowest vibration values, whereas in the ISO and in the ½ ISO it had the highest values.

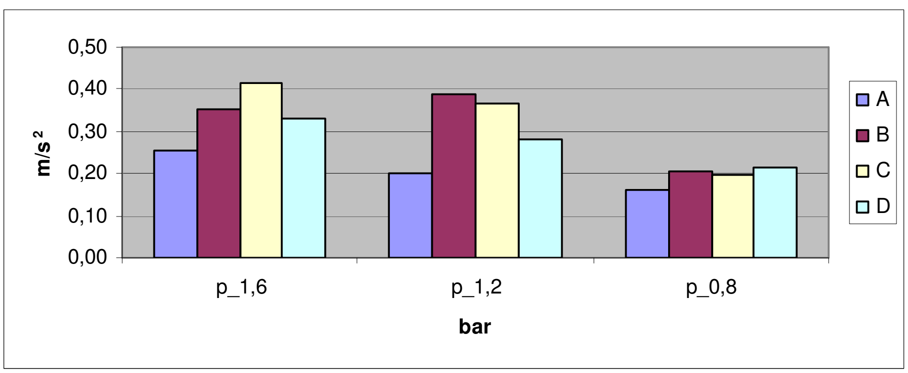

Figure 5. Average vibration values measured on the asphalt track, 12 km/h speed

From a statistical point of view, because the values are smaller and are between 0.16 and 0.42 m/s^2, it is not possible to group the tires among each pressure level: only the one-way ANOVA ($p<0.05$) permits to group them inside each pressure level (table 7).

Table 7. Statistical analysis among vibration tires on the asphalt track, speed 12 km/h

1.6 bar	1.2 bar	0.8 bar
B and D are statistically equal from the vibration point of view	B and C transmit the same WBV	B, C and D are statistically equivalent

7.5 km/h speed. All the test tracks

At the 7,5 km/h speed, only the 0.8 bar pressure has been tested for all the tracks. Because of the very high repeatability, none statistical equivalence has been detected: all the tires are different for vibration emission, also if the averages are very close to each other (figure 6). Only for the asphalt, the vibration equivalence among A, B and C tires has been statistically obtained.

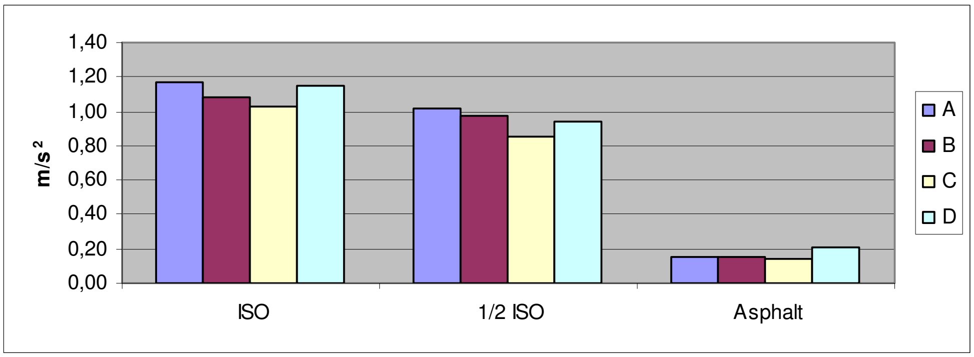

Figure 6. Average vibration values measured over different tracks, 7.5 km/h speed, 0.8 bar tire pressure

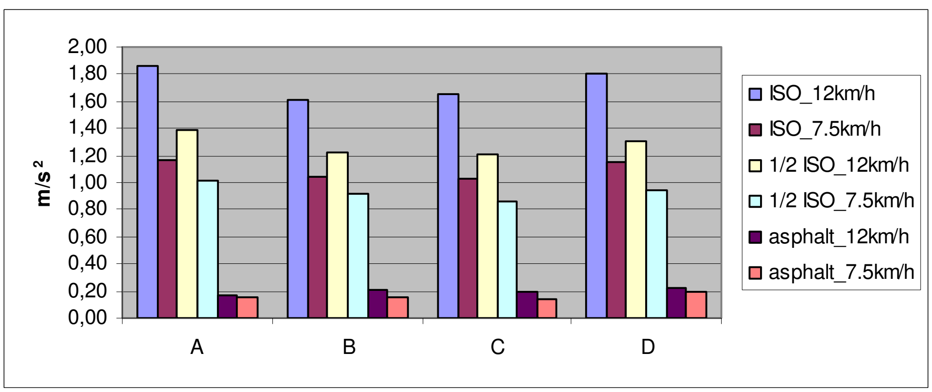

Figure 7. Average vibration values at the 0.8 bar pressure

The comparison of the average vibration values in the same conditions between the 7.5 km/h speed and the 12 km/h (figure 7) reveals that the acceleration is higher at the highest speed: the difference is more evident for the ISO and the ½ ISO track, while it is softer over the asphalt.

Conclusions

Under the vibrational aspect the behavior of tire B (with different structural elements) is similar to the other ones and there are not statistical differences.

In this work, however, there are statistical differences among the vertical (Z direction) vibration measured over the different tires inside each test condition (same track, same speed and same pressure), but it is difficult to say if a tire is 'better' than another, especially when the vibration differences are very low, as in the case of the asphalt. More differences are revealed in the ISO track, where also the measured vibration are higher. Concerning tires behaviour, the tire A reports the highest vibration values in the ISO and in the ½ ISO track, while in the asphalt it registers the lowest vibration data: effectively, there are tires which are more adapt to smooth surfaces (as the asphalt is) and others which are better over irregular soils (as the ISO track).

In all the cases, lower is the speed, lowest are the vibration measured, independently by the soil and tire characteristics.

For longitudinal (Y) and lateral (X) direction no differences have been found among tires.

Also for tests carried out on the ½ ISO tack no valuable results were found, probably because the difference in height between ISO track and asphalt was little and insufficient to generate a lateral dynamic charge.

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Assessment of comfort conditions of an agricultural tractor during operations with trailers

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Abstract

The growing interest in researches on comfort of agricultural tractor operators has conducted the CRA-ING Research Laboratory of Treviglio to define the main critical situations for the drivers.

In the frame of the Vibramag Project (Evaluation and control of the vibrations of agricultural vehicles through analysis methods based on four-post test bench) the CRA-ING has evaluated the influence on operator's comfort on a tractor with trailers and wagons in various work and transport conditions.

Tests were replicated on field and on road. An instrumental chain based on two triaxial and four monoaxial accelerometers was used for evaluating the ride comfort index (CI).

Results have shown that the forward speed and the type of trailer were the most important factors affecting driver's comfort.

On test track, the CI values obtained from tractor and tractor plus wagon were very similar validating the proposed methodology. The adoption of the trailer causes, generally, lower values for the higher weight of the tractor but higher level for the resonance of the trailer tires at certain speeds (27 – 30 km/h).

On grassed field for better understanding the discomfort values is necessary to analyse the values of the single axis. In example, the value at 12 km/h with trailer the contribute is almost completely from back X axis to indicate the hits of the implement at the hitch.

This first approach has confirmed that trailers have a great influence on operator's comfort. Beside, actual manufacturer technical solutions confirm the interest on this way to reduce the effects of trailers on tractor.

Keywords: vibrations; transport; trailer; safety.

Introduction

The researches on comfort of agricultural tractor operators have conducted the CRA-ING research unit to investigate the critical situation for the drivers (EEC, 2002). The evaluation of the real work condition is one of the most followed ways to define comfort and to define the conditions that engineering will have to approach.

Road and/or soil irregularities and forward speed are the most important parameter that influence the vibrations transmitted to the driver (Bukta *et al.*, 2002; Kornecki *et al.* 2006; Cutini *et al.*, 2007), but also mass distribution and implements could characterise the results.

The CRA-ING Research Laboratory of Treviglio in the frame of the Vibramag Project (Evaluation and control of the vibrations of agricultural vehicles through analysis methods based on four-post test bench) has evaluated the influence on operator's comfort on a tractor with different trailers in various work and transport conditions.

Materials and methods

The guidelines followed for this work were established by the ISO 2631/1997. Tests aimed to evaluate the ride comfort index of the driver measuring the accelerations at the three axis of the back and of the seat and the values of the pitch and of the roll.

A 4WD tractor fitted alternatively with a trailer and a wagon has been used (fig. 1).

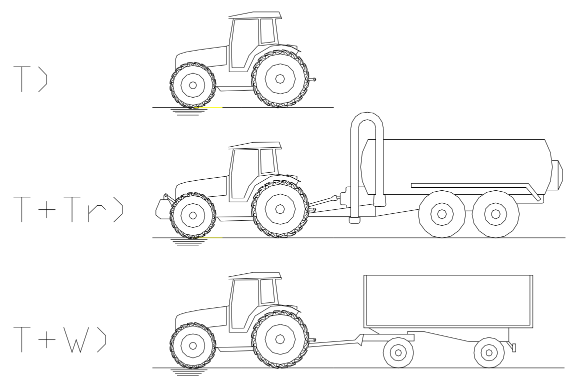

Figure 1. The tractor-trailer/wagon configurations adopted

The settings for the tests are reported in tables 1 and 2

Table 1. Vehicles' masses

	Weight (kg)		
Agricultural tractor * with trailer and front ballast	Front	1825	1755*
	Rear	1465	2685*
Wagon		6750	
Trailer		6800	

Table 2. Vehicles' main settings

Vehicle	Front tires (type)	Rear tires (type)	Inflate pressure (kPa)
Tractor	380/70R20	420/85R28	160 on track 100 on field
Wagon	11.5/80-15.3		120
Trailer	14.00R20		120

Tests were carried on the asphalt ring of the 1050 m test track of the CRA-ING Laboratory and were replicated on a grassed field.

An instrumental chain based on two triaxial and four monoaxial accelerometers was used during the tests for evaluating the ride comfort index, completed with a sixteen channels data recorder. The tractor was tested at different forward speeds for taking into account tires' influence both on grassed field and on track. The chosen speeds were:

- Test track: 27, 30, 33, 36, 39, 42 km/h
- Grassed field: 6, 9, 12 km/h

Results

The comfort index was evaluated taking into account the vibrations at the seat, at the back and at the rotational pitch and roll axes. Results have shown that the forward speed and the type of trailer were the most important factors on tractor behaviour and, consequently, on its influence on driver's comfort (fig. 2).

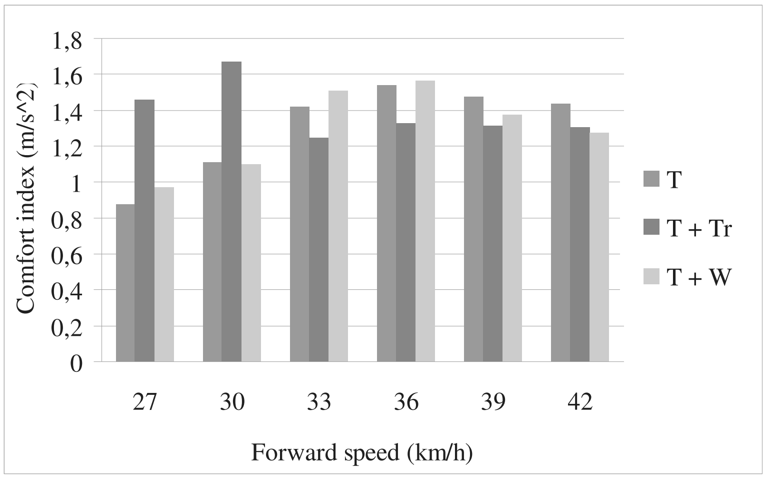

Figure 2. The comfort index (rms) during transfer on track at different forward speed

The value of the tractor alone (T) is the reference compared with the adoption of wagon (T+W) and of the trailer (T+Tr). It's interesting to note as on test track the values of T and T+W are very similar validating the methodology. The adoption of the trailer causes, generally, lower values for the higher weight of the tractor but higher level for the resonance of the trailer tires at certain speeds (27 – 30 km/h).

For better understanding the results on track, it's possible to analise the values at the seat and at the back. The analisys of the values at the seat shows a similar trend (fig.3).

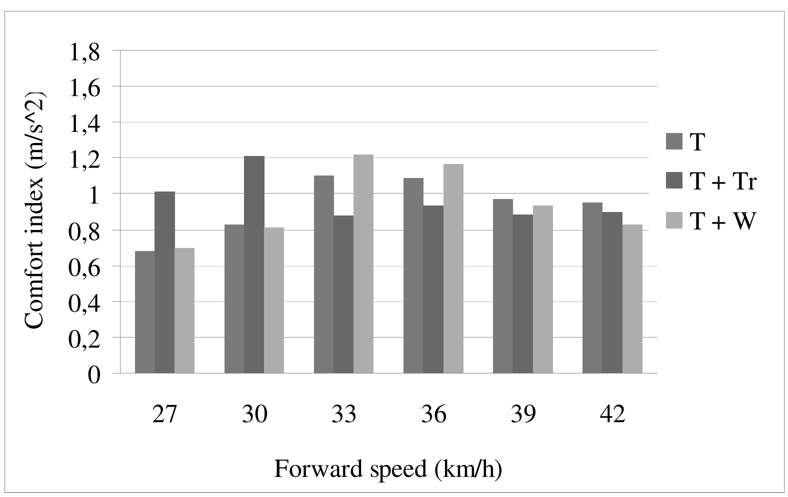

Figure 3. The comfort index (rms) during transfer on track at the seat

Beside, the analysis of the single channels shows a different situation; infact, looking at the longitudinal axis (seat X), for the T and the T+Tr the values are very low but is not negligible for the the configuration T+Tr (fig.4).

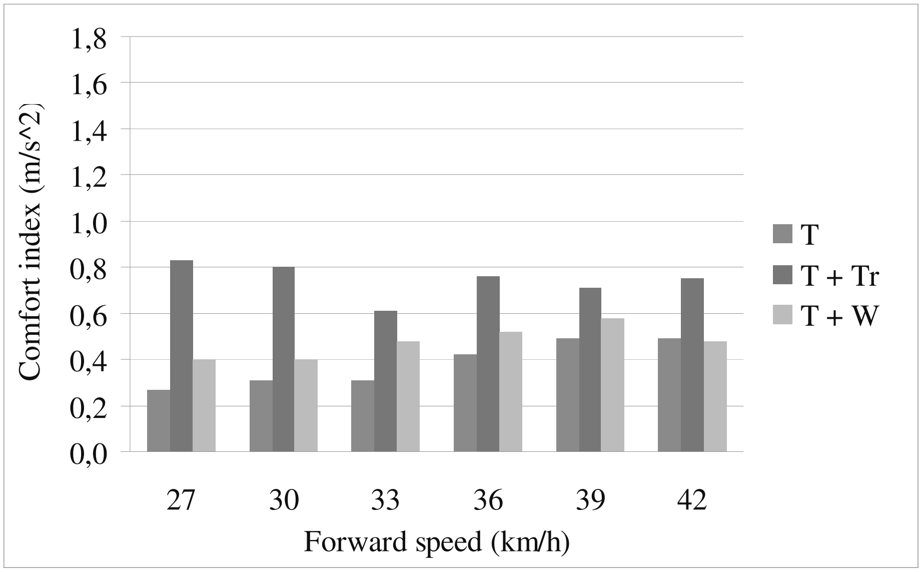

Figure 4. The comfort index (rms) during transfer on track at the seat X

Quite different is the analysis at the vertical channel of the seat (seat Z) where is negligible for the configuration T+Tr and has a great contribute for the T and T+W configurations (fig.5).

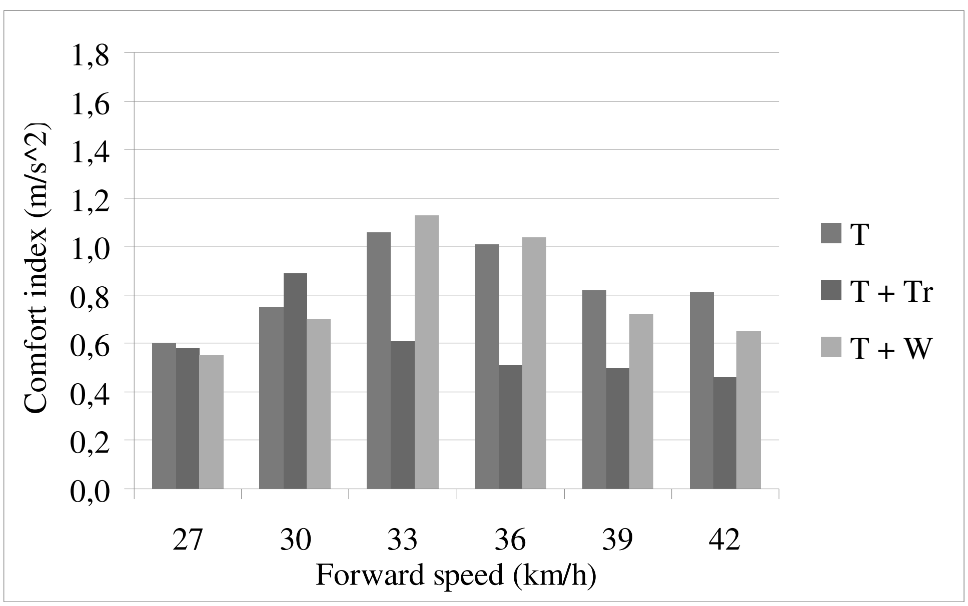

Figure 5. The comfort index (rms) during transfer on track at the seat Z

Very similar to the data recorded at the seat are the values obtained at the back (fig.6) but analysing the single channel it's possible to see as almost all the contribute is from the longitudinal channel (back X, fig.7).

The values at the single channel are not weighted, so they could result greater than the CI.

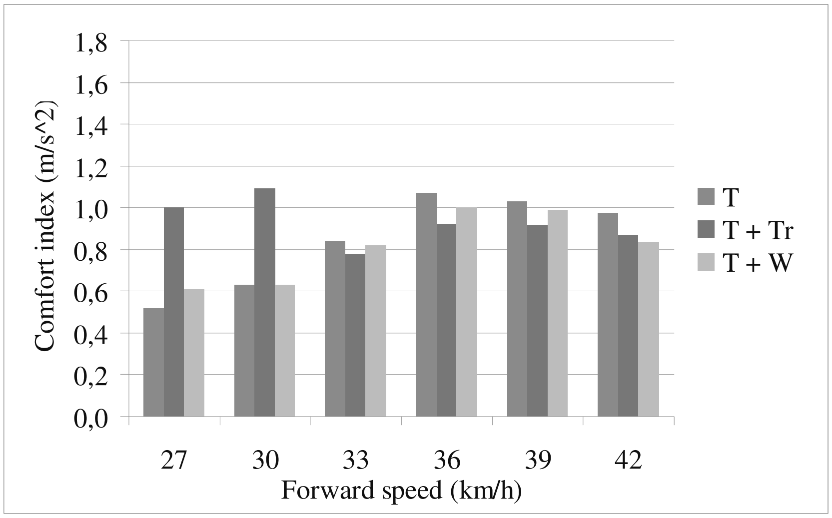

Figure 6. The comfort index (rms) during transfer on track at the back

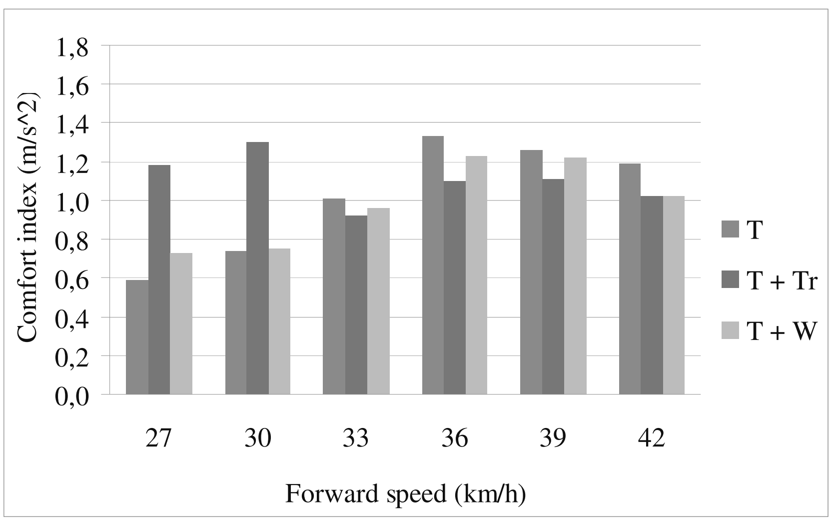

Figure 7. The comfort index (rms) during transfer on track at the back X

On grassed field the situation results very different (fig.8) and, for better understanding the discomfort values (i.e. T+W, 12 km/h), is necessary to analyse the values of the single axis.

Generally, the discomfort is always increasing with speed.

During test with T+Tr, is still present the resonance frequency at certain speed, i.e. 9 km/h.

Tests with T+W give now different values from T, to understand which is necessary to analyse the single channels.

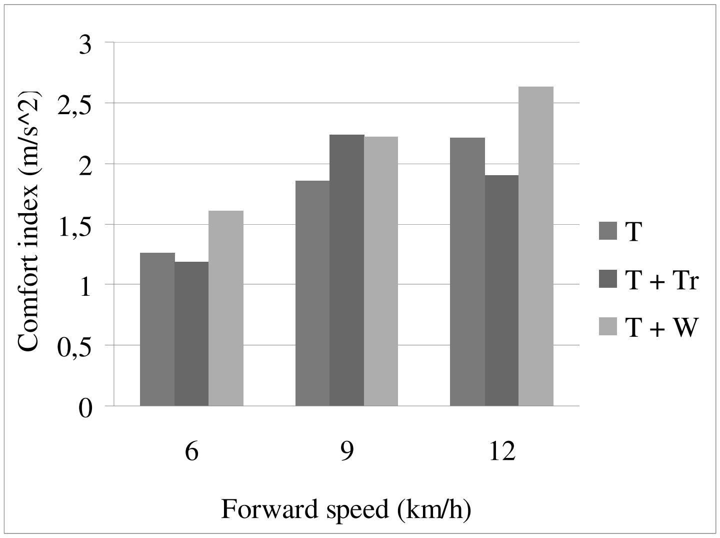

Figure 8. The comfort index (rms) during transport on grassed field

In example looking at the value at 12 km/h with trailer is interesting to note as the contribute is almost completely from back X axis (fig. 9) to indicate the hits of the implement at the hitch.

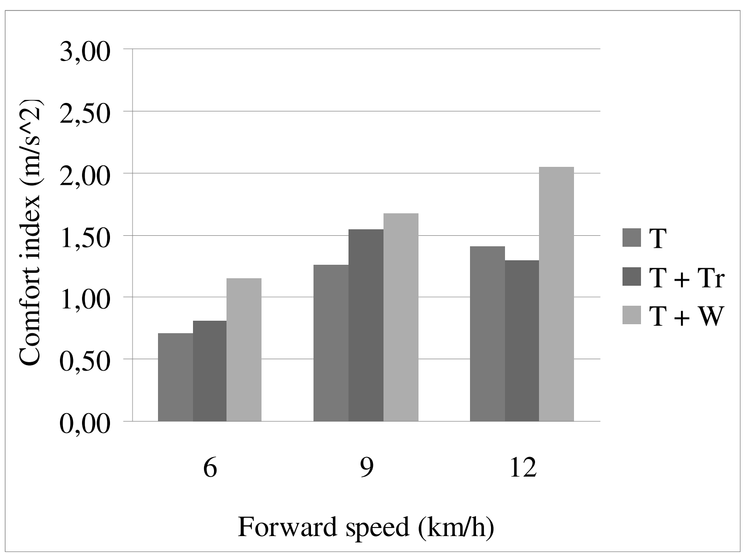

Figure 9. The comfort index of the X channel of the back during test on field

The same phenomena appears at the seat but the values are lower (fig. 10) .

The channel Y, not reported, has a sensible value only in test on field and at low speed and is not influenced from the convoy configuration.

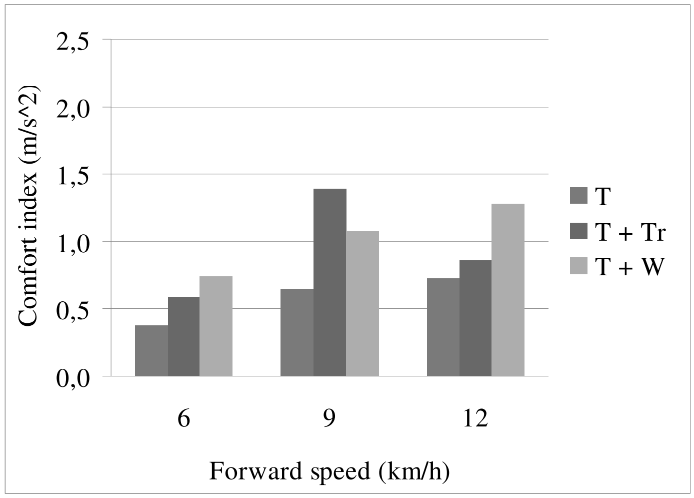

Figure 10. The comfort index of the X channel of the seat during test on field

Conclusions

This first approach has confirmed that trailers have a great influence on operator's comfort. Main factors are the resonance frequency of the trailer's tires and the effect on field on the longitudinal axis of the tractor.

Manufacturer in the last years have introduced several new technical solutions at the hitch to confirm the interest on this way to reduce the dynamic effects of trailers on tractor.

Acknowledgements

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Agricultural tires' behaviour during laboratory reproduction of lateral forces

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Abstract

The development of the EU legislation is carrying on to a growing interest in the behavior of agricultural tractors at high speed and in their comfort properties.

The lateral forces acting on a tractor characterize the tractor behavior in line-change tests, road transport with trailers or implements and the distribution of vibration for operator's comfort. To evaluate and to define the elastic lateral properties, in operational conditions, of agricultural tires the CRA-ING of Treviglio has carried out a first approach to simulate in laboratory the effect of lateral forces on an agricultural tractor.

This work aims to define a methodology, test conditions and apparatus for evaluating the lateral elastic constant of an agricultural tire during turnings.

A 4WD tractor fitted with different couple of rear tires has been used. The front axle of the tractor was picked up for having a null vertical reaction on the ground for not influencing test on the rear axle. A hydraulic cylinder was used for pulling laterally the tractor.

The tested tires have shown a curve constituted by two linear parts both characterised by a combination of the vertical stiffness, of the reaction to the torque of the roll and of the lateral stiffness. Tires were tested at 1.2 and 1.6 bar, this last setting has shown always, as expected, a greater elastic constant.

Future development of the project will take in account correlation with the response of the vehicle on test track.

Keywords: Agricultural tractor, handling, tire, lateral forces.

Foreword

The development of the EU legislation (1) is carrying on to a growing interest in the behaviour of agricultural tractors at high speed.

One of the most actual topic includes safety and comfort; these requirements ask to define the tractor behaviour both during testing (2) and in modelling (3).

The lateral forces acting on a tractor have a great influence on handling, comfort and safety. They characterise the tractor behaviour in line-change tests, road transport with trailers or implements and the distribution of vibration for operator's comfort. To evaluate and to define the elastic lateral properties, in operational conditions, of agricultural tires the CRA-ING of Treviglio has carried out a first approach to simulate in laboratory the effect of lateral forces on an agricultural tractor. In fact the agricultural tires must guarantee stability to the tractor also with heavy implements or trailers. The response to lateral force with high vertical loads is characterized from the mechanical properties of the tire. These last depend, above all, from carcass and belts features (fig.1).

The project, solicited by a tyres' manufacturer, is a first approach to correlate the elastic characteristics of the tires with the tractor behaviour. This work aims to define a methodology, test conditions and apparatus for evaluating the behavior of an agricultural tire.

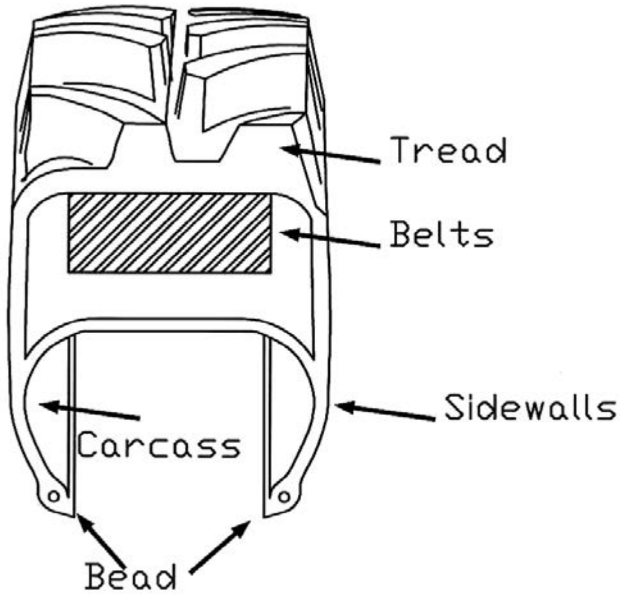

Figure 1. Main tire's components

Materials and methods

The methodology followed for this work was defined according with the manufacturer.

A 4WD tractor fitted with three different couple of rear tires different for design and construction but identical in overall dimensions has been used (fig.2). Two plates of iron were disposed under the tires for having a standard friction surface.

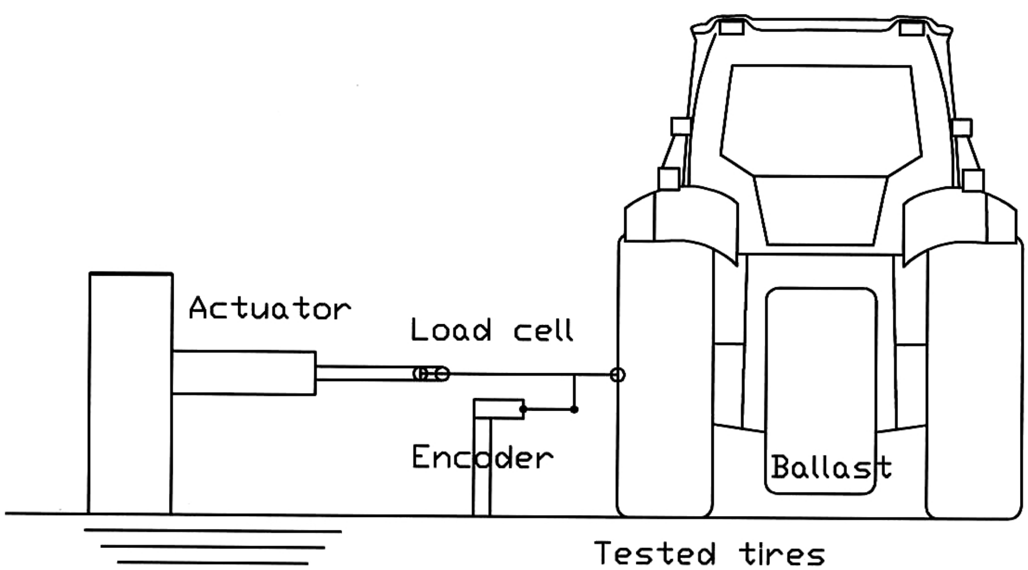

Figure 2. The testing plant

The front axle of the tractor was picked up by a crane for having a null vertical reaction on the ground for not influencing test on the rear axle that was adopting the tested tires.

The measure of the tested tires was 710/70R38. A hydraulic cylinder was used for pulling laterally the tractor. The point of hook for pulling was at the height of the rear axle. Test condition are listed in table 1.

Table 1. Test conditions

	Weight (kg)	
Agricultural tractor (ballasted for test)	Front	2140
	Rear	7900

Tests were replicated with tires inflated at 1.2 and at 1.6 bar. An instrumental chain based on a load cell and on a linear encoder, completed with a PC as data recorder, was used.

Results

The tested tires have shown a curve constituted by two linear part (fig. 3), both characterised by a combination of the vertical stiffness, of the reaction to the torque of the roll and of the lateral stiffness. The pulling force was initially divided among the two rear wheels, than almost all the reaction was of the external tire. For this reason, the tire initially react to compression and to lateral forces, than only to lateral. The consequence is that there's a first linear part characterising a greater elastic costant and a second part of lower value where the displacement increases faster.

The tires at 1.6 bar have showed a greater stiffness both to pure lateral and compression forces, so the first part of the resulted curve has always, in this case, greater costant values than the curve obtained at 1.2 bar. But the results are almost the same for great values of load, cause in this case the tire construction was more important than inflate pressure.

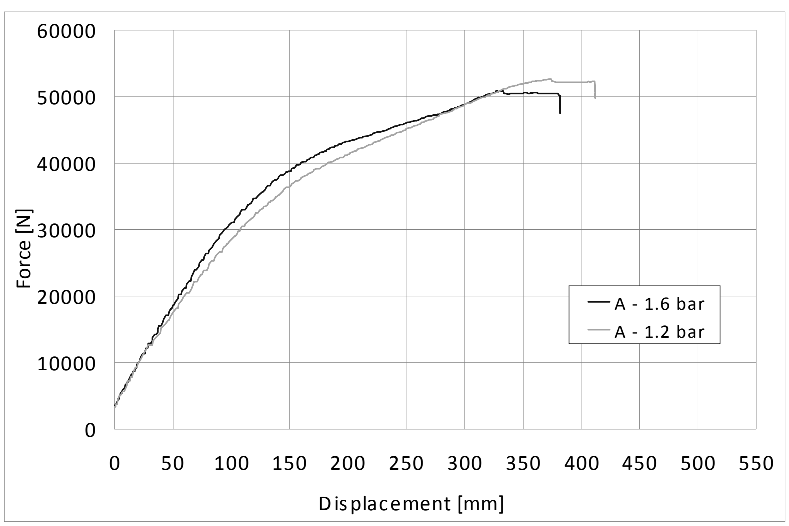

Figure 3. The elastic constant of the lateral stiffness of tire "A"

The tests carried on a tire of the same size but with different mechanical properties show that the lateral stiffness is very important in the first part of the curve characterising the response at medium and low loads (fig. 4).

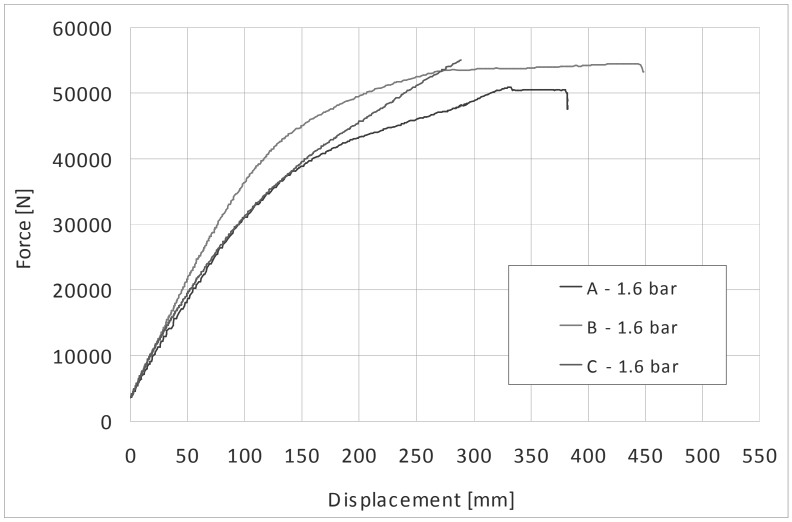

Figure 4. The elastic constant of tire "A" compared with tire "B" and "C"

Considering that on track, generally, lateral acceleration maximum values of 0,7 g, it can be assumed that all the curve trend could be of interest during turning, but the driver feedback response during handling test in a double lane change indicated that a greater stiffness of the first part of the curve and a low gradient in the second are the most important parameters.

In figure 5 are displayed the possible curve groups that could result from this type of test. The curve A indicates low lateral stiffness, probably due to the carcass influence that gradually becomes more rigid for tire B and C. The response at high loads has to be investigated (i. e. curve A) for defining the influence of the components, or their combination, of the tire.

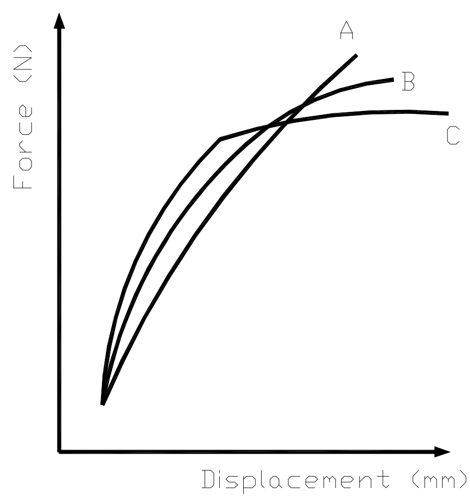

Figure 5. Theoretic trend of the possible curves

The optimum choice is obviously depending from the possible and main destination of use of the tractor.

Future development have to take in account and to quantify the influence of the single parts of the tire (above all carcass, belts and tread) on the tractor behaviour and to evaluate the correlation with the response of the vehicle on test track.

Conclusions

The behaviour of the rear tires of a tractor during turning has been reproduced in static conditions.

The experimental test has allowed obtaining immediately the response of the rear axle and then, of the vehicle, to lateral forces.

Three main groups of possible response have been identified, depending from the construction characteristic of the tires.

Next step of the project will be carrying on tests on test track that will allow to correlate tires properties with vehicle behaviour during tests as line change or double line change in order to a previsional evaluation of comfort and safety behaviour of the tractor trailer train.

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Safety management in zootechnical breeding

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Abstract
The aim of this study was to create a new model for the safety management, through the analysis of the risks and the economic appraisals for the improvement of working conditions The analysis and samples put in evidence the critical situation in the zoo-technical breeding. Numerous critical point in every workspace were found. Workers of this area have a great underestimation of the danger, and a lot of them often does not inform the employers on the real risks of job activity. This study put the bases for the characterisation of new methodologies and instruments in the safety area.

Keywords: stable, model, farm.

Introduction

Over the years from 1970 to 1980 the zootechnical field undergone to a deep transformation. If on one hand the number of farm workers has been reduced on the other side an intense industrialization, with the application of new technologies to different productive phases, has been established.

From statistics cow breeding result as the agricultural activity that alone records the 33% of all accidents at work. In animal farms milking rooms and areas dedicated to free animal stabulation are related with an high frequency of accidents (INAIL statistics, 1998-2000).

Technological innovations applied to animal farming led to a substantial improvement of work conditions but also to a modification and enlargement of some risk factors. This risks are often related to a modern work organization characterized from high fragmentation of processes, presence of repetitive tasks and use of numerous chemical substances. Employers use methods and tools that have been rapidly changed and renovated, furthermore shortage of labour, in some regional reality, has been led to the engagement of workers, coming from different countries, cultures and working environment, in numerous zootechnical productive processes. Information and prevention are key medium to avoid and reduce the most of accidents. The first action to perform is to assure a correct farm organization starting from planning time. In this phase is still possible to optimize productive options on the basis of normative bonds, especially about safety of farm labourers and animals. Considering the continuous technical and technological development in farming animals, farmers have to confront with a dynamic situation that includes fast transformations and changes in destination of pre-existing constructions. This aspect could raise to an increase of risk coefficients because old constructions like stables or barns often are not conformable to new methods and productive processes. From these considerations appears the necessity to adjust productive structures and plants on the basis of the specific production activity and processes. The aims of the study are in order:

- to produce a revised evaluation of farms safety;
- to underline critical aspects of farms considered in the study;
- to classify farms in accordance with specific standards of risk evaluation;
- to identify and employ tools useful for breeders in evaluating safety conditions within frameworks.

Materials and methods

The study has been developed in four steps:

1. A planning and cognitive phase concerning the creation of a farm list and a evaluation model to perform risk analysis;
2. An analytic phase to perform concretely risk analysis within farms;
3. A data elaboration phase fundamental to identify critical areas within each farm and each evaluation class;
4. An application phase to prepare a safety improvement plan.

The research has been performed considering four heterogeneous farm batches to have a global vision of the zootechnical sector (Table 1). In particular farms has been classified on the basis of production (milk and meat).

Table 1. Sample description

	farm 1	farm 2	farm 3	farm 4	farm 5
employees	5	7	7	1	1
production	milk	meat	meat	meat	meat
animals	1600	15	3459	500	1600
stables	4	1	6	1	1

Sampling has been performed in Friuli Venezia Giulia and Veneto region between October 2007 and January 2008. To complete the risk analysis a check-list, branched in macro-areas and topics, has been used. Check-list is a preparatory instrument to research and identify potential risk factors.

Table 2. Research areas

Research areas
Viability and access systems
Structures, deposits
wiring, other plants
tractors, agricultural machines, stables and equipments
veterinary products,
noise-vibrations
safety management , safety

For each check-list macroarea some indications has been reported to orientate the responsible of risk analysis. Each macroarea has been divided into subclasses that represented homogeneous areas of activity and risk. During risk analysis is also necessary to consider the severity and the frequency of accident by means of this formula:

RISK = magnitudo * frequency

Where magnitudo indicate the severity of the potential accident and frequency the number of a particular accident type in course of time. The score to be assigned during evaluation follow a scale from 1 to 9. Values of respective attributes, frequency of accident and assessment on each score, are reported in table 3.

Table 3. Judgement score used during risk analysis

Score	Frequency	assessment
1	low	insufficient risk
2	medium	insufficient risk
3	low	insufficient risk
4	lov	medium risk
5	medium	medium risk
6	medium	medium risk
7	high enough	important risk
8	high	remarcable risk
9	high	high risk

Results

<u>*Viability and access systems*</u>

About this category a substantially homogeneous situation was observable between farms and each unit reached a collocation of middle risk (Figure 1).

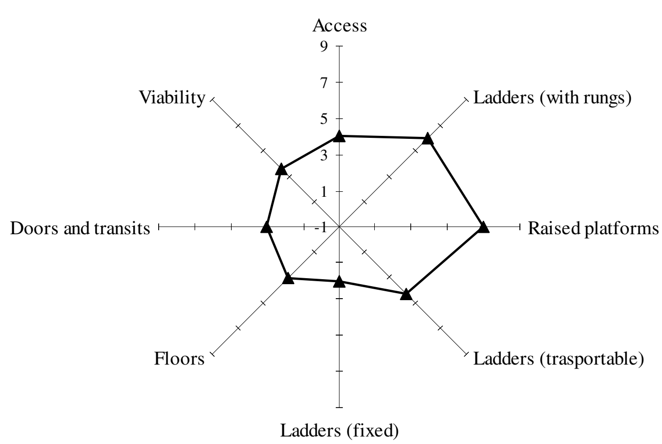

Figure 1. Risk representation of viability and access ways

All units obtained positive scores about dimensioning of farm building and entrance. Warning signage represented a critical aspect of this area and was lacking in all farms.

Buildings, productive structures and deposits

In Figure 2 is represented the considerable presence of dangerous situations pertinent to this area: a great part of units presented also an high risk score.

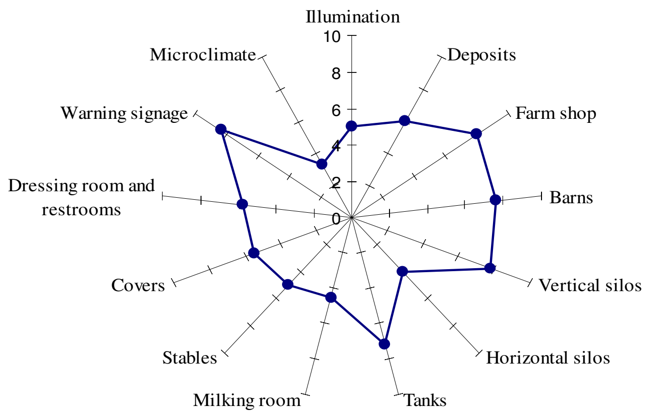

Figure 2. Risk representation of productive structures

Numerous deficiencies were observed relatively to silos and farm shops management, in particular were identified some dangerous elements not in according to the law.

Plants

This category presented an evaluated middle-high risk level. All farms were lacking of emergency illumination devices and were characterized from a real absence of technical systems servicing.

Machinery and works

The category "machinery and works" obtained a medium risk evaluation for all the sample.

Tractors, elements obviously common for all the farms, obtained evaluations near the limit of serious risk. A general lack have been observed in the servicing and use of the machines.

Chemical defence

The problems of this category showed a medium-high risk situation (Figure 3).

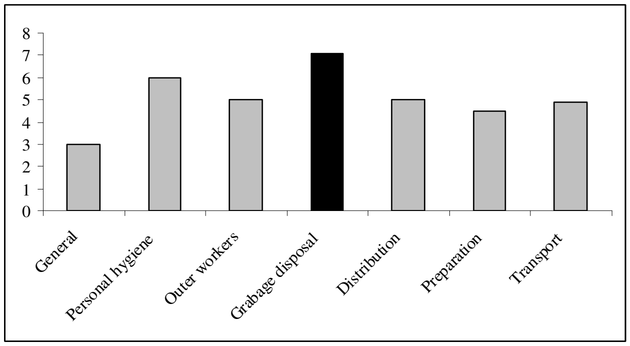

Figure 3. Risk distribution of use of chemical substances

A heavy negative evaluation was observed for the practice of throwing away the wastes (Figure 10). Farms does not perform differential collection, but frequently adopt the forbidden practice of burning the wastes produced. Also the personal hygiene has not received a positive evaluation.

Noise, vibration and asbestos

Heavy risk situation have been observed also in the category "noise, vibration and asbestos" (Figure 4). One of the reasons for a so negative evaluation is the general lacking of knowledge from the employers that have never measured the degree of danger in their farm.

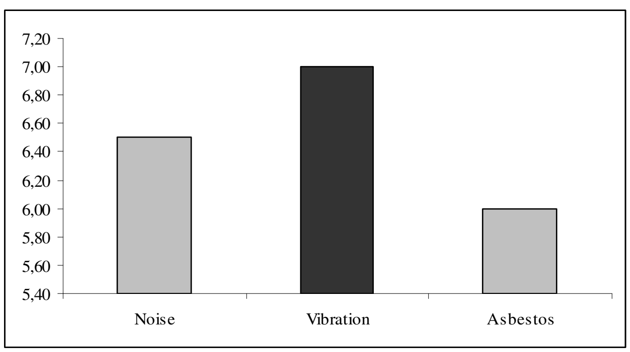

Figure 4. Risk distribution of noise-vibration-asbestos

Management

About management the situation is homogeneous for all the farms. There is only a case in which a low risk condition has been observed, while for the other four farms has been identified an high risk condition (Figure 5).

Farms 4 and 5 showed the higher values of risk, due to great lacking in work organisation.

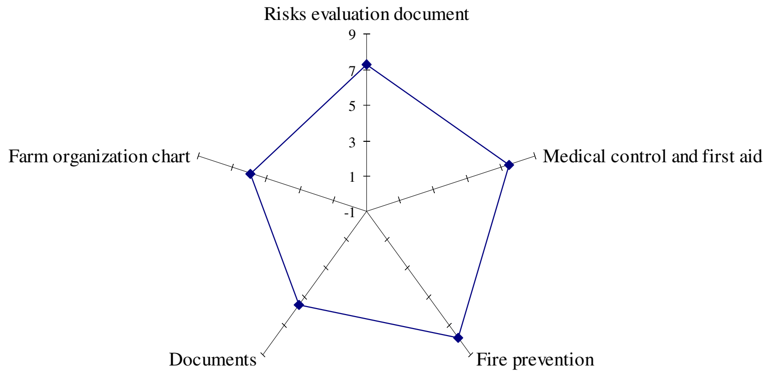

Figure 5. Risk representation of managerial area

Conclusions

Results have shown that the zootechnical area is an high risk field, both for the frequency and the severity of accidents. The areas that received the lowest security evaluation are:

- barns and garage;
- systems;
- machinery services;
- use of chemical defences;
- carelessness in the noise and vibration derived risks;
- farming management.

The lacking of a culture of ordinary services corresponds with a carelessness in the information and training of workers. A linear indirect correlation was observed between number of operators and the security evaluation of farms analysed (Figure 6).

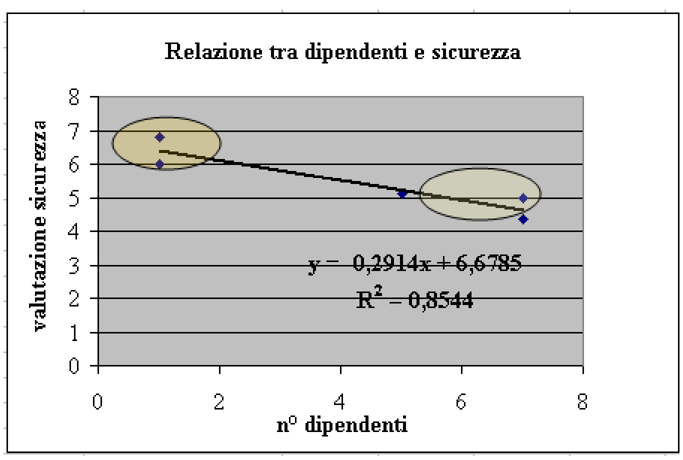

Figure 6. Linear indirect correlation between number of workers and security evaluation of farms

This distribution shows a decrease in the number of defaults with an increasing number of working people. The explanation of this trend could be the fact that there are still many farms with only one operator that often coincides with the owner occupier. In that case security becomes an optional, a not necessary investment.

In conclusion it becomes clear that the problem considered in this work is largely underevaluated. For these reasons it is necessary a greater divulgation of the matter by the media system.

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New methodologies to evaluate risks in the agricultural sector

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Abstract

The agricultural sector is characterized by a set of highly dynamic and diversified productive activities, in which the evaluation of the risks doesn't depend only on elements connected to all these activities, but also on external factors (climatic, biological, pathological, etc.) that during the analysis of the risk at the workplace necessarily have to be considered. So, increasingly emerges the demand to individualize a series of application tools that can facilitate the agricultural entrepreneur in the evaluation of the risks. The principal objectives of this job are the construction of a model of analysis of the risks *ad hoc* for the agricultural sector; the development of operational and managerial safety systems; the construction of prevention and protection measures for the workers of this sector. This research has been divided into four phases (cognitive; analytical; planning; operational). The agricultural entrepreneur underestimates the importance of a correct analysis of the risks and, besides not carrying out the formal obligations of law, he doesn't effect a correct business organization in terms of prevention and protection. Many critical points are emerged also in terms of the training of the workers: the seasonal labour (so diffused in agricultural) is often not trained on the specific risks of his work, and the firms often don't preserve the documentation about safety procedures, training manuals, etc. This research has brought to the construction of an analytical model for the situations of risk. The model has been developed identifying as priority the simplicity in the use and the versatility of the same model. This work wants to be the starting point for the identification of new guidelines to cope with the problem of the safety at the workplace in the agricultural context.

Keywords: safety, agricultural worker, safety management.

Introduction

The elements of risk and danger daily join the working life of the farmers: the agricultural sector is characterized by a high dynamism and diversified productive activities, in which the evaluation of the risks doesn't depend only on elements connected to all these activities, but also on external factors. As reported by OSHA (European Agency for Safety and Health at Work), over 10 million people work in agriculture in Europe. In addition to full time workers, there are many temporary and seasonal workers. Agriculture is a significant employer of women, and women are often on 'family farms'. Additionally, children are often present in the workplace.

Starting from the wine growing sector and arriving to the animal husbandry, all the agricultural workers have to transversally compare with mechanical, physic, chemical, biological risks. Every year the number of the accidents in which farmers are involved grows radically with an average, in the last years, of 1200 deaths. Along with the building sector, the agricultural one is the most dangerous and, despite recent improvements in Italian directives concerning safety at the workplace, records accidents with a high frequency index (INAIL, 2007).

Materials and methods

The objectives of this work are to identify some strategies for the reduction of the risks; to develop some new systems for the prevention and protection of the workers; to define some application models.

The whole search originates from the experience realized in the agricultural, wine growing and of animal husbandry sectors. Starting form the conviction (according to the OSHA precepts that must belong to everybody) that to protect workers' health and safety we may carry out a risk assessment, we have developed our work, for each sector, proceeding through these 4 steps:

a. Context Analysis
b. Evaluation Methods
c. Planning
d. Proposal of operating solutions

STEP 1: Analysis of the context

This analysis has been the starting point of the work and lead up to the development of the following elements of analysis: the characterization of the sampling and the analysis of risk conditions.

Table 1. Elements for the characterization of a firm

Characterization of the sampling
Firm Dimensions
Number of Workers
Address
Production Typology
Technological Level
Machinery
Buildings
Managerial and Organizational Structure
Specific Technical Areas
Storage
Animal husbandry: number of animals
Type of Production

The characterization of the sampling allows the individualization of a series of elements (table 2) in which subsequently develop the evaluation. These are descriptive elements identified depending on the typology and productive address of the firm and correlated to the potential risk deriving from a bad management. So we need to know where the workplace are located; who works there (distinguishing their typology: temporary, seasonal, foreigner and their number); what tasks are performed; what is the technological level; what machinery are used; the conditions of the buildings; the way the firm is organized, etc.

The analysis of the risk conditions (table 3) has allowed us to underline the elements (managerial, formal and substantial ones) external and internal at the business strategies, that determine some negative effects in the safety conditions, increasing the critical points in the working environment.

Table 2. Conditions of risk

Substantial Aspects	Managerial-Organizational and Behavioural Aspects	Formal Aspects
Insufficient mechanical equipment	Underestimate the danger	Lack of documentation
Scarce maintenance	Lack of organization in terms of Safety	Not formalized employments
Scarce predisposition to make investments	Impossibility to determine a business organization in terms of safety	Absence of formal managerial levels
Obsolescence of bulidings and plants	Familiar Management	Lack in training and information of the workers
Incorrect management of workers	Lack of organizational measures	

STEP 2: Evaluation methods used

Two lines of evaluation have been studied: an evaluation based on a quantitative model and an evaluation that use a qualitative one.

1) Evaluation with a quantitative model.

This method has been developed by using check lists specific for the context.

For each area of investigation, some sub-areas of analysis have been identified (Table 1) Then, by using the formula:

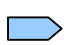
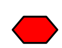
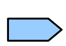
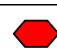
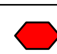
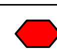
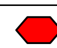
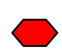
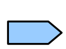
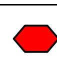
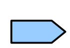
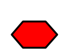
risk = frequency x gravity

The analysis of the context has been developed.

2) Evaluation with a qualitative model

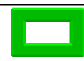
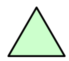
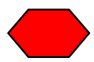
To each area of study we have associated a series of quantitative describers, able to give a visual image of the situation to the entrepreneur.

Table 3. Example of the application of the qualitative evaluation

Locations	Conformity to the destination of use	Hygienic-sanitary conditions	Order	Structures and equipments functionality	Safety operator
Viability					
Warehouse					
Offices					
Machinery store					

This method, from the scientific and analytical point of view, has only been used for managerial objectives: in such way, that the agricultural entrepreneur can easily have the business situation under control in real time.

Table 4. Symbols used for the qualitative evaluation

Good conditions	
Standard conditions	
Good enough conditions	
Not good enough conditions	
Grave anomaly	

<u>STEP 3: Planning</u>
In this step we have developed a series of measures of planning:

- Planning of spaces from the safety point of view
- Planning of interventions on agricultural machines
- Planning of interventions of training
- Redefinition of strategies for the management of the risk

<u>STEP 4: Proposal of working solution</u>
At the end of the three previous phases, we have defined some working solutions in the contexts and business reality with greater critical points. So, the following areas have been identified:

- Development of plans for the management of the risks
- Business plan for the strategic interventions
- Handbook business
- Formation plains

This methodology has been developed on a sample of 60 firms, belonging to heterogeneous economic sectors. Then, all the identified lacks have been analyzed in the analytical part.

Results

We can observe that there are some big problems in the management of the stores: in this context, the analysis have underlined numerous problems, both in the conditions of use and in the condition of exercise and use of the spaces, that are often obtained in not appropriate places.

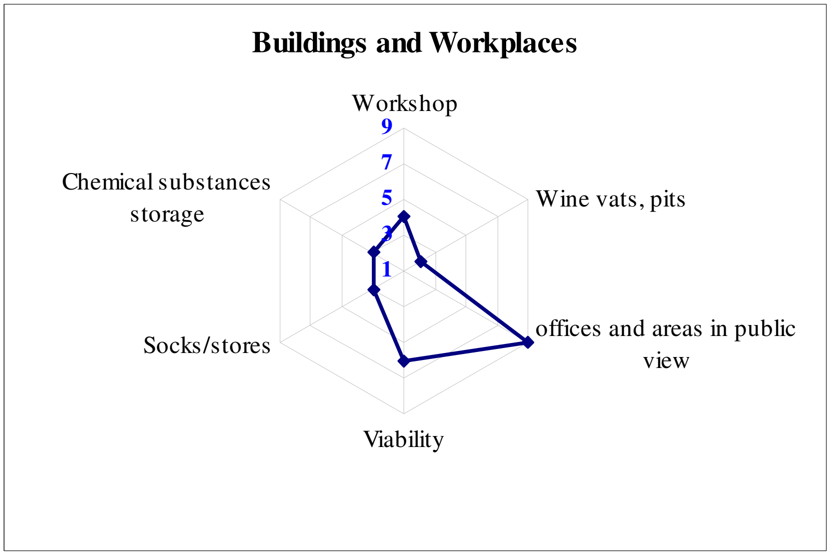


Figure 1. Greater critical points in the structural aspects of the analyzed sample

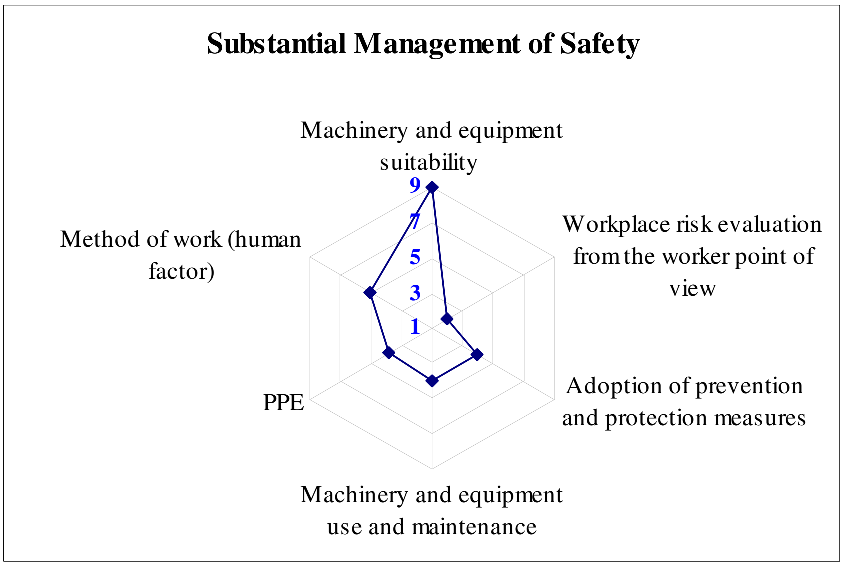


Figure 2. Risk evaluation considering the substantial aspects

Analysing these aspects that we have defined as the 'substantial' ones, we have noticed critical situations in the aspects of normal maintenance of the equipments and also there are incorrect behaviours in the work phases. In particular, there is a lack in the use of the personal protective equipments (PPE) also during the most hazardous activities.

Figure 3. Evaluation of the managerial and organizational aspects

In the firm management, the theme of the safety is hardly considered. This area of analysis is, in fact, the most problematical and many critical points have been individuated.
Safety is mostly lived inside the organizational and managerial context as an element of expending, not tied to the functional context of the firm. Only the certified firms and the one of great dimensions have slightly had some positive evaluations: we found a correlation between the safety levels and the number of busy people. A tool that reassumes all the procedures and best practices that should be developed inside a winery for the management of a tractor is represented in the following graph:

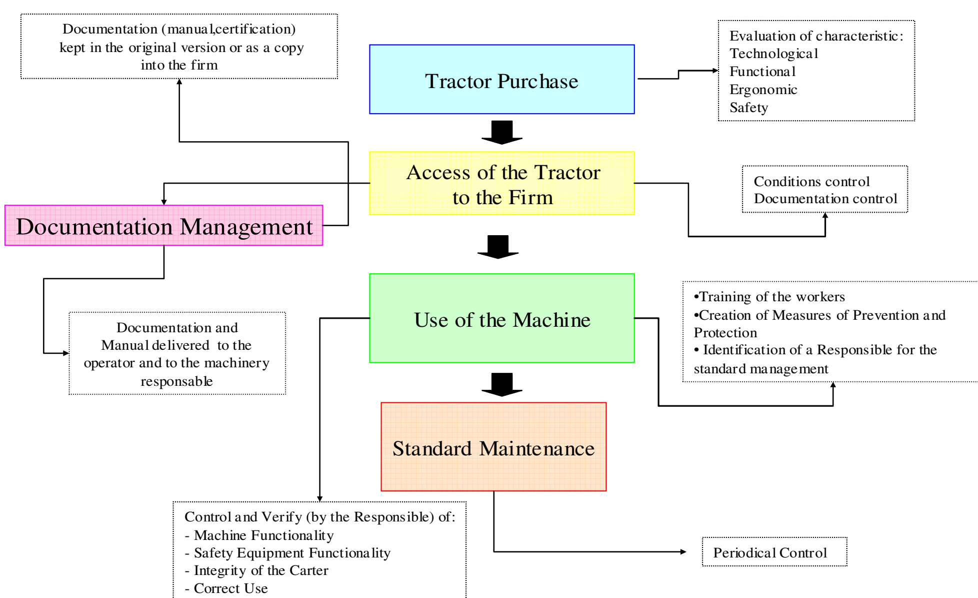


Figure 4. Example of management of the agricultural machines

Conclusions

We therefore need new methodological forms of risk evaluation (see for instance table 4) close to new strategies for the management of the organizational trials concerning the prevention and protection at workplace.

This work has underlined the critical situation of the firms in terms of management of the safety. This determines the necessity to sensitize the agricultural entrepreneur not only on the general aspects of the safety, but also on the aspects of the work organization and of fulfilments of the formal aspects. Resorting to simple mechanisms as the training and the information during the assumption of the temporary or seasonal, a virtuous mechanism that would allow the diminution of the accidents would be established. Besides, from the managerial point of view, the identification of some figures, that internally can make a punctual and constant control on the safety conditions, would be necessary for a correct management of safety levels, in order to make growing the culture of safety. These concepts are already applied in other sectors (agro-industrial, tertiary), while are not present in the agricultural one.

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Ageing workers and agricultural machineries: safety problems

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Abstract

Concerning the farm labour force, 14.7 million persons were working regularly on the 6.6 million agricultural holdings and actually more than half of the holders in EU-27 is older than 55 years. In Italy in 2003 the 40% of the agricultural holders were older than 65 years.
From the occupational safety and health point of view, agriculture has been recognized as one of the most hazardous occupations and in a context where an high percentage of all farm operators are 65 years of age or older, age becomes a serious factor when considering potential risk for injuries among this population.
The fatal injuries caused by machines for the class age >65 in Italy in the period 2000-2006 are the 34,3% of the total to demonstrate how more dangerous is the factor 'machine' for the aged farmers.
Among all the machines, the tractor is the main responsible of all the injuries type also for the older farmers: rollover accidents, collision accidents, striking stationary objects and being struck by moving tractors are a concern to agricultural workers in general and when the physiological responses and the body movements are slower as in the advanced age, many accident situations may become fatal.
Older farmers do often use old tractors, purchased 20-30 years ago, before the European Directives obliged manufacturers to adopt the basic safety requirements for tractors and agricultural machines. Because of their machines age, senior operators have less safety equipment installed on their tractors: they have fewer ROPS, emblems, working lights, power take-off (PTO) master shields, communication devices, and safety decals installed.

Keywords: ageing workers, agriculture, safety, injury.

Introduction

To correctly analyze the problem concerning old agricultural workers, it is important to clarify both the terms 'old workers' and the physical 'agricultural' context where these people work.

Although the current definition of "older" workers is 55-64 years of age, if the socio-economic or policy circumstances change in the near future, a re-definition of "older" worker may need to be expanded to include those 55-70 years of age, in order for the definition to accurately reflect the realities of "older workers" . This is the usual situation in agriculture, whereas it doesn't really exist a retirement age: unlike the rest of the population, farmers tend to remain in farming beyond the normal retirement age. It is not surprising to see farmers in their 70s still farming full time. In a survey conducted in Illinois, farmers in 13 regions were twice as likely to continue working beyond age of 65 as their cohorts in other jobs and the average age was 73 (Sofranko, 2000). Other researches in Kentucky and Iowa found that only farmers with severe physical limitations had completely retired from physical farm labour (Reed and Claunch, 1998).

The physical work environment is important for any worker in the workplace, but perhaps none more so than for older agricultural workers. It is known that normal and pathological changes affect the bones and muscles of older workers, thereby reducing their maximum physical performance. The consequences are particularly damaging for those workers whose jobs require sustained, concentrated, intense efforts (e.g. long periods of time stooping, bending, stretching or moving heavy materials as in agricultural and forestry works). Noise and vibrations also may not be well tolerated by older workers, and the combined effects of such poor physical conditions can be experienced in a multiplicative, rather than additive, manner by these workers. Concerning agriculture, another serious problem arises, that is the higher probability for older workers to be exposed to injuries, more often fatal, because these workers continue often to perform the same tasks they performed in the past, without taking into account that their physical attitudes are limited and they often use obsolete machineries. Concerning the tractor accidents, the major risks are due to transversal and longitudinal roll-over, caused by an excessive load (both mounted and trailed implement), by sudden machine movements and by high soil slope. The Italian law with the D.Lgs. 359/99 obliges to adequate work tools at the minimum safety level requirements (and the point 1.3 of the attached XV underlines the necessity to limit the risks of machine roll-over using the ROPS – Roll Over Protection Structure and the safety belts). Moreover, the D.P.R. 459/96 obliges manufacturers to sell operating machines with the safety devices installed and tested, but more than one million operating working machines in agriculture are more than 12 years old and these machines are more present in farms where holders are not so young.

<u>*Old farmers in Europe*</u>

Considering the farm holder as the natural or legal person responsible for the farm, in 2003 about 5 million of agricultural holdings were operating in EU-15, almost half a million less then in 1999/2000 (Eurostat, 2004). In the new Member States the number of agricultural holdings was 1.5 million with a similar downwards trend.

The greatest number of agricultural holdings is found in Italy, where in 2003 about 1,426,000 holdings were counted: different is the situation concerning the agricultural area, which is largest in France (about 28 millions of hectare), Spain and Germany. With its 12,676,000 ha of agricultural area, the agricultural area per holding in Italy is about 8.9 ha, one of the lowest value in the EU-25, where the average agricultural area per holding is around 20-40 ha.

The latest farm structure survey results, for 2003, indicate that the majority of European holdings are still relatively small in size, with 45% of all holdings using less than 5 hectares of agricultural area. The highest shares, in the total number of holdings, of holdings smaller than 5 ha, is found in Malta (97%) and in Cyprus (80%), followed by Greece (70%), Italy and Portugal (both 69%).

Concerning the farm labour force, 14.7 million persons were working regularly on the 6.6 million agricultural holdings and actually more than half of the holders in EU-27 is older than 55 years. In Italy in 2003 the 40% of the agricultural holders were older than 65 years.

While a larger share of older operators has long characterized European agriculture, there is evidence that the number of younger persons entering in farming is decreasing.

Moreover, in both the old and the new Member States the age structure of the holders, according to the farm size, is similar: the share of holders older than 65 decreasing with an increase in the economic size of the holdings. As showed in figure 1, an high number of old farmers works in farms with a low income and normally these are also little farms, with a low agricultural area. In this context also the agricultural machinery is poor, obsolete (it is normal to find in little farms tractors older than 30 years) and often in a bad maintenance situation, without the simplest protection tools.

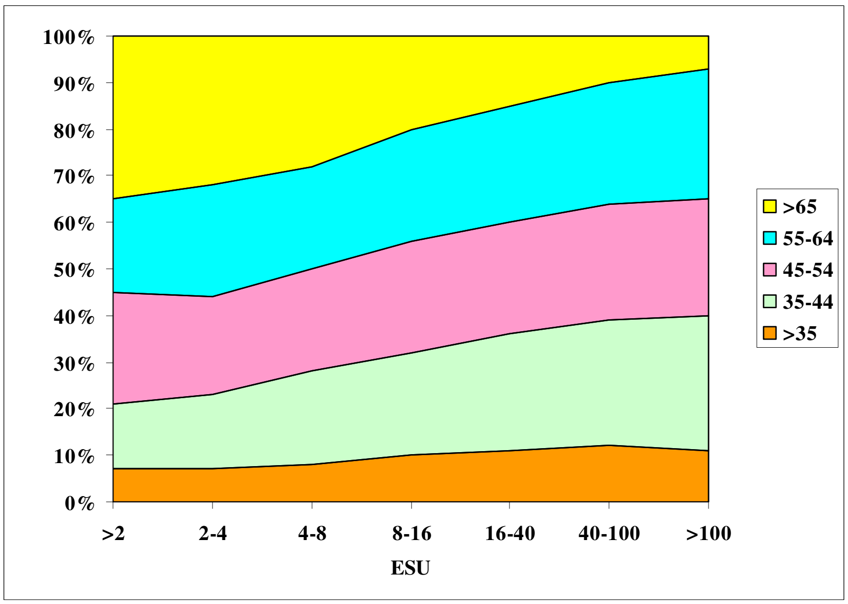

Figure 1. Age structure of agricultural holders by ESU (European Size Unit: 1 ESU is equal to 1200 euro of standard gross margin)

Materials and methods

In order to understand the actual safety situation for aged farmers, the recent literature has been referred and both European and Italian Agricultural data and Health and Safety data bases have been analyzed. Moreover, concerning old agricultural machines, the European and Italian laws have been analysed.

Results

The problem of the old farmers' risks in the agricultural works: the machine factor

Agriculture has been recognized as one of the most hazardous occupations and in a context where an high percentage of all farm operators are 65 years of age or older, age becomes a serious factor when considering potential risk for injuries among this population. Because no mandatory retirement age exists for older farmers, many of them may continue to perform some tasks beyond their ability to safely accomplish their work. Unlike the rest of the population, farmers tend to remain in farming beyond the normal retirement age.

For this reason, farmers routinely work beyond the standard retirement age and frequently farm to an advanced age. As self-employed workers, farmers can continue to farm - often at a reduced scale – after reaching the age at which wage and salary earners have retired. Thus, at a time of physical diminishment, older farmers face increased vulnerability to injuries and illness and may continue to perform tasks beyond their ability to safely accomplish the work.

Older farmers have been said to be a special population that needs recognition and attention. However, with few exceptions, older farmers, to date, have been largely underrepresented in research efforts related to farm health and safety.

In Italy, considering the INAIL data for the period 2004-2006 (figure 2) it is possible to see the accidents rate in agriculture grouped by class age, where the class >50 reports the 40% of the total declared injuries and the workers older than 65 are 9%.

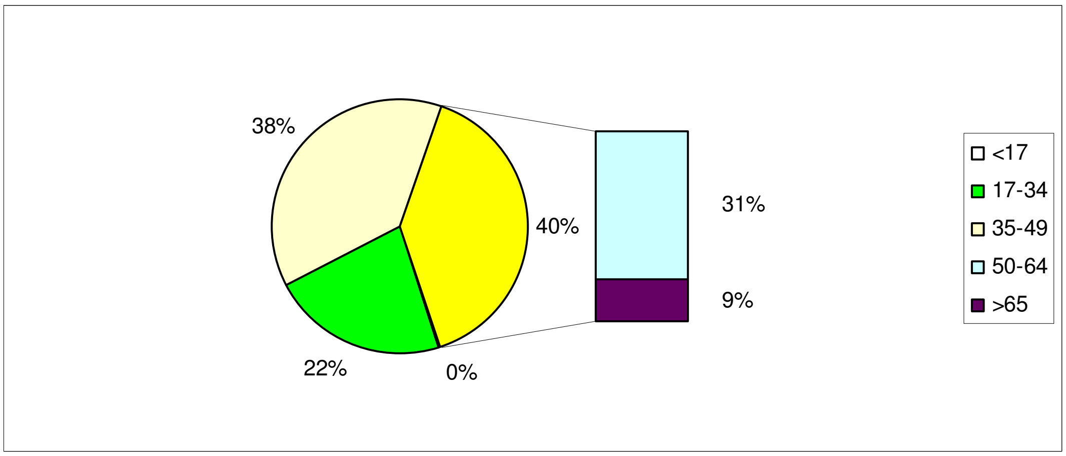

Figure 2. Distribution of the injuries declared in the agricultural sector in Italy in the period 2004-2006 by age groups (source: INAIL)

From a general point of view, in agriculture it does not seem that older workers are more exposed to risks than the others, but the situation changes if fatal injuries are considered.

In Great Britain, the Health and Safety Executive in 2005 (HSE, 2005) reported the fatal injury distribution as represented in the figure 3, where it is evident the high percentage of fatal accidents occurred to the older farmers. In another survey of the HSE, concerning the period 1996-2006, the three main causes of fatal injuries to workers in the agricultural sector over these years were detected:

- transport - being struck by a moving vehicle (25%);
- falls from a height (17%);
- struck by moving or falling objects (16%).

At the end, from the HSE surveys, it comes out that older farmers are more exposed to fatal injuries and the 'machine' factor is quite high.

In Italy, INAIL (Istituto NAzionale Infortuni sul Lavoro) data concerning injuries in agriculture demonstrate that the tractor is the unique responsible of 10% of injuries and it is the 35% cause of fatal injuries. The injury cause represented by machines amount to the 17% of the total and the tractor is the second cause after the soil.

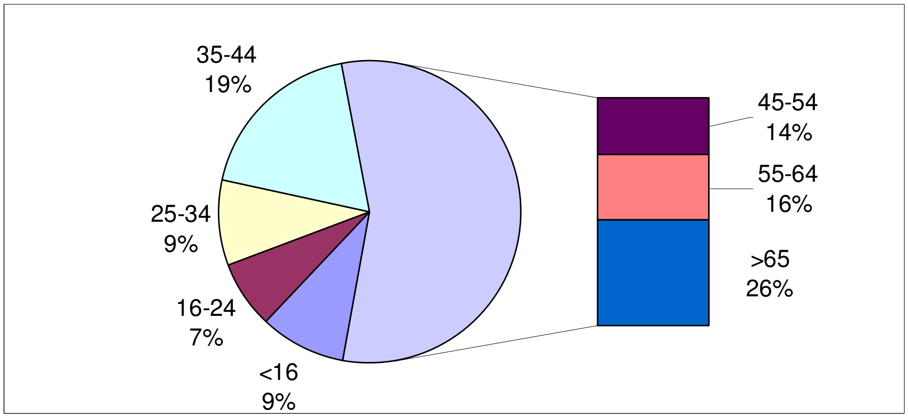

Figure 3. Fatal injuries rates in Great Britain by age groups in 2005 (source: HSE)

Using the ISPESL (Istituto Superiore per la Prevenzione E la Sicurezza del Lavoro) data base, it is then been possible to analyze the situation in Italy for the period 2000-2006, concerning the fatal injures caused by machines in agriculture, by age class (figure 4).

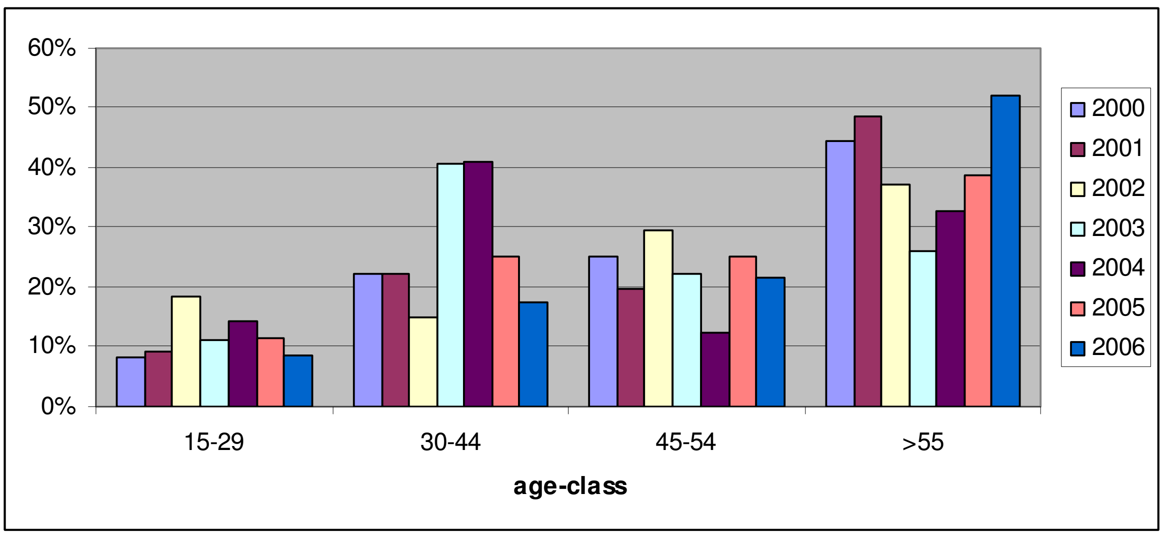

Figure 4. Fatal injuries caused by machines in agriculture in the period 2000-2206 in Italy by age group

The highest incident rate is represented by the age older than 55 and this trend is increasing in the last years (starting from 2003): only in 2006 the number of fatal injuries caused by machines for this class of age has been the highest respect the sum of all the others (52% of the total).

Considering the class >65, it is then possible to compare the fatal injures caused by machines for this class age with the class >55 (table 1): also in this case in the last years (2005 and 2006) the number of injuries for the oldest workers increased.

Table 1. Fatal injuries caused by machines in agriculture in the period 2000-2006 in Italy for the >55 and >65 class age

	2000	2001	2002	2003	2004	2005	2006
>55	48	37	10	7	16	17	12
>65	23	10	3	4	4	9	7

The fatal injuries caused by machines for the class age >65 in the period 2000-2006 are the 34,3% of the total (60 fatal injures caused by machines with a total of 175) to demonstrate how more dangerous is the factor 'machine' for the older workers also in Italy.

Among all the machines, the tractor is the main responsible of all the injuries type also for the older farmers: rollover accidents, collision accidents, striking stationary objects and being struck by moving tractors are a concern to agricultural workers in general and when the physiological responses and the body movements are slower as in the advanced age, many accident situations may become fatal.

From the American literature, in the last 10-15 years one in nine farmers aged 55 and older had been involved in a tractor rollover (Janicak, 2000). In Pennsylvania more than 40% of farm fatalities at the end of nineties involved victims 65 years of age or older and two-thirds of farm fatalities involving farmers older than 65 were tractor related, with a large majority involving an overturn. One Canadian study, addressing work-related mortality in older farmers, found that older farmers died while performing tasks common to general farm work, that most were owner-operators, and that many were working alone at the time of death (Hernandez-Peck, 2001). Focus group research in Kentucky and Iowa (Reed, 1998) found that "only farmers with severe physical limitations had completely retired from physical farm labour." Tasks involving heavy lifting, climbing, and repetitive motion cease when physical limitations precluded their completion without excessive pain and machinery assisted work, especially tractor driving, continued.

There are a number of conditions frequently associated with age (i.e., arthritis, limited vision and hearing, depression) that potentially make the demands of daily farming extremely dangerous for the older farmer. Nonetheless, in many situations older farmers have been described as unwilling to recognize or accept their physical limitations (Whitman and Field, 1995).

Risk evaluation for old farmers in the tractor use

Also if older farmers may use their experience, competence to judge, sense of responsibility and steadiness, on the other hand they must face with the decrease of muscle strength, sight, speed of perception and hearing, all conditions which may become fatal in some circumstances. The most dangerous situation during the tractor driving are: loose of control and of front adhesion, wheelie, lateral skidding, lateral overturning, rolling. As a consequence, operator damages are due to tractor falling, crushing, collision with external obstacles, collision with the tractor structure. Responsible key points of the injuries are the tractor characteristic, the soil condition, the way the machine is driven, the operating connected machine characteristic and the work to be done.

The tractor overturning risk is one of the most dangerous one and it may be caused by many environmental factors, such as soil slope and soil sinking, but also by human factors as wrong operating machines connection, unbalanced charge, high speeds, especially in turns and over sloped soils. The previous circumstances become worst if the tractor is not in a good maintenance condition or if changes are made to the machine, such as mass distribution modification or protective equipment elimination (because: ' ... they slow the working activities').

Older farmers do often use old tractors, purchased 20-30 years ago, before the European Directives obliged manufacturers to adopt the basic safety requirements for tractors and agricultural machines. In a Finnish study, of the overturned tractors, 84% did not have a safety cab and in cases evidence demonstrated that a safety cab or simply a ROPS with a seatbelt could have saved the victim's life (Rissanen and Taatola, 2003).

Unfortunately, the implementation of safety procedures and the installation, use, and maintenance of protective equipment over old agricultural machines is generally a matter of individual choice for the majority of farmers. Because of their machines age, senior operators have less safety equipment installed on their tractors: they have fewer ROPS, emblems, working lights, power take-off (PTO) master shields, communication devices, and safety decals installed.

Also if perceived risk levels are highest among the senior farmers, however, tractor-related hazards such as riding on the tractor drawbar and operating without ROPS are considered by many old farmers as a moderate risks (Whitman and Field, 1995). Another question is the economic factor: in an American survey, though a large percentage of the senior respondents (88%) considered ROPS to be effective in preventing serious injuries and fatalities from tractor overturns, only 26% expressed the belief that the safety benefits of ROPS outweighed the costs of installing the device (Whitman and Field, 1994).

Moreover, another important tool is the seat belts, which protects the driver not only when the tractor overturns (restraining the driver within the survival volume), but also when it is involved in a head-on collision on the road (Molari and Rondelli, 2007).

In this situation, whereas there is a deficiency of the basic safety devices, is quite unrealistic to propose electronic control for the machine stability: electronic systems are important tools at the condition that basic safety supports are guaranteed. In this last case, may electronic support senior farmers' work? The switch from 'mechanic' to 'electronic' does not seem to be appreciated by aged workers, unless they were used to electronic devices when they were younger: it is not simple to assign to a 'cable' a work perceived as human driven for an entire life. Moreover, focusing on the reasons that aged farmers continue to engage in physical farm labours, it was found that they first relinquished mental tasks, such as computerized records and design of new farm programs (Reed, 1998).

Another aspect which must not be undervalued for the senior worker is the access system to the driving seat: because the injury 'fall from the height' is present in the 27% of the injury causes in agriculture, it is important to guarantee a safety access to the driving seat of the tractor. The stair must not be too much high from the soil, handholds must be present and the stairs must prevent the risk of slipping.

Conclusions

Senior farmers, like most agricultural workers, are at risk of sustaining serious tractor and machinery-related injuries. Aged operators, however, may be at additional risk due to normal physical and sensory deficits associated with aging. Evidence also indicates older farmers often do not recognize, or do not acknowledge, that they are susceptible to serious injury (Ambe and Murphy, 1995). A review of agricultural safety programming reveals that relatively few resources target the older farm population. A need exists for intervention efforts geared toward enhancing awareness of tractor and machinery-related hazards, fostering positive attitudes concerning injury prevention strategies, and encouraging safer work practices among senior farmers.

Guidelines free downloadable by Internet are nowadays available in Italy (for example at the ISPESL website) to adapt old machines and old tractors with the elementary safety devices: engineering approaches such as ROPS, seatbelts and slow-moving vehicle signs can be effective in rollover, fall-off and rear-end accidents. But engineering interventions can not entirely eliminate machine-related hazards, particularly if there is no enforcement of their use: the challenge posed to agricultural safety professionals, therefore, is to develop injury intervention programs that more effectively encourage and reinforce the voluntary adoption of safe work behaviours and practices among farmers, especially using the intervention of other farmers who can witness the safety devices effectiveness (Witte et al., 1993). Thirty-five years ago, Simonds (Simonds, 1973) wrote:

> "The mass media can be effective in giving individuals correct knowledge, but personal contacts, especially those that reach individuals in small groups, help actualize the next step by providing the setting and stimulation for individuals to change old health practices or to adopt new ones. Believing that the mass media alone can do the job...is very unrealistic and simplistic..."

The economic aspect is also important: it is true that aged farmers who work in little farms have less economic chances, for example to buy new machines, but the cost to make a tractor safer, for example, with a ROPS, a new seat with seat belt, suitable access systems, PTO and hot surfaces protection, is not too high (1800 euros as average estimation), an amount a lot inferior at the human life value.

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Implication of periodical inspections of sprayers already in use on work safety

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Abstract

Periodical testing and inspections of sprayers are considered an essential tool in reduction and correct use of plant protection products. Therefore in many European countries, as well as in some Italian regions, these tests are compulsory. The tests are carried out according to standard methodologies, where the machinery safety is not directly included in the inspection. The aim of the paper is to stress which points of testing methodology are directly or indirectly related to the operator safety and which points are susceptible to be modified or implemented in the methodology in order to enhance the safety of spraying for the farmer. After both an analytical analysis of the methodology and the potential risks of spraying for the farmer, some suggestions are given in the paper in order to better clarify this issue and a proposal of integration of periodical inspections with safety control of the machinery is given.

Keywords: plant protection products, periodical inspections, testing, spraying safety, standards.

Introduction

The controls and inspections of agricultural sprayers are developed for different purposes. They occur at different steps in the life-cycle of the machinery. In general a number of ISO standards for the testing of sprayers are available, which all contribute to a high level of state of the art of sprayers. An excellent review of standards related to pesticide application is given by Herbst and Ganzelmeier (2002). At a national level, for example, the aim of voluntary certification of a new sprayers is to test the functionality and the performance of a given model sprayer (according to the European standards EN 12761) and also to check the respect of safety rules (Italian laws: Dpr 459/96, Dlgs 359/99 and Dlgs 626/94). During the life of the machinery, a periodical control should be required in order to verify if different parts and features of the individual machinery are still in adequate conditions to achieve better application of plant protection products (Gil, 2007; Biocca, 2007). The tests are carried out according to standard methodologies, where the machinery safety is not directly integrated in the inspection. In fact, as stated in the EN 13790:1-2 (EN, 2003) and in the Enama Documents n° 6-7-8a (Balsari *et al.*, 2007), the scope of the inspections is related to reduce environmental risks, to achieve a good application of plant protection products and to reduce the hazards for the test operator.

With the objective of improving the safety use of plant protection products, in July 2002 the Commission of EU established a new Thematic Strategy on the Sustainable Use of Pesticides. Ultimately, the proposed measures (that include the certification of the new equipment to be placed on the market and "a regular and compulsory inspection of application equipments") are contained in a forthcoming Framework Directive (European Commission, 2007). Therefore, in the next future the inspection of sprayer in use will be organized on a regular and extensive programme in each member state.

Nevertheless, the sprayer safety should be maintained and assured in the entire life-cycle of the machinery and the periodical inspections can represent the event to check the maintenance of safety rules and standards (EN 907, 1997).

The aim of the paper is to check which points of testing methodology are directly or indirectly related to operator's safety and which points are susceptible to be modified or implemented in the methodology in order to enhance the safety of spraying for the farmer. Consequently an integration of periodical inspections with safety controls of the machinery may be implemented. Furthermore, since the methodology requires that the sprayer's owner should be present at the inspection, there is the opportunity to advice and train the farmer about the safe use of the machinery.

Test methodology and potential revisions

The use of pesticides in agriculture introduces hazards and health risks to personnel involved in handling and application tasks. The main hazard to operator health is direct chemical exposure, particularly during mixing and loading. Both engineering controls (induction bowls, closed transfer systems, etc.) and personal protective equipment reduce exposure to pesticide. The other hazards related to spraying work are related to the general machinery use. They are included in the general requirements standards of agricultural machinery (EN-ISO, 2005).

At the present, the documents Enama n° 6 (field crop sprayers) and n° 7 (orchard sprayers) are considered as the reference methodology at national level for the testing of sprayers already in use. The following points of the methodology are directly or indirectly related to the safety.

Enama documents reference		Parts and functions considered
N° 6	N° 7	
1	1	Power transmission parts
-	2	Blower
2.4	3.4	Pressure safety valve
3.1	4.1	Spray liquid tank (leakages and closure)
3.2	5	Chemical introduction container
4	4.1	Cleaning device for products containers
5.1	6.1	Visibility of measuring and controls systems
5.2	6.2	Manometer position and scale
6	7	Pipes and hoses
8.1	-	Boom: stability, locking device, reliability of height adjustments
9.2	9.2	Nozzle dripping

According EN 907, the following points are recommended as controls related to sprayer's safety to be implemented in the test methodology, in order to carry out a test including all the work safety aspects.

The main requirements are as follows:

- Stability of the machinery on an incline of at least 8.5° in any direction.
- Spray boom:
    - if at front, cab required;
    - maximum height at folding/unfolding: 4 m.

- Spray tank:
  - filling hole not more than 1500 mm from ground and 300 mm from tank rim;
  - at least 5 % oversize;
  - no operator contamination in case of leakage.
- Hoses and pipes:
  - if cab, no hoses in the cab allowed;
  - if no cab, hoses shall be covered;
  - marked with allowed pressure.
- Clean water tank with at least 15 l.
- Instruction handbook required.
- Presence of safety and instructional signs.

Conclusion

The extension and diffusion of periodical inspection of sprayers will be common in the next future according to the incoming European directive, that assumes that in all member states will be a “regular and compulsory inspection of application equipments”. In this context may be useful to take advantage to implement a safety test of machineries during periodical inspections, related both to the respect of safety rules and farmer’s training and information. This can be achieved implementing in the compulsory inspection of sprayers already in use a little number of further tests strictly related to the work safety.

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A Survey of Safety Aspects Concerning Horticultural Farm Machinery

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Abstract
In Italy, one farm machine out every three is obsolete under some points of view and certainly as concerning safety aspects. In the south – east of Sicily carrots and potatoes are the most spread cultivations. To cultivate them are used some machines and some of them are used only for these crops. Here we show the results of a survey concerning machineries used in a representative sample of farms under aspects connected with safety and with the correspondence to the currents regulations.

The survey has involved a sample made up from representative farm sited in the south east of Sicily. We visit them with the aim to enhance the machinery that made up the fleet, the age, their characteristics, the maintenance, the characteristics of the shelter or of the garage, and finally to identify modification carried out to the machines.

Many of the examined machines are without bonnets and or chain guard, or they are not in good conditions. It appears that workers and often the employers and consequently the management are not greatly involved in safety aspects. To make adjustment to machineries and to form and to motivate workers are all activities that employers often consider as additional costs. A news survey is in progress with the aim to update the here shown results (that refers to 2005-2006), because we believe that a great awareness is spreading rapidly among the farmers concerning safety aspects.

Key words
D.P.R. 459/96, safety regulation, carrot, potato

1. Objectives

In Italy the agricultural sector is in second place as regards accidents, just after the building industry. There are many reasons for this but it can be said that human error is often the cause. Carelessness, non-observance of safety regulations, progressive aging of the operators, poor technical training of employers and operators and lack of maintenance of safety devices are the main causes of accidents in agriculture. To these can be added the fact that many of the machines used daily in the fields were designed for completely different purposes or are now obsolete.

In fact in agriculture many accidents involve agricultural machinery. Of about one million, seven hundred and eighty thousand registered machines, at least five hundred thousand do not have the requisites to be in circulation and thus endanger the safety of the operators and others. This data is quite shocking in that it means that about one machine out of three of those used daily in the fields is obsolete and, no longer having the necessary requisites for use, should be taken out of circulation.

In the province of Ragusa the most widespread crops grown in open field are carrots and potatoes and both these crops are cultivated with machines generally used also for other crops, machines that can be considered typical (such as the banking machines) and specific machines like those used for harvesting.

This work presents the results of a survey carried out of the machines used on highly specialised farms cultivating carrots and potatoes and assesses the state of the machines also with regard to current safety regulations.

2. Methodology

Farms with a significant area and specialised in the cultivation of potatoes and carrots were identified. Where possible farms also marketing their products were chosen. With the assistance of technical personnel the machinery was inspected on the spot in order to identify the machines present and their condition as regards safety regulations.

For each operating machine data was collected relating to the make, model and date of appearance on the market. The data collected also included the presence of an identification label and safety pictograms, the condition of the hydraulic ducts and the general condition of the machines with regard to the varnishing of the body, the trailer hook and the three point attachment hook structure. The state of wear and any evident crack and/or deformation were noted.

In the case of mechanical transmission, the survey also considered the condition of the PTO protection and. the presence or absence of protection casing and any modifications. As regards operating machines marketed for the first time after D.P.R. 459/96 came into force, the presence or absence of the EC labels and instruction and maintenance manuals required by said D.P.R. was recorded.

The machines considered were divided into those "activated" and "not activated" from the Power Takeoff (PTO). Finally, the double cardan joints connected to the machines were examined.

3. Results e discussion

3.1 Sample Composition

The survey was carried out on a sample of ten farms in the province of Ragusa (Tab. 1), with a surface area of between 14 and 1200 ha.

Table 1. Sample farms

Farm	Farm area (ha)	Carrots (ha)	Potatoes (ha)	Garage or Shelter	Farm Service department	Packing House
A	500	150	270	Yes	Yes	Yes
B	400	50	35	Yes	Yes	No
C	15	4	9	Yes	No	No
D	100	25	25	No	No	Yes
E	65	10	10	Yes	No	Yes
F	1200	120	250	Yes	Yes	Yes
G	14	-	14	No	No	No
H	150	50	50	No	Yes	Yes
I	56	10	15	Yes	Yes	Yes
L	320	110	10	Yes	No	Yes

In all 87 operating machines (56 of which were activated from the PTO) habitually used in the cultivation of potatoes and carrots were examined.

As can be seen from the table, in the sample there are farms of various sizes. They have commercial contacts abroad and in seven cases packing facilities. Even the smallest have a lively business: one operates for third parties and this implies even greater attention towards choice, maintenance and efficiency of machinery. Most of the farms have workshops and personnel qualified to carry out maintenance work and often also to make important modifications.

3.2 State of machinery

The operating machines not powered from the PTO include ploughshares, disc ploughs, tillers. Disc harrows were not found although they are widely used elsewhere. Potato planting machines were included in this group, in which the planting device is powered by a supporting wheel. Of the 31 machines examined, 18 were found to have been marketed for the first time before D.P.R. 459/96 came into force (tab. 2).

All the ploughs, tillers and scarifiers were found to lack instruction and maintenance manuals.

In most cases, where there were broken and worn parts these had been replaced. The oldest machines had been re-varnished and their body structure had been reinforced. Such modifications, combined with the re-varnishing, in general made it impossible to see the make or model of the machine.

As regards the two potato planters marketed for the first time before D.P.R. 459/96 came into force, neither had an EC label, instruction or maintenance manual, identification label, or safety pictograms. In both, the transmission parts were protected and both had been modified with reinforcement of the structure, the addition of microgranulators, an increase in the hopper capacity and posterior footboards to facilitate loading.

Table 2. Machines not powered from the PTO

Machines examined	D.P.R. 459/96 Tot/Before/After	EC labelling	Manual	Label	Pictograms
Ploughs	6/3/3	6	0	2	0
Disc ploughs	4/3/1	1	0	1	0
Tillers	9/5/4	1	0	2	1
Heavy tillers	4/1/3	1	0	0	2
Potato planters	8/6/2	0	0	0	0
Totals	31/18/13	9	0	4	3

Of the operating machines powered from the PTO, 57% were found to have been put on the market for the first time after D.P.R. 459/96 came into force. As well as the parameters examined for the previous sample, the protection of the PTO was also considered – the presence or absence of carters or protective covering and the presence of modifications. The results for each type of machine are presented in the following table.

As regards the machines powered from the PTO, the four rototiller marketed after DPR 459/96 all had EC labelling, instruction manuals, identification labels, safety pictograms, power plug protection and intact cases. None of them had been modified.

Table 3. Machines powered from the PTO shaft

Machines examined	**D.P.R. 459/96 Tot/before/After**	**EC labelling Before/After**	**Manual**	**Label**
Diggers	10/6/4	1-4	1-4	1-4
Centrifugal spreaders	6/3/3	0-3	0-3	0-3
Seeders	5/1/4	1-4	1-4	1-4
Spreyers	6/2/4	0-2	0-2	0-2
Carrot harvesters	10/7/3	0-3	0-3	0-3
Potato windrower	4/2/2	0-1	0-0	0-0
Potato harvester	2/0/2	0-2	0-2	0-2
Totals	43/21/22	2-19	2-18	2-18
Machines examined	**Pictograms**	**Carter**	**Modifications**	**Power plug protection**
Diggers	1-4	6-4	2-0	1-4
Centrifugal spreaders	3-3	-	3-0	3-0
Seeders	0-4	-	0-1	0-2
Spreyers	0-2	-	2-2	1-3
Carrot harvesters	0-3	0-2	7-3	-
Potato windrower	0-1	0-0	2-2	0-0
Potato harvester	0-2	0-2	0-2	0-2
Totals	4-19	6-10	16-10	5-11

The *boom sprayers* examined are used for weeding and for pesticide treatments onto the canopies. In most cases the sprayers did not undergo regular maintenance. In fact maintenance was carried out only on the occurrence of problems during use – problems that interfered with the functioning of the equipment such as blockage of the nozzles, a break in the tubing or filter blockage.

The *fertiliser spreaders* and the precision pneumatic seeders were not found to have been modified and were all in a fairly good or good condition.

The three carrot harvesters bought after D.P.R. 459/96 had come into force all had EC labelling, an instruction and maintenance manual and safety pictograms. Two of them had protection crankcase for moving sections. All the sample machines had undergone modification: the most significant modifications were those regarding digging mechanisms and product transport devices and the addition of a footboard for an operator in charge of checking the regular working of the belt transporting the carrots towards the bin.

During the survey 9 *potato harvesting machines* were examined: 3 were only diggers, 4 digger – windrowers and 2 digger-harvesters. The diggers were made by local manufacturer. They work one row at a time. They did not have EC labels or manuals or even identification labels or safety pictograms. They were, however, in good condition and their use does not represent any type of safety hazard for the operators.

Of the 4 *digger-windrowers*, 2 were bought after D.P.R. 459/96 had come into force. One of these had EC labelling and safety pictograms but neither had an instruction manual or identification label. Moreover neither had protection for the PTO shaft or protection case. Both had been modified to improve harvesting and avoid breakdowns during the operation. Modifications included the replacement of individual hoes with a single blade, this making it possible to regulate the inclination as well as the depth, and changes in the transmission (the addition of chains other than those installed by the constructor). Such modifications should imply constant and careful maintenance but this is often overlooked. Some of the oldest machines had been re-varnished and undergone reinforcement of the body structure. Both the digger-harvesters, bought in 2001 and 2004, had all the safety requisites required by the laws in force and neither had been modified to an extent that would compromise safety during use.

Finally, the 33 cardan joints connected to the machines under consideration were examined. As many as 17 were found to lack the protection required by law. Of the 16 joints with protection, in 8 the protection was not intact or the joints were only partly protected. Moreover, only 9 had warning and signalling pictograms.

Figure 1.

Figure 2.

3. Conclusions

Of the operating machines not activated from the PTO, more than half were found to have been put on the market before D.P.R. 459/96 came into force. Not even all those marketed after 21/09/1996 had EC labels. None of the ploughs, tillers and scarifiers had instruction or maintenance manuals. Of the machines powered from the PTO, only a little over half (57%) were found to have been put on the market after D.P.R. 459/96 came into force and even some of these did not have EC labels or instruction and maintenance manuals. Most of them did not have protection for the PTO, protection carters for the engine transmission parts or safety pictograms. More than half had been modified. Only 8 cardanic cardanic joints out of the 33 examined could be considered safe. The rest either had no protection or else the protection was broken and did not completely protect the shaft.

The safety conditions of most of the agricultural machines examined were found to be poor - either because there were no protection carters or safety devices or because where these were present they were not adequately maintained. The survey showed that most agricultural operators are unaware of the dangers connected with using machinery and unwilling to apply the safety regulations in force. Employers continue to see safety regulations as an extra cost and believe that the risk to workers is already covered by an obligatory insurance policy. The workers themselves, who by law are also responsible for checking safety measures, are generally unprepared for this role and find it difficult. The obsolescence of the machines increases the risk of accidents at work as does the progressive aging of operators in the agricultural sector. There is reason to believe that continual training and an information campaign about safety would significantly reduce accidents and improve productivity.

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A Study About Pesticide Spreading Work Organisation by Organisational Congruence (O.C.) Method

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Objectives
The aim of this study consists in focusing pesticides spreading critical points by using Organisational Congruences Method (O.C.M.). With the aim to validate obtained results we use the GlobalGap check list.

Methods
Organisational Congruences Method claims that every work situation depends on some choices, decisions and actions that are connected with choices about objectives, management of activities and of persons, and all that factors contribute to development of activities that make up the whole work, together with the management of the available technologies. O.C. method requires a careful scrutiny of the sequences of acts that all together make up a job; this survey has to be conducted together with the workers and its aim is to identify and to remove some organisational constraints they meet in the job. In this research we study the distribution of pesticides carried out inside a greenhouse executed by a little team made up from two persons and we gathered some data about the job (time, actions, devices, PPD, sequence of acts, etc).

Results
The accurate division of the whole work into elementary phases has enabled us to identify 8 main phases mutually connected and by taking in account every single moves effected by workers we were able to identify some critical points. Later, we discussed about them with workers and the management. The comparison between the obtained results and GlobalGap check list shows that the as concerning safety this kind of study highlight some critical points that workers and management usually are not able to recognised. The research intends to be mainly a basis for to go into the matter more thoroughly together with work doctors and work psychologists, with the aim to increase dramatically safety, health, wellness of workers and to set up a more efficient method to study work organisation by using Organisational Congruences Method.