Topic 3

“Instrumentation, Equipment, Periodic Procedures and Tests”

Oral Presentation

Improving ROPS designs for agricultural tractors

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Abstract

Tractor overturns are the leading cause of occupational fatalities on farms in the US. Rollover protective structures (ROPS) have been proven effective to reduce fatalities during tractor overturn. ROPS are designed to absorb energy resulting from the impact of the tractor with the ground surface during a tractor overturn, protecting the operator zone from intrusion of outside objects and exposure to the ground plane. A foldable ROPS equipped tractor offers greater mobility and more storage options as opposed to a fixed ROPS. Unfortunately, the time, effort, and safety risks associated with operating foldable ROPS limits their effectiveness. To improve ROPS designs, an efficient method of quickly designing prototype ROPS is needed, as is a method to power the operation of foldable ROPS. The two major objectives of this project are to 1) develop and evaluate a computer-based ROPS design program that will assist in quickly developing ROPS designs based on tractor weights and dimensions and 2) design and construct a powered foldable ROPS.

Keywords: rollover protective structure

Introduction

Tractor overturns are the leading cause of occupational fatalities on farms in the US (Myers and Hendricks, 2010). Roll-over protective structures (ROPS) have been proven effective to reduce fatalities during tractor overturn. ROPS, as described in SAE J2194 (ASABE, 2009), is a protective structure designed to minimize the frequency and severity of operator injury resulting from accidental tractor upset. ROPS are designed to absorb energy resulting from the impact of the tractor with the ground surface during a tractor overturn, protecting the operator zone from intrusion of outside objects and exposure to the ground plane.

Current ROPS installation rates on agricultural tractors are near 51%, but are not sufficient to reduce fatality rates (Loringer and Myers, 2008). Even with the current ROPS research, retrofit and social marketing programs, ROPS retrofitting is still not progressing. ROPS are still not available many tractors (Purschwitz, 2008). Purschwitz observed that "A Guide to Agricultural Tractor Rollover Protective Structures" (National Farm Medicine Center, 1997) revealed ROPS are still unavailable for common tractor brands as Allis Chalmers, Belarus, Deutz, Farmall, Long, Oliver, White, and Minneapolis Moline.

A large number of tractors do not have current ROPS designs, and thus have no ROPS availability. Costs of low production number ROPS are expensive as the design costs are not spread out over a large number of units sold. In a relatively small four county ROPS retrofitting program conducted by New York Center for Agricultural Medicine and Health (NYCAMH), 76 tractor models and 99 ROPS requests could not be accommodated due to lack of ROPS availability (Sorensen, 2008). These tractors included both pre-ROPS (tractors manufactured prior to ROPS) and post-ROPS tractors (tractors manufactured to fit a ROPS).

The recommendations from the recently completed National Agricultural Tractor Safety Initiative indicate "ROPS must be available" (Reynolds, 2008). CROPS (cost effective ROPS) can be made quickly, using mostly Off –The-Shelf (OTS) materials, but still need a technically valid design for a specific tractor (McKenzie and Harris, 2010). CROPS research with NIOSH has shown that ROPS designs can be simple and easy to manufacture.
ROPS designs require a balance of 1) ROPS material strengths and allowable deflections to meet energy criteria, 2) elasto-plastic material behavior to reduce peak moments at the mounting brackets, and 3) ROPS positioning and alignment in order to meet appropriate operator protection. The ROPS design process is not a simple straight-forward procedure and requires experience and engineering analysis to develop a feasible ROPS design. Once an appropriate ROPS design is developed, the construction of the ROPS, while requiring skill, is a straight-forward process. Testing of the ROPS design is required to assure the design meets appropriate OSHA regulations and ROPS performance standards.
Foldable ROPS are designed using the same procedure. However, during tractor operation many foldable ROPS are not placed in the safe position, due the time and effort required to raise and lock the ROPS. Thus fatalities are occuring involving tractors overturns with the ROPS in the lowered position.

Materials and Methods
A current need in the ROPS retrofit program within the US is to develop and demonstrate a computer-based ROPS design program to assure ROPS availability for all post-ROPS tractors. The program would provide ROPS retrofit designs for tractors that were engineered to receive a ROPS, but for which ROPS designs are lacking. It needs to be based on appropriate OSHA 1928.52 regulations and/or SAE J2194 standards.
A similar model, named ESTREMA, was developed by Mangado et al. (2007). This model was developed for the construction of a more complex 4-post ROPS, and utilized OECD ROPS codes for the perfromance criteria. This approach is not OSHA approved. Two-post ROPS are desired for the tractors in the US, due to their simplicity and low cost.
The computer-based ROPS design program should not require specialized/expensive software, and provide a design (and associated mechanical drawings) that is easy to implement and construct by ROPS manufacturers and/or local custom fabricators (machine shops). An inventory parts list and associated material costs would provide support to ease material acquisition and feasibility.
The approach to the development and evaluation of a computer-based ROPS design program (CRDP) includes 1) providing tractor dimension and weight inputs, 2) ROPS construction design, and 3) outputting the ROPS design drawings.
A powered foldable ROPS retrofit was designed and built to raise and lower the ROPS at the push of a button utilizing the tractor's 12V power supply. Linear actuators remove or replace the locking pins, and a 0.05 hp gear motor raises or lowers the ROPS in less than 10 seconds. The powered foldable ROPS operates at the push of a button.

Results
Previous guidelines for tractor ROPS design and construction were developed by Thomas and Ayers (1995). This document and approach describes the 1) material types, 2) weld quality and procedure, 3) gussets and cross members, 4) fasteners and mounting, 5) sizing of ROPS, 6) seat belts and 7) cost of materials associated with ROPS construction.

These guidlelines were used to successfully design, construct and test ROPS for five tractor models (for which a previous ROPS design did not exist) under NIOSH R01 OH003612 project titled "ROPS Design and Testing for Agricultural Tractors" (Ayers, 2003, Ayers, 1997). Mechanical drawings were developed for these ROPS designs and several of these tracotor models now have commercial ROPS available for purchase. Tremendous experience and design techniques were developed during the design, construction and testing of these tractor ROPS.

To assist in the ROPS design process a model for evaluating the exposure criteria during ROPS testing was developed, validated and implemented (Ayers et al., 1994). This model utilizes tractor dimensions, ROPS mounting points and ROPS deflection to determine allowable ROPS deflections to meet SAE J2194 ROPS performance standards.

A computer-based ROPS design program (CRDP) is being developed that will assist in quickly achieve ROPS designs based on tractor weights and dimensions. The final product from the model will be ROPS design drawings with specifications that can be used to construct the ROPS for testing.

The ROPS design model input and output components are described below. The inputs provide the positions of the seat reference point and operator clearance zone in space. The allowable deflection can be determined using these dimensions and the exposure criteria model described by Ayers et al. (1994).

The model requires the tractor dimensions described below as inputs.

Tractor Mass (used to define static energy requirement)
Rear tire diameter
Rear tire width
Front and Rear tread width
Front tire diameter
Horizontal distance to seat reference point (SRP) from center of rear axle
Vertical distance to SRP from ground
Horizontal distance from SRP to point 40 mm past the forward upper edge of the steering wheel
Vertical distance from SRP to top of steering wheel
Steering wheel diameter
Vertical distance from SRP to top of back seat rest
Wall thickness of back seat rest
Horizontal distance from rear axle to front hood corner point
Vertical distance from ground to front hood corner point
Horizontal distance from tractor center line to front hood corner point
Tractor wheel base
Horizontal distance from front tire point to center line
Horizontal distance from rear tire point to center line

The model output would include ROPS dimensions:

Material type (Steel grade)
ROPS box main stem dimension (wall thickness, cross section height and width, and length for upright stems and top crossbar)
ROPS top corner bracket sizes (wall thickness, height and width)

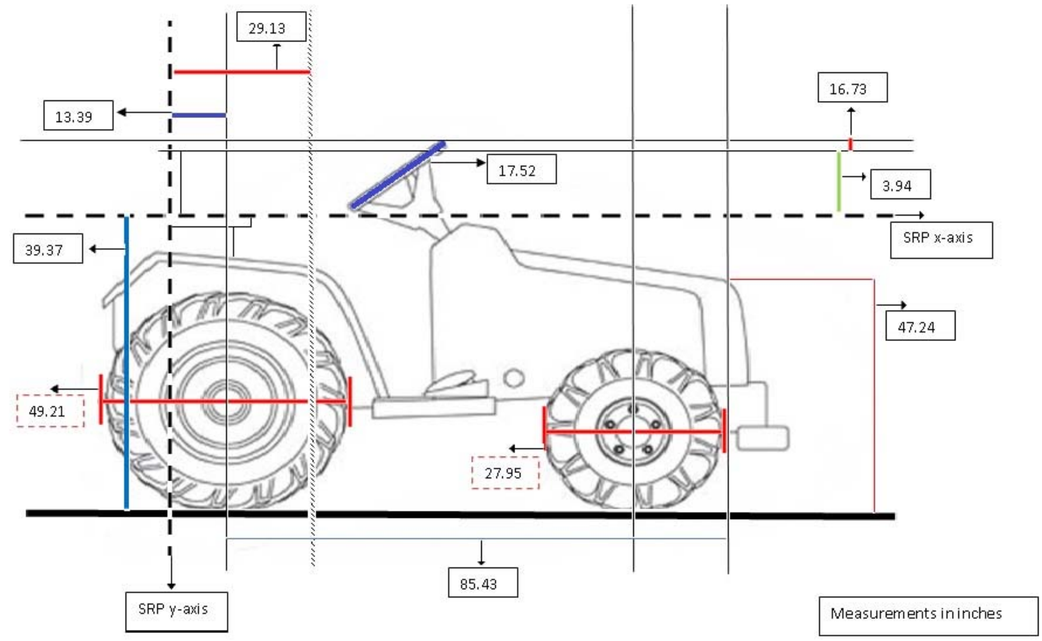
ROPS base plate sizes (thickness, height and width)
ROPS fastener/bolting pattern, sizes and grades
ROPS slant angle
Mounting fastener/bolt torques
Gusseting dimensions and locations.

The required inputs and outputs for the CRDP have been established, and are shown in Figures 1 and 2. The model input parameters were organized into a form and tested at the 2012 National Agricultural Machinery show in Louisville, KY. Model parameter inputs were determined for 6 tractors. In addition, ROPS dimensions were acquired utilizing the developed ROPS output CAD drawing (Figure 2). This drawing not only is used to obtain existing ROPS dimensions, but will also be the output of the CRDP.
A powered system which performs the raising, lowering, pinning, and unpinning processes was developed and allows full utilization of the foldable ROPS while eliminating safety risks has been developed. It provides the unpinning, and raising/lowering of the foldable ROPS in less than 10 seconds, and at the push of a button.

Conclusions
Preliminary ROPS design relationships have been observed and are being further investigated as described below:

- ROPS thickness and box dimensions increase with tractor weight, but thicknesses are less sensitive.
- ROPS heights increase with distance of the seat reference point (SRP) above the axle housing.
- ROPS slant angle increase with horizontal distance of the (SRP) behind the axle housing mount.

These are obvious trends, but the mathematical relationships are being developed.
The initial framework and platform for the CRDP has been established (MS Excel/AutoCAD). This includes defining model inputs and outputs, development of ROPS CAD drawing format, and the protocol development and acquisition of preliminary tractor and ROPS data.A powered foladable ROPS was successfully designed, constructed and tested.



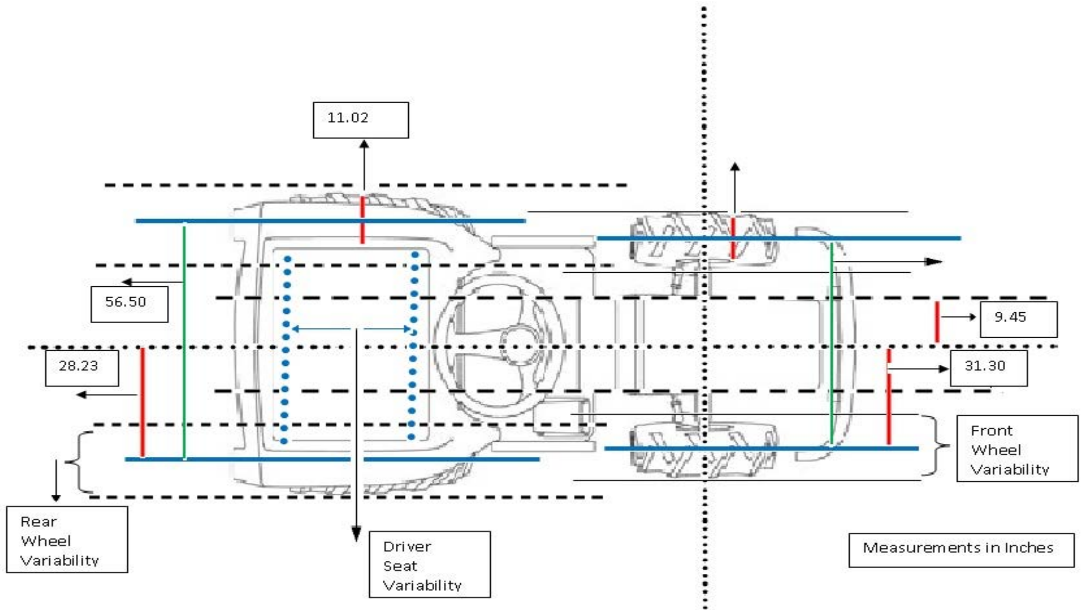


Figure 1. Tractor dimensions required for the Computer-based ROPS Design Program

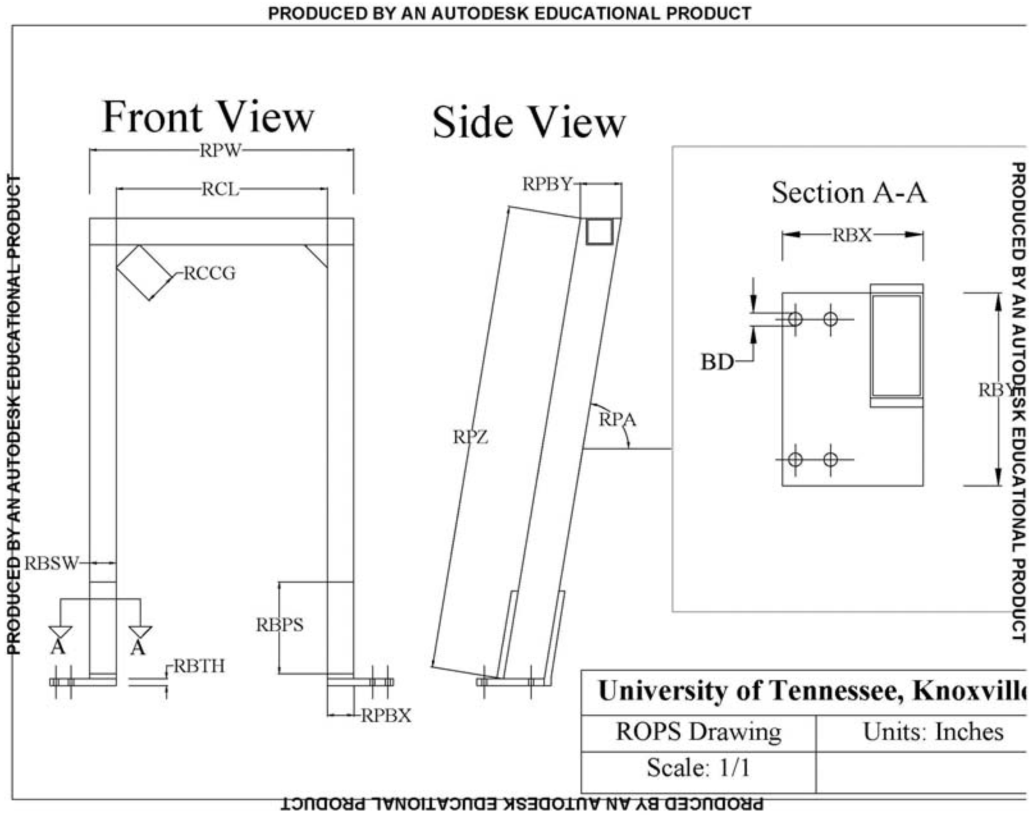


Figure 2. ROPS dimension output of Computer-based ROPS Design Program.

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INTRAC: a research project on the integration of safety elements with ergonomics in the design of agricultural machinery

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Abstract
Designing agricultural machinery firstly takes into account the specific technical aims the machine has to reach. Only then, if a compulsory standard exists, the safety aspects related to the operator, the environment and the road circulation are carefully introduced in the design in order to not penalize the main performance. Generally, the most evident and frequent risks are considered, and rarely the possible causes of occupational diseases - that are more subtle to detect, but unfortunately, irreversible – are considered.
The present research project aims to analyze and to propose methods and models to assess the level of integration of technical and safety aspects in the designs of different working place of agricultural machineries. Vibration, noise, microclimate conditions and ergonomics will be taken into account and innovative assessment methods, for the agricultural sector, will be introduced.

Keywords: tractors, seat place, safety handbook, comfort, participatory ergonomics, usability

Introduction

The current legislation foresees some fundamental aspect for devices, of respect of measurements, of color or shape of lights to reduce the risk during the use of agricultural machineries. Besides, the specific technical aims that the machine has to reach is firstly taken into account.
Several technical standard could be a guideline for engineering in a safety way but a legislative situation of this kind ends by leaving to the sensitivity of the manufacturers to search solutions to make the equipment vehicle safe, easy and of immediate communication with the user. Moreover, the design choices has to respect also trends, fashions and more specific forms of the market logic.
Generally, the most evident and frequent risks are considered (European Parliament Directive 2002/44/EEC, Decree n. 81, 2008), and the possible causes of occupational diseases, that are more subtle to detect, could not be taken into account in the same way.
This project aims to study some of these risks that doesn't represent the most analyzed or frequent but that could be reported closer to the professional injuries.
The project analyzes ergonomics and vibration (Okunribido, 2006; Seidel, 1986) and an actual topic relevant to the breaking test of agricultural tractor with ABS.
The presented research project will be carried out along the following main working package:

1. Development of a methodology to assess the whole body vibration of the agricultural tractor's operators by a four poster test bench and standard test tracks;

2. Development of a methodology for the evaluation of the braking performance of “fast” tractors (> 40 km/h) with devices of Anti-lock Braking Systems, ABS;
3. Development and validation of a methodology for the evaluation of the comfort of the different tractors’ seat;
4. Experimental study of the ergonomics tractors’ cab requirements for the operators by using a Participatory Ergonomics approach (focus group, questionnaires) compared to Usability testing;
5. Usability evaluation following the ISO 9241-11 of the operation and maintenance manual of the agricultural tractor and readability by qualitative and quantitative methods by a direct involvement of evaluators and users for the development of a prototype of usable safety handbook;
6. Ideation, engineering and development of a prototype of usable safety handbook.

Material and methods

A new method to assign a vibration level, respecting the guidelines of the UNI EN ISO 12100:2010 and ISO 2631-1:1997, to agricultural tractors will be attempted basing it on dynamic tests carried on a vibrating bench, on ISO standard tracks and in field conditions. The aim is to correlate the real surface profile and that acting under the tractors’ tires both on hard surface (road transport) both soft (agricultural terrain) to identify the real solicitation acting on the vehicle. The different settings of the vehicle and operating condition will have to be taken into account considering their influence on operator’s comfort (Cutini, 2010).

The correlation of the results between the relief on a standard test track for evaluating vibrations and the test bench of the laboratory of vibration will allow to define a standard profile for evaluating the response of the vehicle to vibrations with a test that has to result easy to carry out as already developed for other kind of machineries (i.e. EN 13059:2002).

In this context will be introduced a novel study about the risk of exposure to vibration of the tractor’s passenger.

A way that could be of interest for evaluating operator’s whole body vibration on tractor is that of measuring in real time the exposure. For this reason portable vibration counter offered from the market will be tested both for evaluating the applicability of the products, both to validate the developed method previously described.

The approval of the agricultural tractor of category T5, will allow these vehicles of forward speed > 40 km/h. A technical proposal for increasing safety could be to require for these vehicles the Anti-lock Braking Systems, ABS, system. This project will analyze the applicability of the OECD code 2 for tractors with speed > 40 km/h and fitted with ABS. In detail, the requirements proposed from the ECE R13 standard regarding braking performance of industrial vehicle will be evaluated also for tractors.

Regarding to ergonomics, several aspect will be analyzed. The seat device will be one of the most important part of this study. An industrial, patented “comfort index” will be used to assess the comfort level of different tractor-type seats introducing a new anthropometric-dimensional evaluation together with barometric and subjective analysis.

As agricultural tractors’ seat have several factors as requirements (static, dynamic on road and on field) this method will allow to define a focused procedure taking also into account the several parameters that define the word comfort and its link with operators’ safety and health.

The comfort level will be evaluated by a representative sample of seats considering different layout, padding, suspension. The evaluation of the different posture, gender and physique will complete the variables’ grid.

Another topic of this research focused on ergonomics is the analysis of the work place both as layout, both as usability.
The analysis of the requirement of a tractor driving place will be carried out by the standard ISO 6385:2004 "Ergonomic principles in the design of work systems" that provides "In work system design, a participatory approach is essential in order to avoid sub-optimal solutions, because the experience of workers provides an indispensable knowledge base". The study of this package will analyze also the critical situations and risks that could occur by activity focus groups formed by experienced users and privileged observer.
The activity will be completed by usability tests carried out on specific tasks and following the standard ISO 9241-11.
The research aim to investigate and improve the main sources of discomfort and risk of safety by an ergonomic participatory approach and test of usability. A participatory approach can be defined as "ergonomists and workers working together with the end-users (i.e. workers) taking an active role in identification and analysis of risks, as well as problem solution and implementation of these" (Noro & Imada, 1991).
The term usability is defined in the technical standard UNI EN ISO 9241-11:2002, ISO 20282:2006 and UNI 11377:2010, "The effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments with effectiveness, efficiency and satisfaction".
The effectiveness is the accuracy and completeness with which specified users can achieve specified goals in particular environments; the efficiency is the resources expended in relation to the accuracy and completeness of goals achieved and the satisfaction is the comfort and acceptability of the work system to its users and other people affected by its use. In case of tractor means the possibility of doing or not the necessary jobs of the farmer.
The efficiency is the energy employed for the accuracy and completeness for reaching the results. The efficiency is quantified measuring the employed time and the number of errors during specific processing.
The user satisfaction is the freedom from discomfort, the aptitude to the product. In this research discomfort is referred to each element that, subjectively perceived, increases the operator's uneasiness, fatigue, physical and psychological tensions.
Moreover, considering the growing number of instruments, displays, controls, etc. variably distributed on the dashboard of a modern tractor and their possible influence on driving stress and attention, a method of ergonomic analysis of the driving place based on eye-tracking technology will be introduced in order to measure the sequence of movements of the driver and his driving effort.
The end of the project foresees the development of a technical report with the aim of furnishing useful information for engineers and manufacturers for increasing comfort and reduce risks in the use of the machine.
The activity starts with the analysis on the data relevant to injuries, professional sickness and the scientific literature of the agricultural tractors.
Two typologies of tractors will be chosen (i.e. specialist or open field) for the analysis of usability test, to identify the privileged witness and the definition of the expert users for the final focus group.
The materials for the analysis (working group, focus group, questionnaires) and of the methods (test and usability procedures) will be focused in detail after the first approach with the privileged witness that will allow to define the processing dynamics and the recurrent problems.

A series of meetings will be organized involving a panel of professionals operators who will be asked to make its operational needs in the use of agricultural machinery during the running sessions of focus / working group .

Particular emphasis will also be given to the recognition of the critical set of operators and their proposed solutions. Operators participants will be divided into separate groups and each sample of each group will be stratified to represent the most important categories of users: for example, young, old, men and women.

Each group will focus its own meeting and a final session will involve all groups simultaneously. In the latter part of the work, the data previously collected will be "validated" inter-group coming to a structure of needs, problems and proposed solutions to be shared by everyone involved.

The output of this activity will be constituted by a shared framework that will include the major critical areas of human-machine as perceived by the operators themselves. This phase will also gather information on transactions considered most critical in terms of safety and need for comfort in the activities.

Based on the output provided by the activity of focus / work group, a questionnaire will be developed that will take into consideration the needs of operators, the critical issues most frequently encountered and solutions proposed. This instrument will be built with a series of statements each of which users can respond operators reporting their level of agreement / disagreement on a Likert scale with five steps.

This methodological strategy is considered necessary to obtain an estimate of reliability of the factors in the analysis (i.e., interface layout, general safety equipment, level of perceived comfort during shifts) involving a large sample of workers. This phase of work, therefore, provide as output a reliable comparison, at the statistical level, between different types of machines based on the factors "critical" previously identified in the focus / work group. As introduced above, the first phase of focus / work group will also provide guidance on the most critical operations.

This information will be used at this stage, to define the operational tasks on which will be conducted usability testing in an operational setting. A panel of professionals (minimum six per type of machine) will be involved in this phase of testing. Each operator will be asked to perform a particular operational activity by interacting with a particular type of agricultural machine. During this activity will be recorded some objective indicators of usability including: number of errors (index measure of effectiveness) and execution time of operations (effective weight) at end of work each operator will be asked to fill a specific standardized questionnaire to report the perceived workload and satisfaction of use.

In addition, each participant will wear a special pair of glasses that allows to record eye movements of the operator on the dashboard of the car and on the instrumental visual scenario. This instrumentation eye-tracking will then allow to analyze empirically the interaction between the operator and the instrumentation on board evaluating, in particular, the layout of cockpits. This last phase of the intervention will provide objective data for the analysis of the effectiveness, efficiency and satisfaction of the interaction between the operator and the different types of machines. Furthermore, empirical evidence will be provided about the appropriateness of the methodology of analysis used to investigate the role of human factors in design and development of agricultural machinery.

The project foresees the development of a usable manual that will be developed on the basis of the described experiences. The manual will look like "rapid guide", developed by iterative ergonomic design with two stages of verification, this book focuses on the prevention of accidents and occupational diseases during the operation and maintenance of tractors will be

made with lifetime policy, readability and understandability unseen by the agricultural machinery sector.
This part of the research aims to create a model of user information / training "usable" focused on the prevention of accidents and occupational diseases during the operation and maintenance of tractors. Also the manual will respect the concept of effectiveness defined as the accuracy and completeness with which users achieve specific goals. In case of manual will be related to the information / training of the worker. The user satisfaction is the freedom from discomfort and attitude to the use of the product. The latter is related to the sphere of subjectivity (this is assessed through qualitative methods such as questionnaires and interviews) and is often described as pleasant to use.
The activity will require to collect and organize information, procedures, and the most important skills that must be learned by operators to ensure their safety during use and maintenance of a tractor. The usage context of the editorial product will be considered for defining the format and print materials more suitable to agriculture (issues paper stationery), to the place of use (tractor) and to the type of user (farmer).
The level of usability will be measured through objective evidence by the working group of PAN-PAN Edizioni Srl and through subjective and hypothetical involvement of a consumer. The adequacy of terminology and syntax will be measured through the administration of a questionnaire for evaluating the familiarity of users with the "language" used in the text.
The phases and related activities to achieve the objectives given are: the analysis of databases of accidents, occupational diseases and the popular and scientific literature and reference standards in the industry; the analysis of booklets use and maintenance of tractors and publications concerning the prevention of risks from the use and maintenance of tractors; design "logical-dispositive" of the manual; development by the graphic design of "draft 1".; evaluation of usability (effectiveness, efficiency and satisfaction of product use); general revision of the manual and delivery of the "draft 2" pre-final. Final stage of the iterative process of verification and implementation of ergonomic hand through a further evaluation of usability (effectiveness, efficiency and satisfaction of product use) through the objective and subjective tests.

Expected Results

Test methods and prototype devices to assess and control vibration and chemical dust exposition in tractor cabs will be proposed. Results from an integrated investigation on technique, ergonomic and anthropometric aspects of representative tractor driving places will be presented. An inedited prototype of user-centered safety manual will be published.

Acknowledgements

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ISO 20282-1/4:2006/2007 Ease of operation of everyday products

UNI 11377-1/2:2010 Usabilità dei prodotti industriali

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A recycling tunnel to reduce environmental drift in spraying goblet vineyards

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Abstract

Since about 50 years ago, goblet vineyards were progressively abandoned in favour of espaliers, because they presented some critical points as low vine quality and no adequate mechanisation. Nowadays, experts and oenologists claim that goblet vineyards, cultivated with modern criteria, may provide high crop quality. Moreover, some growers are going to set up cultivation with increased distance between rows (about 1.8 2.0 m), that allows the use of conventional tractors designed for espalier vineyards. In order to fulfil the mechanisation requirements of the crop, the Section of Mechanics and Mechanisation of the DiGeSA of the University of Catania is developing and optimising an innovative multi-functional straddling frame, pulled from a conventional tractor, which is able to carry several tools, as vine-trimmer, sprayer, rotary hoes for soil cultivation, horizontal booms for herbicide treatment under canopies, easily available on the market. This paper reports the results of some trials carried out with the frame equipped with a tunnel sprayer, able to reduce the environmental drift during pesticide treatments. The first results showed that the recovery at fixed point, at varying pressure, distance between shields and number of open nozzles, ranged from 4% up to 83%, with general mean of 44%, whereas that during in field tests, with vineyard Leaf Area Index of 0.73 m^2/m^2, ranged from 37% up to 53%, with general mean of 46%.

Key words: pesticide application, alberello, tunnel sprayer.

Introduction

Goblet vineyards have been progressively abandoned in favour of espaliers, because of low vine quality and lack of mechanisation. However, recent experiences in Sicily and Tuscany (Schillaci *et al*., 2009a) demonstrate that high crop quality may be obtained from goblet vineyards by adopting modern criteria of cultivation. Moreover, this growing form requires only a single stake per trunk, so resulting in less impact on the landscape, less initial outlay, and less waste disposal. In addition, recent plants present distances between rows of about 1.8-2.0 m, that allow the use of operating machines, towed by or mounted on common narrow-track tractors, for soil and canopy management and for pesticide application.

All these factors show a great sustainability of goblet vineyards in confront of espaliers and justify the interest in this growing form, together with the research of solutions able to increase the mechanisation of the crop activities. To this end, a promising solution came from an idea of a wine-grower of the South-East of Sicily that built a handmade frame to which could be applied several tools of easy availability (Schillaci *et al*., 2009b). This pre-prototype consists in a frame supported by two pneumatic tyres, towed by a common "vineyard"

The Authors equally contributed to the present study.

(narrow track) tractor and designed to operate straddling the rows. Thanks to the financial support of the ENAMA and the scientific direction of the Section of Mechanics and Mechanisation of the DiGeSA Department of Catania and of the CRA-ING of Treviglio (Bergamo), this pre-prototype was redesigned and is now under optimisation.

Presently, the machine consists in a steel-made frame with rectangular lay-out (1.80 m × 1.55 m), maximum height of 2.61 m, ground clearance of 2.40 m, and track of 2.40 m. The frame can carry the tools used for the commonest activities in vineyard, as vertical and horizontal pruning-bars for canopy management, inter-row rotary hoes for soil tillage, and a tunnel sprayer for pesticide application.

The present paper reports the first results of some static and in field tests when the frame was fitted with the tunnel sprayer.

Materials and Methods

The tunnel sprayer

The tunnel sprayer (Figure 1), manufactured by LIPCO (Germany), is specifically designed for pesticide application in espalier vineyards and similar crops. It consists of two shields equipped with a collector at the bottom for the recovery of the mixture, and a recycling unit, based upon a Venturi tube (Figure 2), that, after filtration, returns the recovered mixture to the spray tank.

Figure 1. The frame equipped with the tunnel sprayer.

Figure 2. The recycling unit with the filter.

Each shield has rectangular shape (width = 1.25 m, height = 2.20 m) and is equipped with a spray boom fitted with 5 fan Albuz APE 80 nozzles. The distance between the shields can be adjusted from 0.2 up to 1.1 m by means of a hydraulic piston. The sprayer is completed with a 500 L spray tank, a diaphragm pump, a pressure regulator, and the oil-pressure system. The shields are applied to the frame, while spray tank and pump are placed on a shelf located on the hydraulic lift of the tractor. At this development stage, the machine isn't equipped with auxiliary tanks. Moreover, in order to limit costs and complexity, the shields aren't equipped with fans, even if this could affect negatively the uniformity of the applications on vine canopies (Planas *et al*., 2002; Molari *et al*., 2005).

The research activity

The research activity consisted of both static and in field tests.

Static tests were aimed at assessing the recovery capabilities of the sprayer, in absence of vines, at varying:

- distance between the shields: 0.9 and 1.1 m;
- working pressure: 5 and 6 bar;
- number of open nozzles per side: 2, 3, and 4.

Four replicates we carried out for each test condition, for a total of 36 measurements. The recovery *R* was calculated per each replicate according to (Pergher and Petris, 2009):

$$R,\% = \frac{V_r}{V_s} \times 100,$$

being:

- V_r (L): the amount of water recovered by the recycling system;
- V_s (L): the amount of water sprayed by the nozzles.

V_s and V_r were measured by means of two water meters, the first inserted in the nozzle feed pipe, the second in the Venture tube feed pipe. The amount of water issuing from the recovery unit, equal to that recovered by the shields and that in input to the Venture tube, was collected in an auxiliary tank. Definitively, calculations were performed according to:

$$V_s = WM_n(t + \Delta T) - WM_n(t)$$
$$V_r = WC - \left(WM_V(t + \Delta T) - WM_V(t)\right),$$

being:

- t: start of measuring time;
- ΔT : spraying time;
- WM_n: reading of the water meter inserted in the nozzle feed pipe;
- WM_V: reading of the water meter inserted in the Venture tube feed pipe;
- WC: water collected in the auxiliary tank.

The in field tests were conducted in a six years old *Syrah* vineyard with row spacing of 0.9 × 2.0 m, at beginning of fruit setting phenological stage (code 71 of the BBCH scale). Vines were characterised by measuring Leaf Area Index (LAI) and height and width of the canopy.

The average height of the vines, branched at 0.3–0.4 m above the ground, was 1.4 m; the width of the canopy in the bunch zone was 0.5 m and that in the tying zone 0.3 m. Each vine had on average 7 shouts 1.2 m long, each carrying 23 leaves. The LAI of the vineyard (0.73 m^2/m^2) was estimated on the basis of a sample of 115 leaves, whose surface was measured by using a flat scanner to acquire their images and the *ImageJ* software (Abramoff *et al*., 2004) to analyse them.

Spraying tests were carried out by setting the following working parameters:

- boom sprayer fitted with four open nozzles per side;
- working pressure: 6 bar;
- distance between the shields: 1.1 m;
- total flow rate: 8.16 L/min;
- working speed: 1.28 m/s;
- theoretical volume rate: 533 L/ha.

Four rows about 135 m long were sprayed with water only and the recovery for each row was computed as in the static tests. Moreover, four water sensitive papers were also putted on the ground, inside *Petri* dishes, near three sprayed vines. Their analysis, carried out by using again a flat scanner and the *ImageJ* software, allowed the gathering of the first indications on the ground losses.

All data analyses and graphical representations were carried out by using the open source software *R* (R Development Core Team, 2009).

Results and Discussions

Static tests

The recovery, averaging all the test conditions, was 44.5%; it ranged from 4.0% (5 bar, 1.1 m, 2 open nozzles) up to 82.7% (5 bar, 1.1 m, 3 open nozzles) (Figure 3).

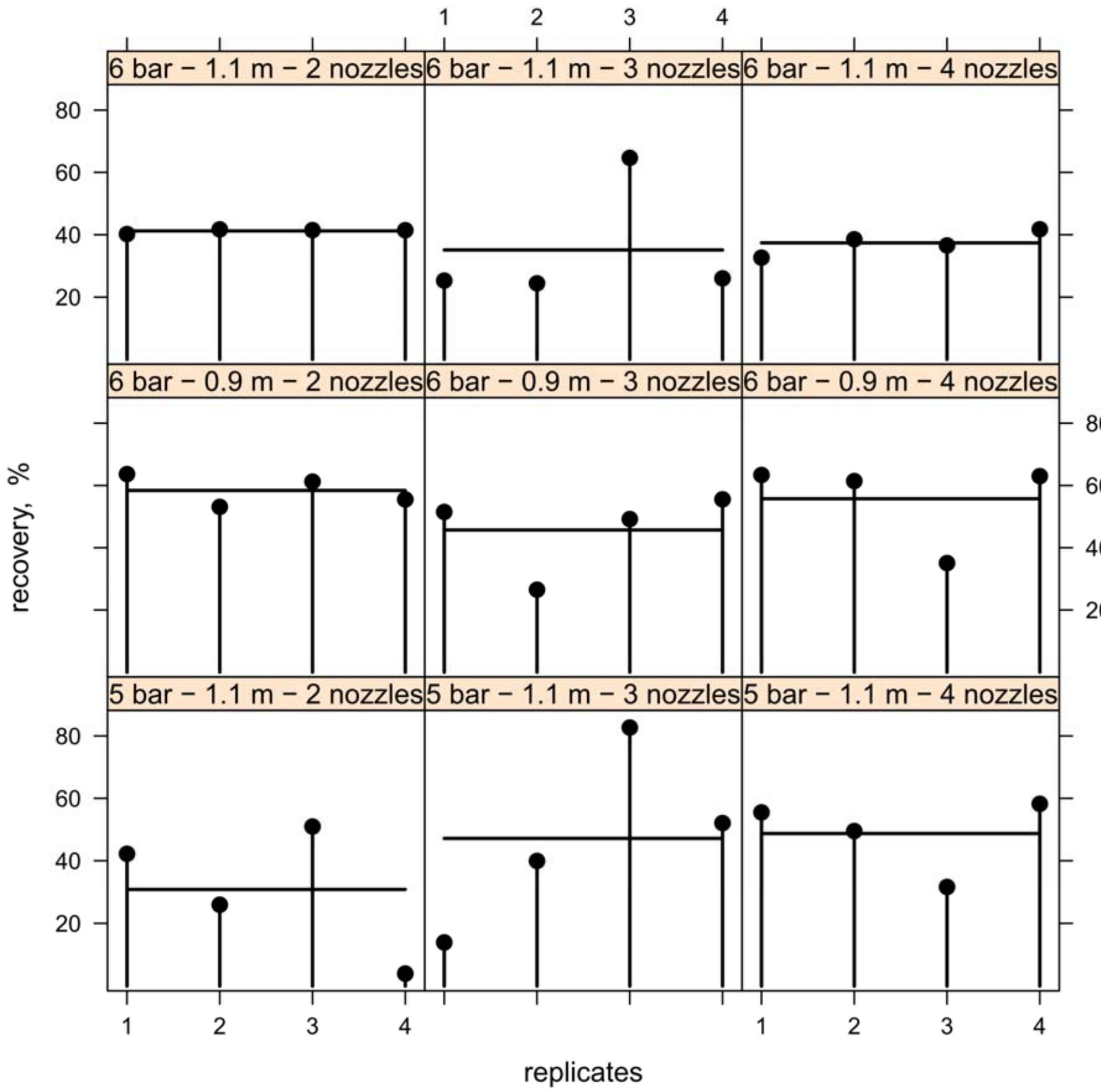

Figure 3. Recovery for each replicate of the static tests (horizontal lines represent mean values).

The analysis of variance applied to the recovery values produced the results reported in Table 1. Mean values for each factor considered in the analysis are reported in Figure 4.

Table 1. Analysis of variance of the recovery values.

Source	df	SS	MS	F	*p*-value
Distance	1	1394.7	1394.7	5.778	0.0234
Pressure	1	111.7	111.7	0.463	0.5022
Nozzles	2	146.1	73.1	0.303	0.7413
Distance × Nozzles	2	424.5	212.3	0.879	0.4266
Pressure × Nozzles	2	653.4	326.7	1.353	0.2753
Residuals	27	6517.7	241.4		

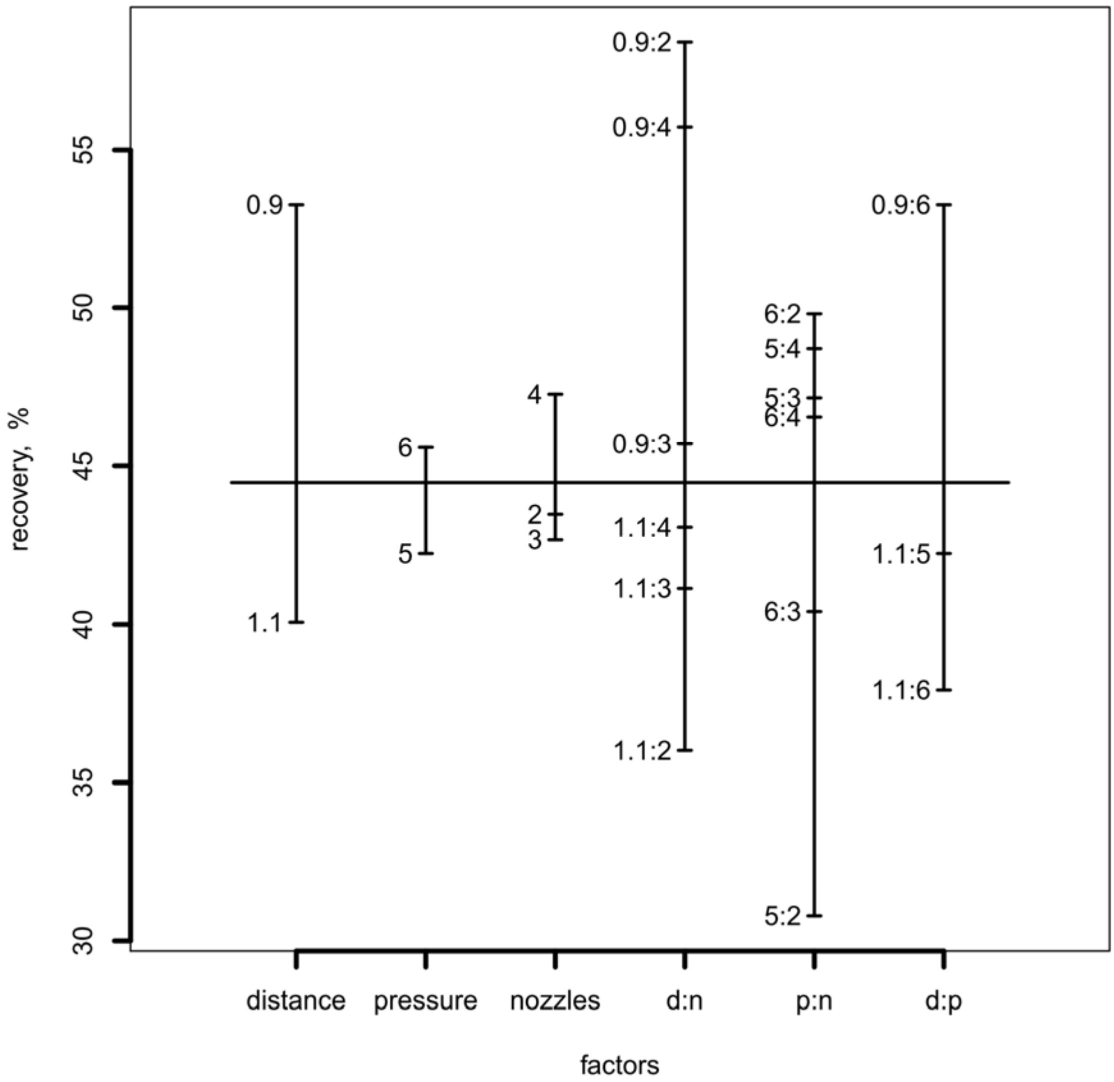

Figure 4. Mean values of the recovery at varying distance between shields (d), pressure (p) and number of open nozzles (n).

The results show that only the distance between the shields had a significant effect on the recovery (*p*-level = 0.023): it was 53.3% when the distance was 0.9 m and 40.1% when it was 1.1 m. This means that the increase in the distance between the shields makes the recovery worse, so the machine should be used in field keeping the shields as much as possible close, compatibly with the vine size. Moreover, the increase in the distance had also effect on the data dispersion (Figure 3), probably because of a greater influence of external factors as wind and temperature. In fact, recovery values ranged from 26.5% up to 63.7% (CV = 22.0%) when the distance was 0.9 m and from 4.0% up to 82.7% (CV = 41.4%) when it was 1.1 m.

The increase in pressure improved the recovery, but not significantly (*p*-level = 0.502). The recovery increased from 42.2% up to 45.6% when the pressure increased from 5 to 6 bar. High pressure values, in fact, help drops to reach the opposite shield, so increasing the recovery. Higher differences in pressure levels could make significant this factor.

Finally, the influence of the number of open nozzles was not statistically significant ($p = 0.741$): the highest value of recovery (47.3%) was measured with 4 open nozzles, the lowest (42.7%) with 3.

The interactions were all not statistically significant: the recovery was always smaller when the distance between the shields was 1.1 m, whatever the number of open nozzles and the pressure level, while no relationship emerged between pressure and number of open nozzles.

In field tests

The in field tests, even if absolutely preliminary, showed a recovery ranging from 36.9% up to 52.5%, with mean value of 45.5%. The analogous static tests (same pressure—6 bar—, same distance between shields—1.1 m—, and same number of open nozzles—4—) provided a recovery of 37.4%. Even if further investigations are necessary, with different foliar development and other working parameters, these first results are encouraging: almost half of the sprayed mixture was recovered, so greatly reducing the environmental losses.

Ground losses near the sprayed rows were quite high: the covered surface on water sensitive papers ranged from 62.9% up to 68.8%, with mean value of 65.6%. May be they could be reduced by properly adjusting the nozzle angle and by reducing the distance between the shields.

Conclusions

The study, even if preliminary, allows for the following conclusions, to be integrated by further investigations:

- The results concerning the spraying system induce to consider the machine an interesting solution to pesticide application in goblet and low espalier vineyards as regards the reduction of drift losses. A recovery of 45.5% at beginning of fruit setting phenological stage states that almost half of the sprayed mixture can be recovered.
- A full evaluation of the machine requires further experimentations, among which a comparison with a conventional sprayer in terms of foliar deposition and its distribution on the canopy. Some Authors report in fact some asymmetry of distribution, which produces different deposits on the two sides of the canopy (Ade and Pezzi, 2001), or lower deposits in the high parts of the canopy when using drift-mitigating air induction cone nozzles (Jamar *et al*., 2010).
- Further experimentations should be carried out in order to identify the optimal working

parameters in terms of pressure, nozzle type and angle, distance between the shields, working speed, all variables that may affect foliar deposition and its distribution on the canopy.

- Finally, further development should regard a re-design of the frame and of the shields, reducing the size of the machine in comparison to the goblet vine size. Moreover, it should be evaluated the advisability of fitting the shields with fans so to improve spray distribution and penetration, even if this increases costs and complexity.
- After all, the frame, equipped with operating tools easily available on the market at low cost, may represent a valid solution to the mechanisation requirements of goblet and low espalier vineyards.

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Development of a compact roll over protective structure for agricultural wheeled narrow track tractors

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Abstract
Most of serious accidents occur when using a tractor which is not compliant with safety protection requirements, especially when the roll-over protective structure (ROPS) was not installed, or it was temporary folded in order to carry out some particular works. Even if two posts front mounted foldable ROPS can be folded down only for tractor storage or maintenance (as formally specified also in users' manuals provided by manufacturers), and always kept upright up the rest of the time the tractor is used, an high percentage of cases of non correct use of this type of ROPSs has been encountered. Thus, a specific research work was carried out in order to design a non foldable ROPS for narrow-track wheeled tractors, which provides rollover protection all the time without making agricultural works more difficult.

Keywords: ROPS, computer aided design, finite elements non-linear analysis, machinery safety

Introduction
A large number of serious accidents recently occurred in Italy are related to the use of tractors which is not in conformity with safety protection requirements with respect to roll-over risk, especially when the roll-over protective structure (ROPS) was not installed, or, in the case of two post front mounted foldable ROPS, it was disabled in order to carry out some particular works (e.g. in vineyards). A considerable effort has been made by public Italian authority with the aim of reducing at minimum level this phenomenon. In particular, a national working group, led by the former Institute for Occupational Safety and Prevention (now belonging to INAIL, the Italian Workers' Compensation Authority) has been working on providing technical guidelines, of a legal value, which provide technical information on how to adapt tractors with ROPSs.

Nevertheless, a difficulty emerged concerning narrow-track tractors, which are used mainly in works where dimensions are smaller than usual (both in height, and in width), such as in vineyards, glasshouses, orchard, etc. The most common ROPSs for this kind of tractors are two posts front mounted foldable structures: they can be folded down only for tractor storage or maintenance (as formally specified also in users' manuals provided by manufacturers), and always kept upright up the rest of the time the tractor is used. Stating the high percentage of cases of non correct use of this type of ROPSs, a research work was carried out in order to design a non foldable Compact ROPS (CROPS) for narrow-track tractors, which provides rollover protection all the time without making agricultural works more difficult.

Methods

Since 2009, the Italian national authority is working on the design of specific compact tractors to be installed on old tractors not equipped with ROPS. The main target to be reached with CROPS design is to protect and preserve an operator clearance zone by means of a non foldable structure shaped in such a way to facilitate the work under trees or in greenhouses. The first proposed models of CROPS were based on the clearance zone defined in OECD code 7 (Laurendi et al., 2010). In this paper the CROPS designed is based on the clearance zone defined in the standard ANSI/ASAE S478:1995 concerning "*Roll-Over Protective Structures (ROPS) for Compact Utility Tractors requirements*".

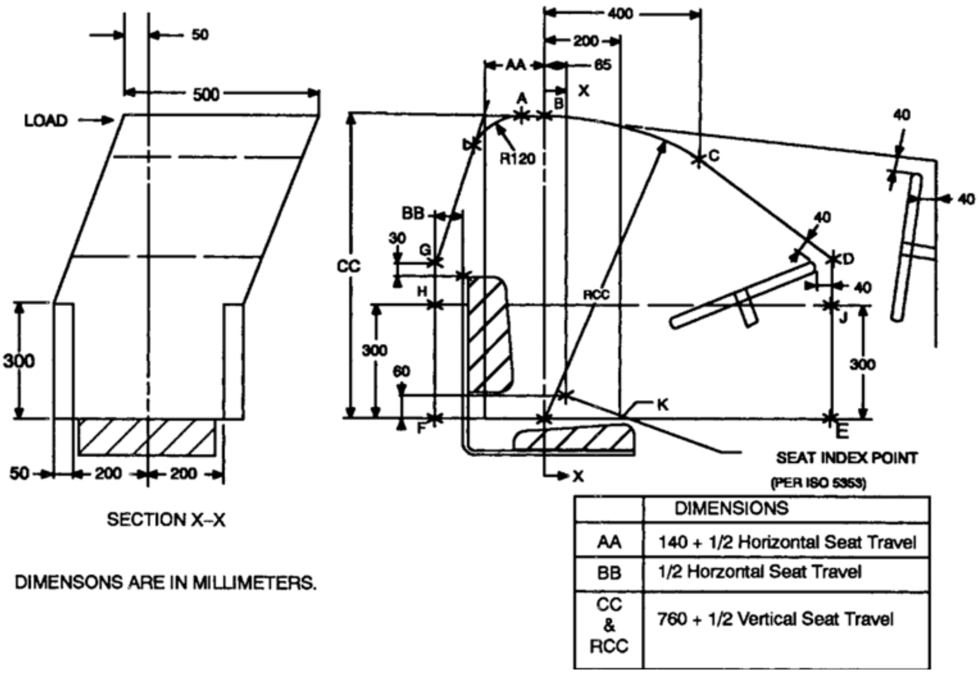

Figure 1. Clearance zone according to ANSI/ASAE S478:1995 standard

From a comparison of ANSI/ASAE S478:1995 clearance zone (figure 1) with respect to OECD code 7 one it emerges that:

- the side deflection of the ANSI/ASAE S478:1995 clearance zone is 50 mm greater;
- the height of the ANSI/ASAE S478:1995 clearance zone in correspondence of SIP is 50 mm lower.

In particular, its reduced height is the reason for designing a CROPS based on ANSI/ASAE S478:1995 clearance zone in order to maximize the overall height reduction of the structure without reducing the required safety level. Also in this case the CROPS design is based on the following steps:

1. reverse engineering of tractor and CAD virtual prototyping of CROPS;
2. finite element analysis (FEA) of CROPS according to ANSI/ASAE S478:1995;

3. shape and dimensions optimization in order to model after the physical prototype for performing in-field tractor handling, ergonomic and visibility analyses.

Reverse engineering and virtual prototyping

The first step of our research approach was based on the reverse engineering scheme proposed by (Wood and Otto 1998) for a reverse engineering and redesign methodology, as described in (Fargnoli et al., 2012). In other words, it was necessary to make a reverse engineering of tractor in order to virtually reproduce the position and the relative disposition of the anchorage points suitable for the CROPS. This also allowed us to faithfully reproduce the standard ANSI/ASAE S478:1995 operator clearance zone on tractor, and to avoid interferences between protective structure and tractor itself. Then, the CROPS was shaped in its upper portion according to the profile of the clearance zone and in its lower portion in such a way to smoothly reach the mountings connection points. In figure 2 an example of CROPS obtained with this reverse engineering and redesign methodology is shown.

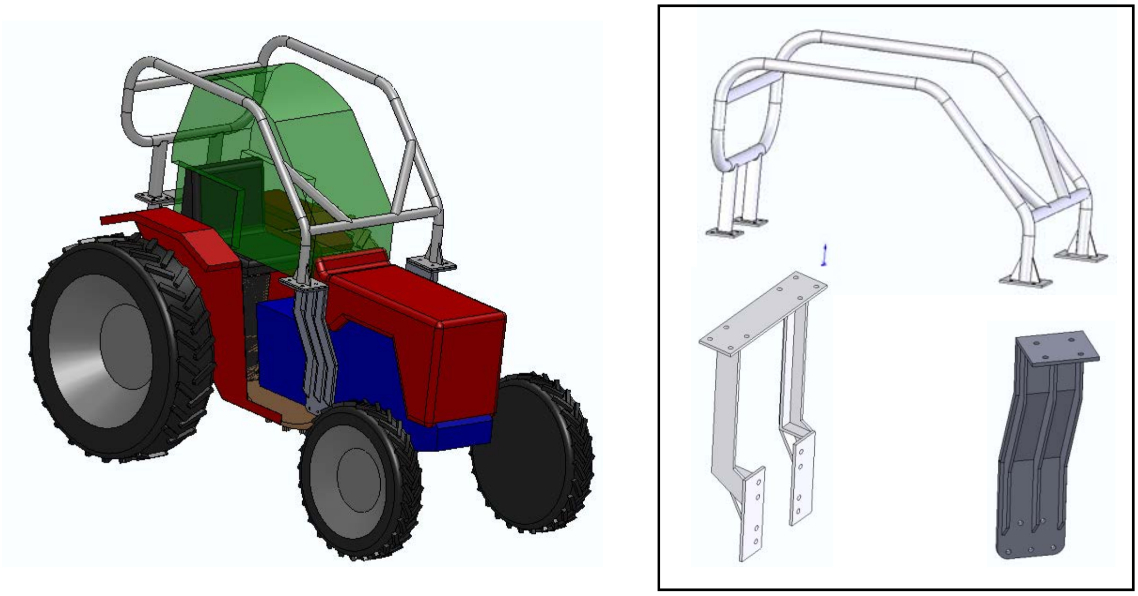

Figure 2. Tractor reverse engineering and CAD model of the CROPS

Finite element analysis

The finite elements analysis is necessary in order to verify:

- the strength of the protective structure according to the sequence of test defined in the ANSI/ASAE S478:1995 standard;
- that any part of it has not entered the clearance zone round the driving seat;
- verify that the clearance zone is not outside the protection of the protective structure.

Once verified the aforementioned requirements the CROPS is shape optimized. It is important to note that any modification of CROPS' shape or dimensions at this stage might affect its structural strength. Thus, it is necessary to perform another finite element analysis to recursively verify the compliance with the above issues.

The CAD prototype of CROPS has been meshed in order to perform the finite element analysis. The geometrical properties have been modelled by means of plate elements of variable thickness. Since the ANSI/ASAE S478:1995 test procedure requires to evaluate the plastic energy absorbed by the protective structure, it is necessary to mimic the plastic behaviour of the material and to represent the large deformations which the structure undergoes. For these reasons the *Ramberg–Osgood* equation has been used for reproducing the elasto-plastic behavior of steel. As the CROPS is connected to the front and rear mountings by means of threaded connections the constraints in the model are of pinned type. They have been applied at the centre of each hole representing bolt by means of rigid elements. In figure 3 an example of contour diagrams obtained during FEA of the CROPS under investigation is shown.

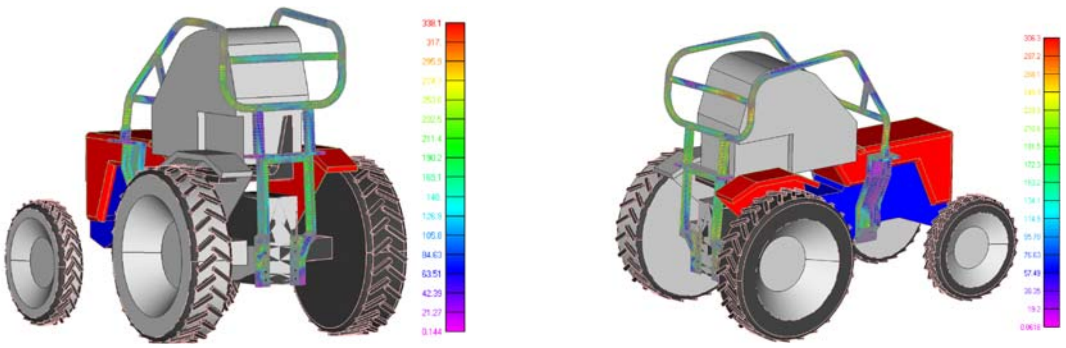

Figure 3. CROPS's FEA contour diagrams: side test (on the left) - longitudinal test (on the right)

CROPS physical prototype

Once the finite element analysis has been performed, the CROPS virtual prototype undergoes changes related to its mechanical behaviour (e.g. some reinforcement are added, its width is increased, etc.) in order to fulfil the acceptance criteria of the test method applied.

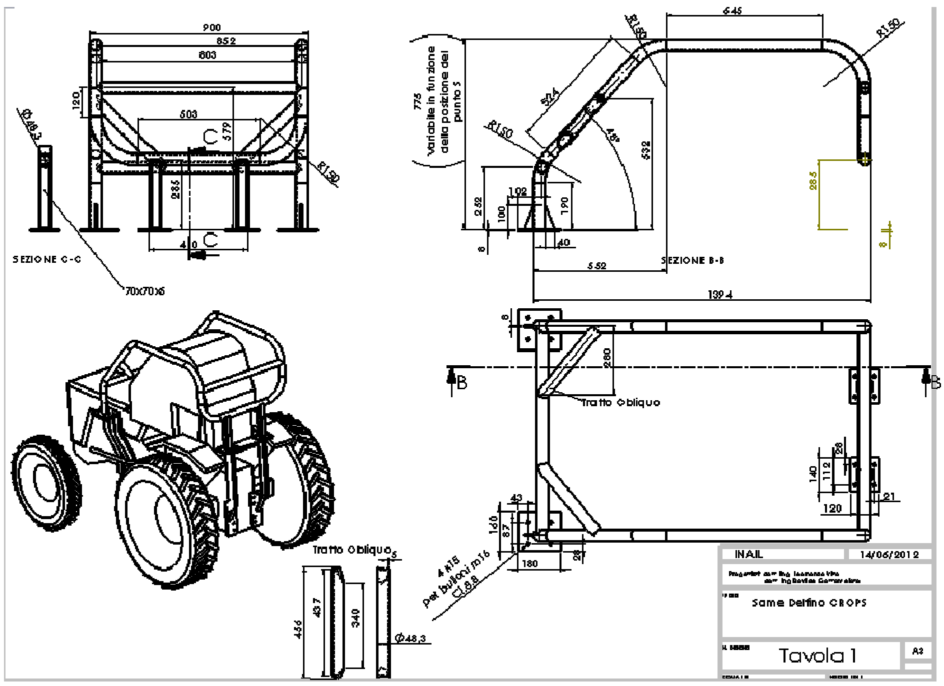

Figure 4. CROPS preliminary blueprint

Then, the working drawings are elaborated and submitted to the mechanical workshop in order to realize the physical prototype (see figure 4). The compact roll over protective structure herein presented has been realized by means of steel circular tubular having a diameter of 48,3 mm and a thickness of 5 mm. The overall width in transversal direction is 900 mm, its height from the seat index point is 847 mm and its length in longitudinal direction is 1394 mm. The tractor chosen to be equipped with this structure is an old Same Delfino not equipped with a roll-over protective structure. In figure 5 the CROPS installed on the aforementioned tractor is depicted.

Figure 5. Physical prototype of CROPS installed on a Same Delfino

Results

The first result achieved consists in a reduction of the overall height of the tractor from the ground of about 350 mm with respect the same tractor equipped with a two posts front mounted foldable ROPS compliant to the INAIL national guide lines (see figure 6).

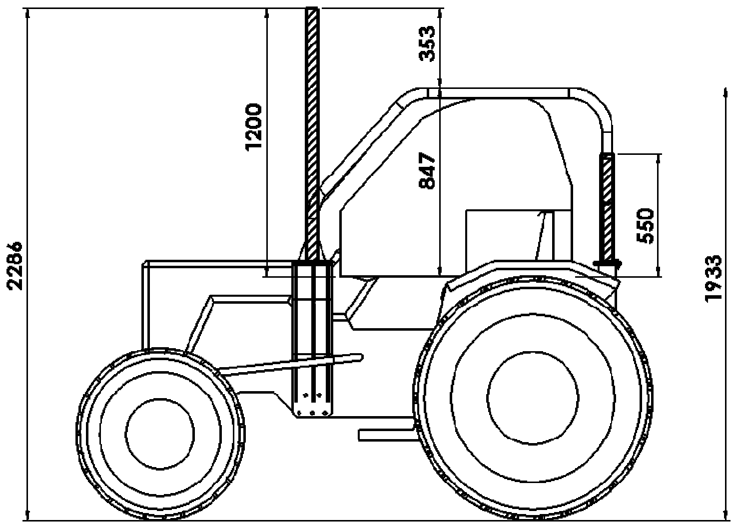

Figure 6. Tractor overall height reduction

The shape of the CROPS has been modelled in such a way that it could easier the work under trees or in greenhouses. This aspect will be deeply investigated during in-field handling tests. In fact, this research activity will be developed by the agriculture, forest nature and energy dept. of University of Tuscia. In particular, different models of CROPS will be tested in vineyard, hazelnuts field and olive tree grove in order to verify their effectiveness and, eventually, to characterize how to optimize their shape. For what concerns ergonomic aspects, it seems that no particular hindrances emerged in stepping on/off tractor or in remaining seated at the operator station with tractor staying still for the CROPS realized (see figure 7).

Figure 7. Operator seated on tractor with CROPS

Conclusion

From a technical point of view, the use of ANSI/ASAE S478:1995 clearance zone allowed to reduce the overall height of the tractor equipped with the CROPS under investigation of about 50 mm more than a CROPS designed on a OECD code 7 clearance zone. It is now important to investigate in the next step of the research activity if this further reduction has a significant impact on the results of the in-field handling test. Then, other important aspects have to be taken into account for a complete analysis of these compact structures before proposing them for installing on old tractors: ergonomics, moreover during step on/off the tractor, and visibility.

First feedback from users in the hazelnut sector seems to be positive, but a wider analysis is necessary. As far as costs are concerned, a detailed analysis could not be carried out yet, since only several prototypes were prepared so far. Anyway the cost of these handcrafts is comparable with the cost for realizing a two posts front mounted ROPS compliant with INAIL national guide lines.

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Roll over risk analysis for agricultural self-propelled ride-on machines

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Abstract
Many agricultural self-propelled machines present roll-over risk without fitting a ROPS. This problem has been aroused by the Italian occupational safety authority (INAIL ex ISPESL) and, nowadays, a specific standard EN ISO 16231 has being developed concerning roll over risk assessment and technical measures to reduce it. In the mean time, INAIL ex ISPESL during its market surveillance activity had to deal with several machines which were not in compliance with the essential health and safety requirements *3.4.3 roll-over and tip-over* of annex I of directive 2006/42/EC. The main typologies of the encountered machines were grape harvester, hazelnut harvester, liquid fertilizer sprayers and hay rakes. In many of these cases the roll over risk was not deeply investigated by the manufacturer even if it was accounted for. The experimental research developed is based on some information collected in the national agricultural information system data base enriched by the information acquired from a detailed satellite map of Italy interlaced with a global position system analysis. The main target to achieve is to arrange the soil where the crops normally grow in Italy in slope ranges with respect to the agricultural self-propelled ride-on machines used on. Results obtained allowed us to arrange proper technical comments to be submitted to the ISO working group during the development of EN ISO 16231.

Keywords: required static stability angle, crops typical angle, soil mesh, machinery safety

Introduction

The ever increasing importance of safety in the agriculture and forestry fields has been characterizing this sector both from equipment manufacturers and from users point of view. This is mainly due to the latest developments of legislation and standards in the sector, concerning both occupational safety and machine safety, as well as machinery safety.
During market surveillance activity the Italian national authority (INAIL) encountered many agricultural self-propelled machines with a seated operator which present tip or roll over risk during normal working conditions without fitting proper tip/roll over protective structures (TOPS/ROPS) (see figure 1). The variety of agricultural works carried out by companies, the use of obsolete equipment, as well as the continuous change of workplaces are by themselves factors which make the management of agricultural activities more difficult to deal with. From engineering point of view, this goal can be achieved taking into account both manufacturers and users perspectives. From compagnie' point of view, difficulties related with the implementation of safety measures appear to be quite numerous, especially due to the

fact that more than the 80% of enterprises operating in the agricultural sector in Italy are small and medium sized companies (SMEs), or even companies run by family members. This situation certainly leads to hindrances in affording costs for the being always in compliance with safety requirements and best practices. At the same time, the main reason accounted by manufacturers for not installing a proper TOPS/ROPS is based on a lack of technical information concerning how to test, and consequently design and develop protective structures for the manifold typologies of this kind of agricultural machines. Nowadays a specific standard EN ISO 16231 is under development in order to deal with the roll over risk assessment of these machines (part 1) and to define specific testing methods for their protective structures (part 2). In particular, the first step of risk assessment procedure, as defined in part 1, requires to evaluate the static stability angle of the agricultural self-propelled machine and to compare it with a reference value. The reference values for the static stability angle is specific for each typology of machine and they shall take into account the operating slope of the machines, with particular reference to:

- the cultivation they work on,
- the dynamic effects which could lead to a roll over;
- etc.

Moreover, if the static stability angle of the machine is greater than the static stability reference value, the roll rover risk is considered as not relevant for that kind of machine, and no technical measures shall be taken. Thus, it is particular important to identify the real and most common operating slope for each kind of machine, because it represents the starting value to define the threshold static stability angle magnifying it by a specific safety factor.

Figure 1. Examples of roll over accidents of agricultural self-propelled machines

For this reason INAIL with the technical support of Department of Rural Development of Italian Ministry of Agriculture has developed a specific investigation, which is still in progress, in order to define the typical slope of the principal cultivation in Italy. This paper deals with the description of the methodology applied for acquiring these data and the discussion of the first results obtained.

Methods

The developed investigation is based on some information collected in the national agricultural information system data base (POPOLUS) enriched by the information acquired from a detailed satellite map of Italy interlaced with a global position system analysis. The method applied could be summarized in the following points:

1. definitions of the range of the operating slopes;
2. mapping of the the agricultural soil according to the range defined in 1;
3. merging resuls of the analyzed cultivations together with the defined slope range;
4. evaluation of the maximum slope for each cultivation.

Range of operating slopes

For a first rough classification of the possible operating slopes, the following three gradients have been chosen:

a. slight slope – gradient up to 20°;
b. medium slope – gradient greater than 20° and up to 35°;
c. steep slope – gradient greater than 35°.

Generally speaking, the slight slope is the gradient where it is expected to encounter the higher number of cultivations. It is important to underline that these gradients are only static values since they represent the gradient on which the agricultural machines specific for that cultivation are asked to work on.

Agricultural soil mapping

In order to evaluate the operating slope, the satellite view of the Italian agricultural soil has been meshed by means of specific identification points (nodes). By means of a global positioning system (GPS) analysis for each of those nodes the exact location and altitude with respect see level has been evaluated. Thus, the soil has been mapped by means of a more o less square mesh having a distance of 20 meters between adjacent nodes and a geographical unit has been identified. For each geographical unit, represented by a grid of 9 adjacent nodes, the maximum gradient has been evaluated as follows:

- the gradient between node 0 and node *i* is calculated as in formula (1):

$$P_{0i} = \left| \frac{(Q_i - Q_0)}{d} * 100 \right| \qquad (1)$$

- the gradient between node 0 and node *j* is evaluated as in formula (2):

$$P_{0j} = \left| \frac{(Q_j - Q_0)}{d * \sqrt{2}} * 100 \right| \qquad (2)$$

In the above mentioned formulas:

d is the distance between nodes in the digital map of the soil;
Q_i represents the altitude on sea level at *i* node;
i represents the number of even nodes *(i* = 1, 3, 5 and 7);
j represents the number of odd nodes (*j* = 2, 4, 6 and 8).

A scheme of the grid representing a geographical unit is shown in Figure 2.

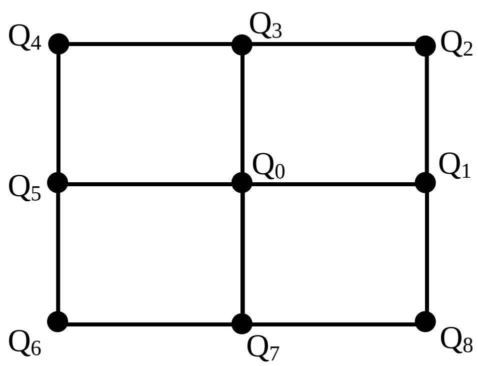

Figure 2. Geographical unit

Then the maximum gradient of the geographical unit is obtained by using formula (3):

$$P_{max} = max[P_{oi}] \text{ with } i = 0,..,8 \qquad (3).$$

Therefore each geographical unit is linked to the proper slope gradient (slight, medium or steep).

<u>*Gradient of cultivations*</u>

Once classified the slope gradient for each geographical unit, it is necessary to correlate it to the specific cultivation which is contained. For this purpose the cultivations' data base of the Italian Ministry of Agriculture has been used. Such data base uses the same soil grid described before. Thus, once defined the exact location of the geographical unit nodes by GPS reference, it is possible to classify the crop tillage for each region according to the aforementioned slope gradient and, consequently, to identify the operating slope of the machines involved in the cultivation working process.

Results

The main cultivations which were analyzed are the followings: cereals (maize, corn, rise, etc.), soy, sugar beets and vegetable garden products (tomatoes, potatoes, courgette, etc.). From first results of the research work carried out it emerged that the only cultures which grow on medium slope (greater than 20° and up to 35°) are corn and some vegetables. Over 35° there are mainly grasslands and orchards for domestic use. On slight slope (up to 20°) it is possible to find all the main cultures tilled in Italy. Some examples of this type of machines are shown in figure 3.

Figure 3. Examples of agricultural self-propelled machines

The most widespread among cereals are corn and maize, significant are also sunflower fields, soy and vegetables.
From the operative point of view, it came out that a large number of the agricultural self-propelled machines are involved in the working process of these kind of crops, such as:

- harvesting machines (such as combine harvester, grape harvester, sugar beet harvester, potato harvesters, etc.),
- self-propelled sprayers,
- self-propelled solid fertilizer spreader,
- self-propelled bale collecting vehicles,
- self-propelled mowers, etc.

From this first analysis, it is quite clear that since self-propelled agricultural machines are used at least on slight slopes, while specific harvester machines and self-propelled sprayers are used even on medium slopes, a large number of machines are used for works having a gradient of 20° or indeed higher. The use on steep slopes may involve only machines related to grassland, as for example self-propelled mowers.

Conclusion

The first data acquired from this investigation enable to set the minimum value of typical operative slope for agricultural self-propelled machines in 20°, which sould be used as basic gradient for their stability risk assessment. Continuing and refining the research should lead to better identify the maximum operative slope of the most common typologies of agricultural self-propelled machines, moreover in the range of slight and medium slopes. It is worthwhile to recall that the operating slopes represent the basis for the definition of the static stability threshold angles required for these machines. In fact, the operating slopes shall have to be weighted by a safety factor to take into account the dynamic effects of the working condition in the field and in the related environment. Thus, the safety factor is another key element of the static stability angles determination. For these reasons, in order to deep analyze the phenomenon it is foreseen a second phase of the investigation consisting in equipping the principal kind of these machines with a slope indicator recording system. In fact, the slope indicator recording system will allow us to compare the date acquired during working operations to the slope of the working field, already known, in order to better define a proper safety factor, even related to the typology of the machine and its working use in the field. The results already obtained and the further coming results will be used for elaborating an Italian technical comment to be discussed at the next EN ISO 16231 working group meeting.

Human reliability at electrical equipment service in agroindustry companies

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Abstract
Reliability of the electromechanical system couldn't be better than human reliability, so we must use information about human reliability in analysis of this kind of systems. Performance shaping factors (PSF) are differs from sector to sector so our aim is to choose PSF's for electrical equipment service workers using expert judgment, calculate PSF weights and develop model for working places examination and dynamic simulation of system degradation process using fuzzy sets theory. We have made expert survey in 2010 year for PSF choosing and weights calculating. The target group was middle-level management of the agroindustry companies and electrical equipment service companies. Using our SAM method modification we receive weights of PSF's and define core of them. The main factors, with respect of results of our survey, are: small experience of work, carelessness, badly formed specialist, unconscientiousness, bad emotional condition. So, we can use survey results for quantitive evaluation of reliability of "man-machine" systems.

Keywords: reliability, PSF, expert survey, fuzzy sets, hierarchy analysis method

Introduction

Usually the first place at electromechanical system reliability analysis take calculation of technical system reliability and this value using for decision making. But one of the most unreliable part of systems now is a man, and the losses, connected with "human factor" can be really huge. By the words of S.E. Magid, chief of «Technical educational systems in energy technologies» UNESCO department: "Number compelled faults of domestic power units because of equipment refusals on heat power stations is 30 %. The share of operational personnel fault in these infringements makes considerable size (to 15 %). As a whole in the RAO "United Power Systems" the infringements percentage because of the personnel from infringements total makes 2 %. At the same time, on power stations this quantity makes 18 %. In power supply systems of Siberia the relative quantity of infringements because of the personnel reaches 50 %." [Магид 2006].

So, we must have model for human reliability evaluation for personnel, taking part at electromechanical system assembly and service. Here under for "human reliability" we use definition: human reliability is a probability of (1) it carries out correctly some, demanded by system, action for demanded time and (2) doesn't carry out the superfluous actions, capable to lead to decrease in reliability of served system.

Materials and methods

We are spent expert survey in 2009-2010 where energy department's managers has been asked for feedback form completion. We received 47 fully filled questionnaires, and all of them used for work. For an estimation of human error possibility in the set conditions we are offered the approach consisting in paired comparison by experts of importance of negatively influencing factors for revealing of their relative scales [Гущинский, Рузанова, Гальченко, 2010]. In total it was offered to use 30 performance shaping factors (PSFs) effect on the personnel serving the power equipment, that concern six groups: psychological, social, external industrial, physiological, an equipment condition, qualification.

We represent questions as a scales, where center is an equal influence degree of two PSF's on worker, and the ends – maximal degree of influence by near written to mark of expert PSF under second. For example, on fig.1 expert is offered to compare two factors from "External industrial" group: noise and lighting.

Figure 1.Example of scale for noise and lightning comparision

Expert mark three point – maximum, expect and minimal influence, so, we have triangle fuzzy number, that we can use for our purposes. Because of some PSF's are noncomparable, and for question count reduction we compares factors contained in one groups, and ask to compare groups of factors. So, we have only 29 question for form, that reduce time of expert.

Results are coded in table, using scale [1/9,9], where 1 represent equal level of influence.

For survey results processing we used the SAM method [Hsi-Mei Hsu, Chen-Tung Chen 1996], where the distance between the triangular fuzzy numbers, calculated under formulas (1) — (3).

$$S(\tilde{R}_i, \tilde{R}_j) = \frac{\tilde{R}_i}{\tilde{R}_j} \quad (1)$$

$$Val(S) = \frac{(\bar{S} + 4 \cdot \dot{S} + \underline{S})}{6} \quad (2)$$

$$D = \begin{cases} Val(S), Val(S) \le 1; \\ \dfrac{1}{Val(S)}, Val(S) > 1 \end{cases} \quad (3)$$

Where $\tilde{R}$- the fuzzy number corresponding to an expert estimation of the superiority of one factor over another, S — a measure of same factor estimation by the different experts, D — defuzzifying distance, degree of distinction of expert estimations.

For models triangulation method we used hierarchy analysis method (HAM) [Ногин, 2007]. First, we defuzzify numbers using (2) for groups and PSF's relative weights. On second stage we calculate pair compared matrix. For this purpose weights of PSF's were recalculates by (4)

$$rw_{ij} = \sqrt{rwd_{ij} \cdot rwg_j} \quad (4)$$

where *rw* – PSF relative weight, *rwd* – "dirty" PSF relative weight from questionnaire, *rwg* – group of PSF relative weight from questionnaire, *j=1..6* – group number.

For aggregation of experts choices we used information about groups of factors weights from questionnaire and expected group relative weight, calculating by (5).

$$EW_j = \sqrt[k]{\prod_{i=1}^{k} rwd_{ij}} \quad (5)$$

where *k* – PSF's count in group, *j=1..6* – group number.

Quality of every expert work we evaluate with measure, calculating by formula (6):

$$Q = \begin{cases} \prod_{j=1}^{6} \frac{EW_j}{rwg_j}, Qvalue \leq 1; \\ \prod_{j=1}^{6} \frac{rwg_j}{EW_j}, Qvalue > 1. \end{cases} \quad (6)$$

Quality of expert work is a number in [0,1] and 1 match up great expert work: expected weights of all groups are equal to weights from questionnaire. In our case about half of experts (46%) have quality Q>0.8, and about 70% have Q>0.6. So, we can say that most part of questionnaires can be used for aggregation and quality of survey is good.

After calculation of weight vector for each expert by HAM method [Ногин, 2007] we aggregate this values, using weighted arithmetic average for each PSF and groups of PSF's. Results of weights calculation can be found at table 1.

Table 1: Weights of PSF's groups, two methods

Group	Weight, HAM	Weight, SAM
External industrial	9%	1,00
Psychological	20%	2,30
Physiology	12%	1,12
Social	12%	1,18
Equipment condition	22%	2,21
Qualification	25%	2,78

Results are quite equal, so we can conclude that methods are correct and choosing survey method guarantee quality results on groups of PSF's level. We can conclude, that qualification, equipment condition and psychological factors are gives about 67% for human failure and must be corrected firstly.

For PSF's we have more complex problem: our experts has slightly different types of work, so marks for concrete PSF's can reflect nature of concrete type of workplaces. So, we have deviations between results of two methods (Table 2).

Table 2: PSF's with highest weights and ranks

Group	PSF	Weight, HAM	Weight, SAM	Rank, weight HAM	Rank, weight SAM	Rank difference
External industrial	Bad lightning	5,01%	1,71	1	8	-7
External industrial	Low/high temperature at working place	4,42%	1,55	7	9	-2
Psychological	Inadvertency	4,73%	2,92	4	2	2
Psychological	Shortcoming	4,70%	2,83	5	4	1
Psychological	Bad emotional condition	4,18%	2,51	8	6	2
Psychological	Bad educability	4,05%	2,33	9	7	2
Qualification	Badly formed	4,94%	2,86	2	3	-1
Qualification	The small experience of work	4,94%	3,00	3	1	2
Qualification	Absence of the admission	4,68%	2,71	6	5	1
Total		41,65%				

Results shown that specialist with small experience of work and badly formed specialist are unreliable and theirs work places must be formed taking into account this fact. But, inadvertency and shortcoming gives dangerous situation for human reliability. So, using tables for PSF's and PSF's, HR specialist can recruit personnel on more scientific basis, using tests and probation period results.

For human reliability value calculation statistical data or simulation data needs. Main problem for this part of work became falsification of this kind of data on enterprises or assignment it to commercial classified information. At [Pekka, 2000] can be find model, based on logistic distribution for human failure probability and some remarks for model validity. Using this model as base we try to simulate results for it and model, constructed on our PSF's and PSF's groups with the similar description [Гущинский, Липатов, 2012] (7), where all variables in [0,4] interval.

w_1 — Expressiveness of a sluggishness,
w_3 — A skill level of the personnel,
w_4 — An estimation of complexity of the equipment,
w_5 — An estimation of a condition of the equipment,
w_6 — Degree of expressiveness of negative psychological factors.

$$p = \frac{e^{2.67-0.29\cdot w_1-0.48\cdot w_3-0.33\cdot w_4-0.38\cdot w_5-0.40\cdot w_6}}{1+e^{2.67-0.29\cdot w_1-0.48\cdot w_3-0.33\cdot w_4-0.38\cdot w_5-0.40\cdot w_6}} \quad (7)$$

Models shows similar results. Using this fact we can suppose, that sigmoid function with HAM weights can be used for calculation of human reliability, using full set of parameters with undefined constant C (8).

$$p = \frac{e^{C-\sum_{i=1}^{30} w_i\cdot(x_i-xp_i)}}{1+e^{C-\sum_{i=1}^{30} w_i\cdot(x_i-xp_i)}} \quad (8)$$

where w_i – PSF weight, calculated with HAM, x_i – estimation of PSF intensity, $x_i \in [0,9]$ xp_i – estimation of PSF intensity liminal value (minimal value of intensity, influenced on worker), $xp_i \in [0,9]$. When x_i=0 for all *i* human error probability must be near zero, and when x_i=9 for all *i* human error probability must be near zero. This conditions gives us possibility to find diapason of *C*, and this diapason [2.2, 4.6]. On this interval probability on ends of PSF values intervals looks as shown on fig. 2. So, we can conclude that on the ends of intervals with *C* variation *p* grows smoothly and chosen interval can be recommend for *p* evaluation.

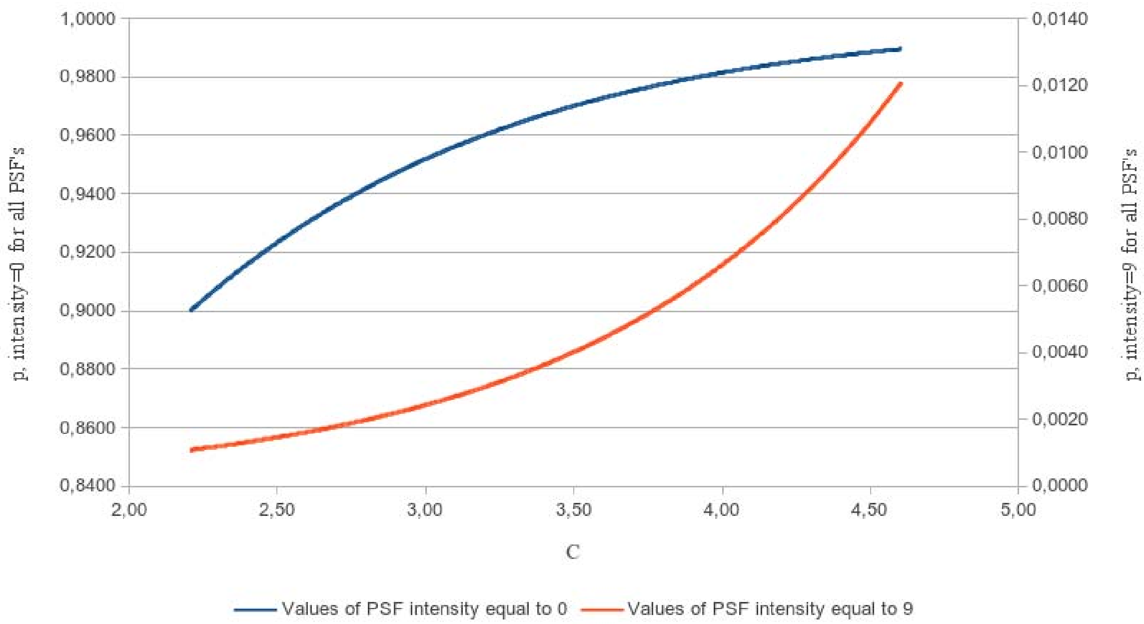

Figure 2.Human error probabilities on the end of PSF intensivity intervals, C variation

Questionnaire for experts have parts, where experts marked estimation of PSF intensity liminal value and shows level of equipment failures at 5-balls scale. Only 39 questionnaires had this part filled. Thats why we binned 5-balls scale on two parts: from 1 to 3 – failures rating more average, and from 4 to 5 – low failure rating.

For *C*=3.5 analisys with KNIME [7] shown, that predictability in this binary scale is good: accuracy of model is 67%, so we can use this model with coefficient *C*=3.5 (9) in described above cases.

$$p = \frac{e^{3.5-\sum_{i=1}^{30} w_i \cdot (x_i - xp_i)}}{1 + e^{3.5-\sum_{i=1}^{30} w_i \cdot (x_i - xp_i)}} \tag{9}$$

Results

Our experts choose only some PSF as main. As we see, the qualification, psychological factors are the main at the PSF's structure. So, skills and characteristics, mentioned above (table 1, 2) must be corrected firstly at departments. Using this set of characteristics we can calculate human reliability.

Conclusion

Now we work under more complex dynamical model and multiagent simulation, where time-factor can be allowed. More, we try to use more complex models for error possibility, that can use information of one factor intensity strengthening depending from others.

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Environmental assessment of livestock farms: a comparison of different methods to estimate emissions to air

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Abstract

Emissions to air, water, soil resulting from livestock are determined mainly by manure handling. In order to evaluate the environmental impact from livestock farms and to identify possible actions to reduce pollution sources, suitable methods, generally based on models, should be applied.

The aim of the work is to compare the air emissions values obtained using different methods in practical farms in order to improve the applicability of the methods and support an objective assessment of a farm. Ammonia (NH_3), methane (CH_4), nitrous oxide (N_2O), PM10 and PM2.5 are pollutants calculated by the models. For the comparison we used data from eight farms subjected to Integrated Pollution Prevention and Control (IPPC) procedure, collected from the applications and verified visiting the farms in connection with the official routine inspections.

Keywords: pollution, air pollutant, models, IPPC

Introduction

Agriculture is considered as one of the productive sectors most responsible for diffuse source of pollution to the atmosphere, surface water and groundwater. This is due to emissions from agricultural practices, in fact, nitrogen and phosphorus are essential for crops, but they can be leach into the water, especially when they are distribute unequally or in larger quantities to the crops requirements (Provolo G., 2005).

Among agricultural activities, the livestock sector is the most critical, because it produces large quantities of manure, increasing the risk of inadequate management, with consequently more pollution from agriculture (Magette, 2001). Animal manure represents the main share of pollution of farms (Merkel J. A., 1981).

The main air emissions from farms are: methane (CH_4) produced by ruminal digestion and stored manure, ammonia (NH_3) and carbon dioxide (CO_2) as a result of animal respiration and manure stored. Finally, during the spreading phase produces losses of NH_3 volatilization and nitrous oxide (N_2O). NH_3 causes acidification of soil and water. Approximately, 90% of NH_3 emissions are due to agriculture, in several European countries, 40% of which coming from animal housing and manure storage (Rigolot et al., 2010). CO_2 emissions in agriculture is negligible because it is derived mainly from burning fossil fuels. The amounts of CH_4 and N_2O emitted to the atmosphere are low compared to CO_2, but their global warming potentials are, respectively, 21 and 310 times higher than that of CO_2. Within the European Union, agriculture has been estimated to contribute 49% of anthropogenic CH_4 emissions and 63% of N_2O emissions (Sommer et al., 2004). The extreme involvement of agriculture and livestock farming on environmental issues, involves using computer models to estimate the pollutants emissions of during farm activities. These models can be used both to highlight the criticality of the farms and to establish sustainable manure management systems (Burton and Turner, 2003).

In recent years several models have been developed for estimating NH_3 emitted and greenhouse gases. Hutchings et al. (2001), Groenwold et al. (2002), Luesink et al. (2004), Menzi et al. (2003), Reidy et al. (2003), Webb and Misselbrook (2004) have developed model for estimating emissions of NH_3 for different types of livestock such as pigs, dairy cattle, beef cattle and poultry in various European countries. The algorithms in the just mentioned models consider the different management activities of grazing (for cattle), housing, storage and spreading.

Pinder et al. (2004) and Van Evert et al. (2003) have developed models for the estimation of NH_3 exclusively for dairy cows. They have studied the emission more accurately for pasture. Dammgen et al. (2003) has developed a model that calculates NH_3 emitted but also the main greenhouse gases including CH_4, for the storage phase, and N_2O after spreading. These pollutants were also estimated by Sommer et al. (2004) and by Rigolot et al. (2010) using algorithms derived from emission inventories IPCC (Intergovernmental Panel on Climate Change) and CORINAIR (Coordination Information AIR). These algorithms have been integrated with specific parameters and variation factor. Reidy et al. (2008 and 2009) have compared the above mentioned models and estimated the NH_3 emitted, highlighting and explaining the differences obtained.

The aim of this paper is to compare the emissions to air from livestock farms using the IPCC (CH_4) and Corinair (NH_3, N_2O, PM_{10} e $PM_{2.5}$) approach in comparison with specifically developed models (Erica and ValorE) in order to analyze the differences between the methods, motivating, and evaluating the effect of more detailed emission factors contained in Erica and ValorE.

Materials and methods

This paper considers various models for the calculation of emissions in the atmosphere, with different degrees of complexity, including the EMEP / CORINAIR Tier 1 and Tier 2 (Dammagen and Webb, 2006) (emission inventory guidebook 2009, updated June 2010) by estimating the NH_3, N_2O, PM_{10} and $PM_{2.5}$ while for the estimation of CH_4 was used the IPCC tier 1 and Tier 2 (inventory 2006). Furthermore, we used two specific models: Erica and ValorE, developed by Lombardy Region, the first to support IPPC applications and the second for expert systems to improve the management of livestock manure and the environmental protection of the territory of Lombardy, these models estimate NH_3, CH_4 e N_2O.

These methods have been applied to eight farms where detailed information about manure management has been collected by direct survey.

Description of models and corresponding algorithms

<u>*IPCC e Corinair*</u>

Tier 1 is a simplified approach where the emissions are calculated by multiplying livestock heads by emission factors (EF) per animal (Buijsman et al., 1987), the Coinair EF depends on the livestock category and manure type (slurry or solid), while IPCC Tier 1 EF depends on the livestock category, average annual temperature and regional characteristics.

Tier 2 is a more specific approach. Corinair uses EF for housing (grazing, indoor and outdoor), storage (specific parameters for manure management systems) and spreading. The emissions in the Tier 2 depend also from total nitrogen and total ammoniacal nitrogen (TAN) which are contained in the manure. In the IPCC approach the EF depends from several parameters, like volatile solids (SV) excreted by livestock, manure type and storage systems.

Erica e ValorE

Unlike above methods, the Erica and ValorE models use more diversified EF for each stage. Additionally they share in a more accurate way livestock categories (mainly for pigs and cattle), and require information about animal feeding to calculate more accurately the nitrogen excreted.

Algorithms for the estimation of ammonia (comparison Erica/ValorE and Corinair)

- In Corinair the nitrogen excretion is a default data, while In Erica and ValorE it is calculated with specific algorithms based on the ingestion and retention (this factor depend on the quantity of protein in the feed and on livestock categories)
- Nitrogen mineralization rate: it varies from 60% to 70% in Corinair, while in ERICA the percentage is 57%.
- The emission algorithm of ammonia from housing is different between the methods, in Erica and ValorE, EF depends both the animal category and the type of structure (mainly the floor type), while in Corinair EF depends on livestock category and manure type.
- The emission algorithm of ammonia from storage is different between the methods, particularly EF, in Erica and ValorE the parameters depend on the storage type, while in Corinair the EF depends on livestock category and manure type. Moreover the emission algorithm in Erica and ValorE contains a coefficient to consider the storage duration.
- The emission algorithm of ammonia from spreading is different between the methods, particularly EF, in Erica and ValorE the parameters depend on spreading type, while in Corinair the EF depends on livestock category and manure type.

Algorithms for the estimation of nitrous oxide (comparison Erica,ValorE and Corinair)

- The emissions are estimated by Corinair and ValorE exclusively for the storage phase and only for the solid manure, EFs slurry are very low therefore inconsiderable, while in Erica the emissions are estimated both during the storage phase and after spreading in field.
- EFs storage are not always homogenous between the models.
- The EF storage depends mainly on livestock category for Corinair, however for Erica and ValorE it depends on storage type.

Algorithms for the estimation of methane (comparison Erica/ValorE and IPCC)

- The values of volatile solids (VS) are default data for IPCC Tier 2 and they depend on the livestock category and the regional characteristics, while in Erica and ValorE the VS are calculated by the specific Bref factors (BAT reference documents).
- In Erica and ValorE the emission algorithm are modulated according to the storage duration. On the contrary, IPCC do not considered this aspect.
- In IPCC Tier 2 algorithm the methane conversion factors (MCF) is the same of EF in Erica, but for some storage types (e.g. storage tank and Lagoon) this parameter is different between methods.

Results and discussion

Comparison of model results

The comparison of the models showed significant differences for each pollutant. These variations depend on the parameters and algorithms contained in the models. Below are described and justified the differences between the methods analyzed.

NH_3: Figure 1 shows as Corinair model assumes similar values for both Tier 1 (simplified method) and Tier 2 (specific method). The parameters used by Tier 1 are the animals number,

livestock category and standards EF while Tier 2, in addition to the parameters listed above, information of the manure management system are used. NH_3 emissions estimated with ValorE are always lower than Corinair, except farm A, the reason is that the parameters used by ValorE are more detailed for each farm, because the parameters contain information about feeding type and livestock housing, thus the detailed parameters of ValorE, compared to Corinair, decrease the estimate of NH_3 emissions. Erica model uses parameters and algorithms that are very similar to ValorE, but for some farms the values of Erica are higher, probably because some farms were not used BAT (best available techniques) in housing and storage structures, causing an increase of NH_3 emitted.

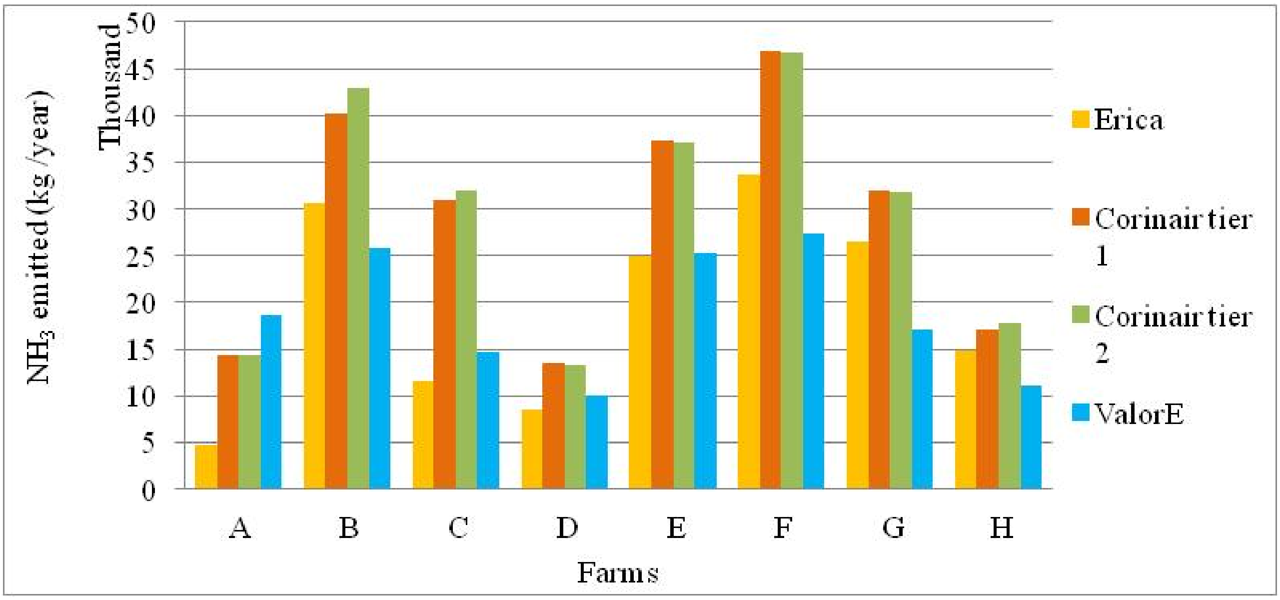

Figure 1. NH_3 emissions are estimated with the different models for each farm

<u>*CH_4*</u>: Figure 2 shows how the different emission values of the models. The estimated emissions with ValorE are always lower than IPCC, therefore the information and experimental parameters contained in ValorE decrease the values of CH_4 emissions in comparison with IPCC. However for Erica model the situation is uncertain, some results are similar to ValorE whereas others to Corinair, except farm G (farm with the highest number of breeding swine), where CH_4 emitted is the highest compared to other models. This result shows how Erica generates higher values when there are breeding swine. Finally, for IPCC model, Tier 1 shows values slightly higher than Tier 2, therefore the specific parameters of Tier 2 decrease the values of CH_4 emissions. Unlike the farm B (only farm which has dairy cattle), Tier 2 value is greater than Tier 1 value, this result shows how specific parameters of Tier 2 generate higher values when there are dairy cattle.

<u>*N_2O*</u>: Figure 3 shows that Erica model achieves higher values than other models, this is because Erica estimates N_2O emitted during storage phase and after spreading, while other models calculate N_2O emissions only during storage phase. Moreover Erica and ValorE calculate N_2O emissions for manure both slurry and solid manure whereas Corinair Tier 2 only for solid manure.

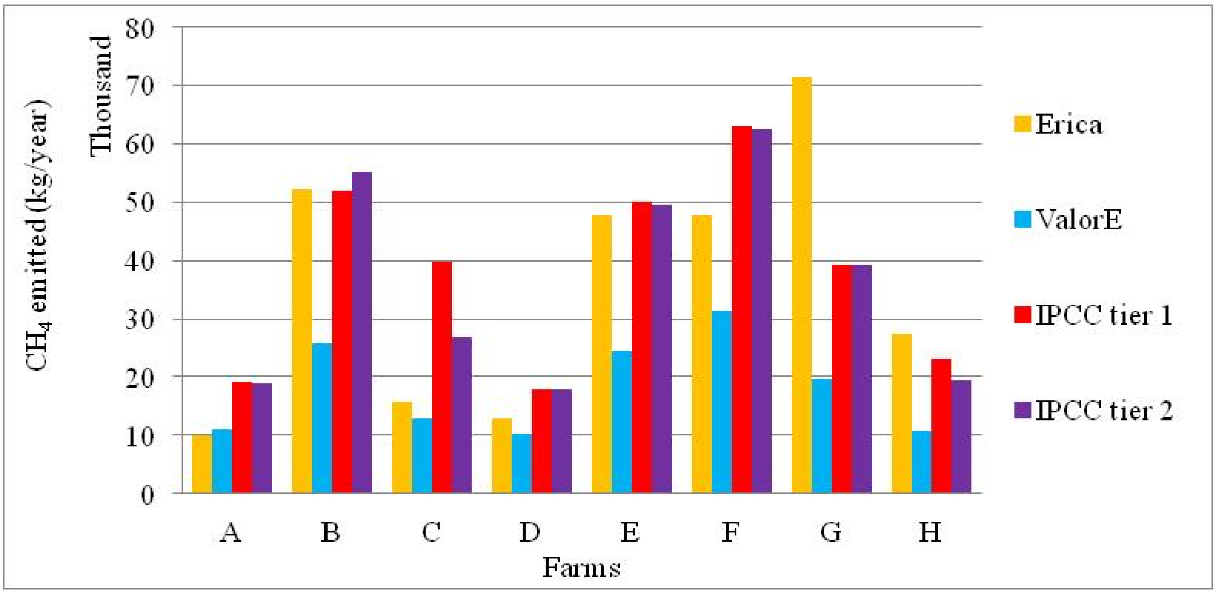

Figure 2. CH_4 emissions estimated with the different models for each farm, indicated by a letter

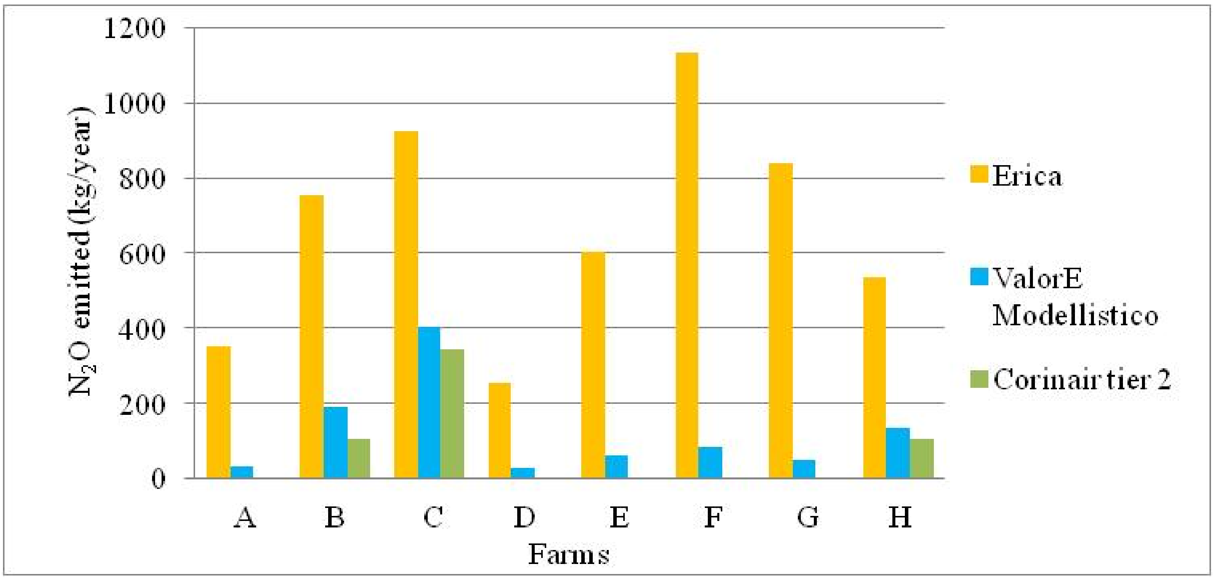

Figure 3. N_2O emissions estimated with the different models for each farm, indicated by a letter

PM_{10} and $PM_{2.5}$: The model used for the estimation of these pollutants is Corinair both with Tier 1 and Tier 2. Figure 4 shows that the results of Tier 2 are always more elevated then Tier 1, therefore the specific parameters of Tier 2 (e.g. storage time) increase the values of PM emission.

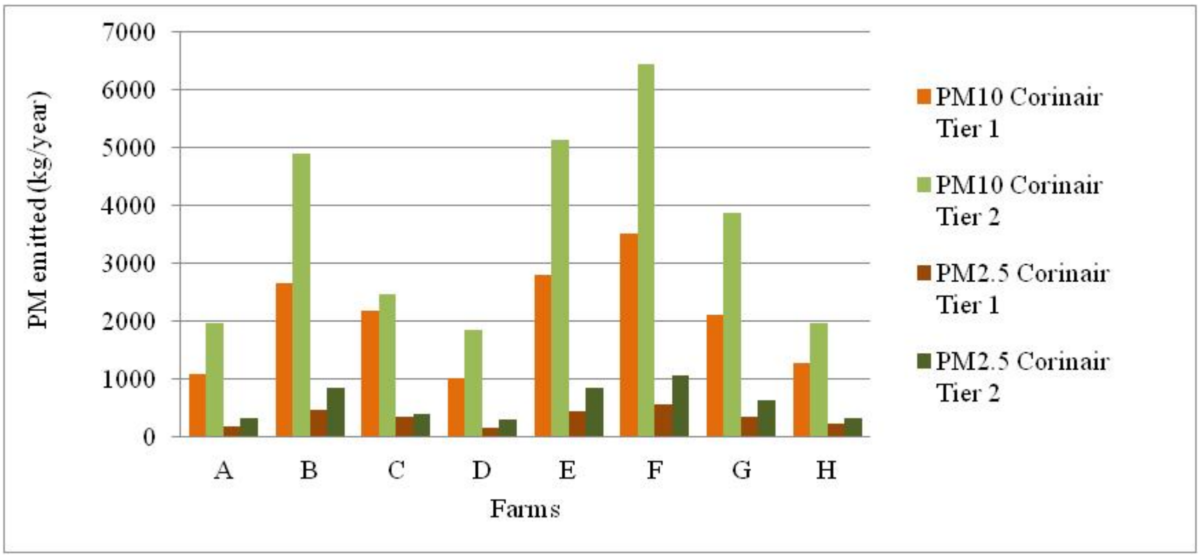

Figure 4. PM_{10} and $PM_{2.5}$ emissions estimated with the different models for each farm

Conclusions and perspectives

The comparison between the models showed differences in the results:

- NH_3: The estimates obtained with Corinair are always higher than the models Erica and ValorE, the latter have more specific parameters, they describe more accurately the farm situation. Thus increasing the detail of the model reduces the NH_3 emitted but it increases the errors and uncertainties, because the comparison between Erica and ValorE shows significant differences although the algorithms are very similar.
- CH_4: Estimated methane with IPCC Tier are very similar; the implementation of more detailed parameters of Tier 2 does not affect considerably the results. Comparison with other models used shows many discrepancies on CH_4 emitted.
- N_2O: The three methods used are incomparable because Erica estimates N_2O emitted during storage phase and after spreading, while other models calculate only during storage phase. Moreover Corinair Tier 2 estimate N_2O emitted only for solid manure.
- PM_{10} and $PM_{2.5}$: The implementation of more detailed parameters of Corinair Tier 2 increase the values of PM emission compared to Tier 1.

The use of different methods has shown that despite the results of the quantities of substances emitted is very different, the comparison between farms is always similar. This confirms the validity of these tools to identify the degree of reduction that can be achieved with mitigation techniques. However they must be used with caution to determine the absolute values of emissions.

Activity carried out in the framework of the project "Evaluation of manure management and treatment technology for environmental protection and sustainable livestock farming in Europe" (MANEV), LIFE09 ENV/ES/000453

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Topic 3

“Instrumentation, Equipment, Periodic Procedures and Tests”

Poster Presentation

Accident analysis during the chainsaw use: prevention and protection measures to reduce injuries

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Abstract

The chainsaw is a widely-used tool in agriculture, in forestry as well as for professional and hobby-related purposes. This article has the aim to highlight the state of injuries both for professional and domestic uses. As far as its methodologies are concerned, this study analyses and compares several data (including domestic data, statistical data, non-conventional data as well as news stories documenting chainsaw-related injuries). Our results are going to define and emphasise two key points: 40% of injuries are either serious or mortal, causing an average of 40 days of prognosis and permanent disabilities (including finger and toe amputation). Furthermore, it is confirmed that the operator's head is the most exposed area of the body and is often correlated with the death of the operator. (Death is often due to collision against the chainsaw blade, facial traumas as well as sudden contact with sharp parts of the plant). In conclusion, this article develops and proposes a fast-running software tool for evaluating competences both in forestry and in hobby-related matters. This software tool can be seen as a propaedeutic tool for risk management, both for professional and domestic uses.

Keywords: statistics data, chainsaw and electric saw, software

Introduction

Preliminary Remarks

Operating in woods might be highly dangerous as it takes place in hard environments because of slopes, uneven ground and the presence of the underwood that may prevent machines and operators from moving. This requires the use of highly dangerous machines and equipment, including sharp tools. The frequency of injuries is, therefore, 1.5 times higher (and their gravity is four times higher) than the average value in domestic industry and tertiary sectors, with an average value of four injuries causing permanent disability or death for every million of hours worked (I.N.A.I.L. source, 1996).

After a web-based research, this study considers all pieces of news concerning the use of a chainsaw. These include mortal and non-mortal deaths involving both skilled woodcutters and unskilled hobbyists. Moreover, this research has included both direct injuries (i.e. cuts) and indirect injuries that may be due to a fall from a ladder while trimming a hedge using a chainsaw. The chainsaw as well as all cutting tools may be a highly dangerous source of risk, both for foresters, farm operators as well as hobbyists because of possible contacts with moving parts (Cavazza, 2009).

According to FOEN, the Swiss Confederation's Federal Office for the Environment, several accidents occur each year while using a chainsaw and timber harvesting. Several of them are mortal. The main cause is often to be found in lack of knowledge, carelessness and lack of exercise:

- Most injuries involve persons without any background in forestry-related matters, who were working in woods during their free-time, or farmers who were carrying out complementary activities;
- In privately owned forests, the frequency of accidents is four times higher than the frequency in firms and logging companies;
- Very serious injuries have involved persons using a chainsaw for professional purposes or in their free-time, in particular during construction works, gardening, horticulture, maintenance and demolition.

(Refer to http://www.bafu.admin.ch/wald/01248/01253/index.html?lang=it)

Hence there was the need to develop a software tool that, through several tests – either theorical or practical – might prove the level of hobby-related and professional knowledge as well as background of the person who is going to use a chainsaw.

Materials & Methods

The research focused on web-based pieces of news published between 2007 and 2011 about mortal and non-mortal accidents occurred in Italy and involving people who were using a chainsaw. On the whole, 118 cases were collected over a 5-year period. The following parameters were identified for each single accident and later analysed in an Excel file:

- number of accident per year
- year in which the accident took place
- date
- Region, Province and cause of the accident
- age, profession and nationality of the injured person
- seat of the injury
- link with the news.

The analysis of some parameters required us to assign numeric codes reported as follows in order to allow your faster reading and data analysis.

DEAD/WOUNDED	
WOUNDED	1.00
DEAD	2.00
SEAT OF INJURY	
HAND	1.00
ARM	2.00
LEG	3.00
FOOT	4.00
HEAD	5.00
BODY TRUNK	6.00
NATIONALITY	
ITALIAN	1.00
RUMANIAN	2.00
MACEDONIAN	3.00
ALBANIAN	4.00

MOROCCAN	5.00
FOREIGNER	6.00
EVENT	
CONTACT WITH MOVING ELEMENTS OF CHAINSAW	1.00
CONTACT/BLOW/SQASHING DUE TO BRANCHES OR TREE TRUNK PARTS	2.00
INFARCT	3.00
FALLING	4.00
FULGURATION	5.00
BURNING	6.00

Table 1. Numeric Codes

Some news reported partially uncompleted data. Thus, we were not able to analyse each parameter for all 118 accidents.

Results

Consider each age group of persons involved in fatal accidents. It can be deduced that they mainly involve elderly people (aged 60 years or over) while using a chainsaw. All other age groups, 30 to 60 years, show a still high number of accidents, over 9 units. Consider that those figures also include several hobbyists and persons who use a chainsaw for unprofessional purposes.

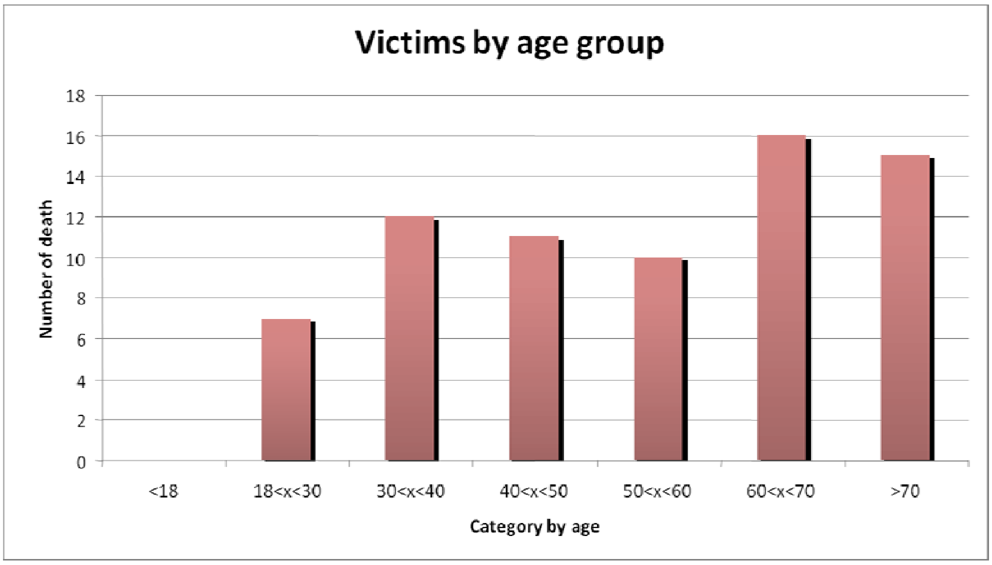


Figure 1. Age Groups

As far as wounded persons are concerned, two peaks involved age groups between 30 and 40 years (9 wounded persons) and between 60 and 70 years (12 wounded persons).

Probably, the former age group (30-40 years) includes several skilled loggers, whereas the latter one (60-70 years) involves several pensioners who use a chainsaw for hobby-related purposes.

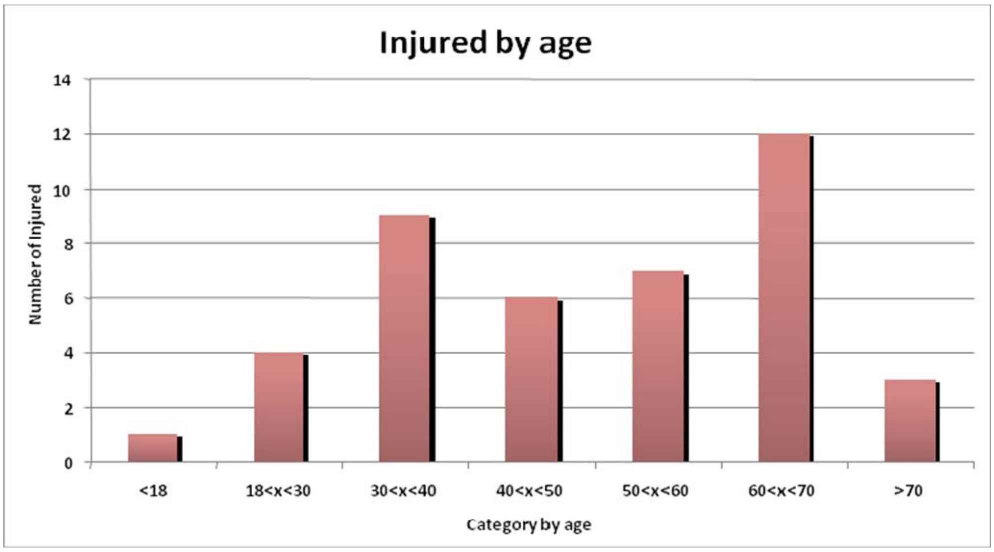


Figure 2. Wounded Persons

The sum of serious and mortal accidents per age group confirms that the age groups 30 to 40 and 60 to 70 years are the most prone to risks.

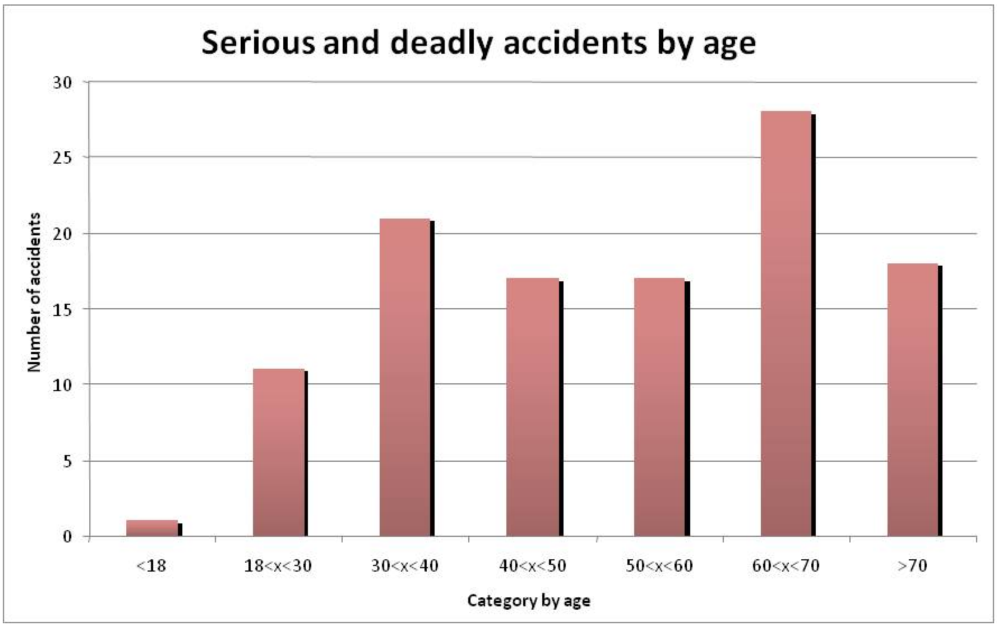


Figure 3. Accident by Age Group

If you get a closer look at the Regions where the accidents took place, the highest distribution is registered in Lombardy (23 accidents), followed by Tuscany, Trentino Alto-Adige and Liguria. In Southern-Italy, fewer accidents are registered. The only Regions where no accident took place over the five-year period considered are Valle D'Aosta and Basilicata.

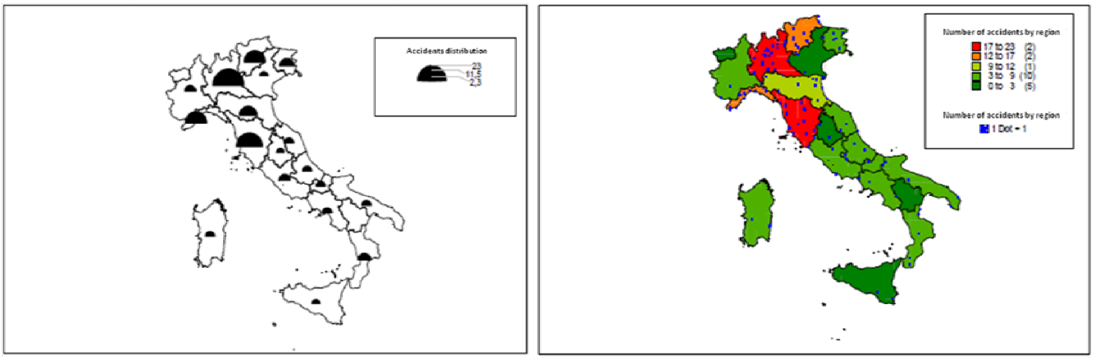


Figure 4. Accident Distribution by Region

The distribution of serious or mortal accidents shows a peak between January and April.

This is mostly due to trimming and cleaning and maintenance of green areas as well as loggers' professional activities, which is about to start. The number of accidents is expected to reduce in summer, whereas it strongly increases in autumn and drops again in winter.

Figure 5. Accident Distribution by Month

As far as the days of the week are concerned, Monday and Thursday (i.e. at the beginning and in the middle of the work-week) show the highest peaks; the lowest values are registered over the weekend.

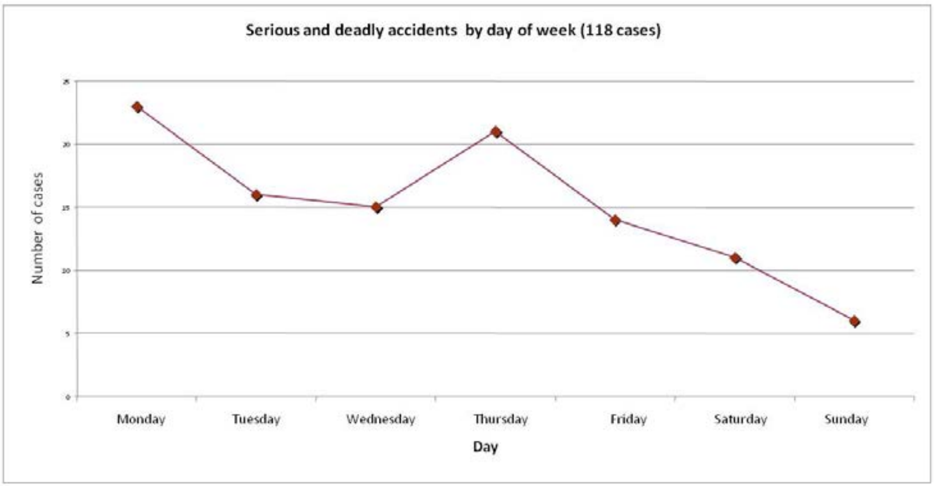


Figure 6. Accident and deaths distribution by day of week

The highest number of accidents is registered late in the morning, when, after working for a couple of hours, our attention may reduce, and after lunch, when digestion weighs us down and reduces our clear-headedness.

By analysing web-based data about the seat of the body which is mostly lesioned after non-mortal accidents, it is brought out that the use of chainsaw involves lower arts in 37% of cases and the head in 32% of cases. Furthermore, the number of cases due to accidents lesioning lower arts appears very high, with particular regard to hands.

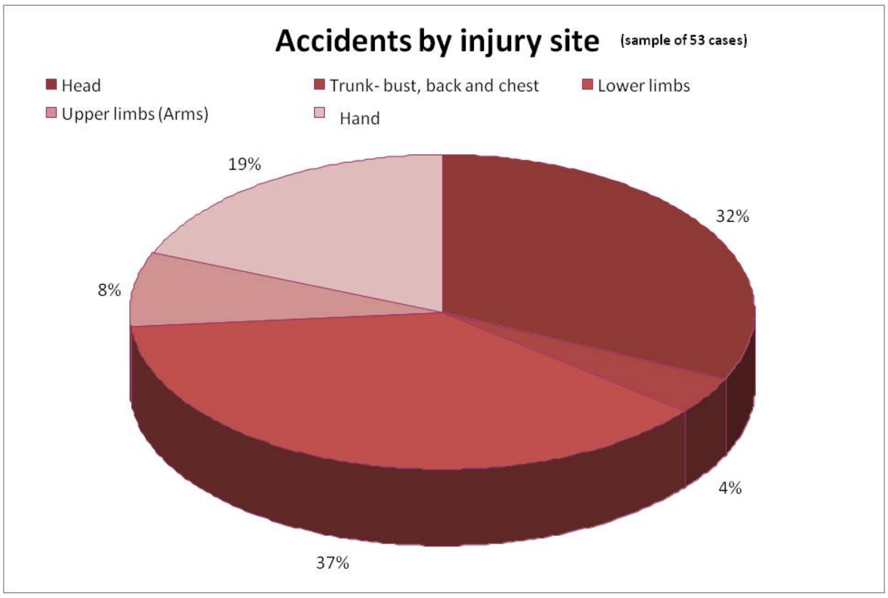


Figure 7. Accidents by injury site

On the other hand, if you get a look at total, serious or mortal accidents and compare them to the French Safety Institute's data, it is highlighted that legs are the mostly lesioned part of the body (30% of accidents), followed by hands (27% of accidents). The head and the arms then follow, each of them showing values around 14% and 12%, respectively. The comparison with French data seems to be quite consistent with.

The only differences are to be found in injuries involving hands, which, according to French statistical data, are not so high (22%), and feet, which, on the contrary, involve 15% of cases.

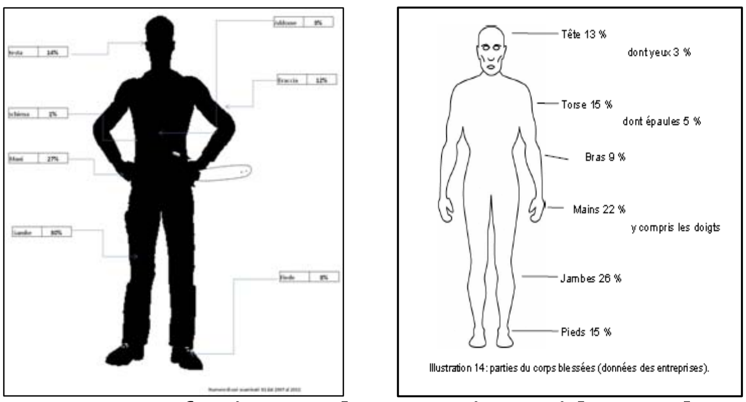


Figure 8. Seat of Injury and Comparison with French Data

Conclusions

Firstly, we deeply analysed and searched for accidents taking place in Italy between 2007 and 2011. By doing this, we were able to perceive how dangerous the chainsaw might be while being used. We later collected a series of key points pertaining education and training within foresters, with an eye to the use of the chainsaw.

We started by analysing handbooks by bodies (including Regions, Provinces, Municipalities, several chainsaw manufacturers, Institute of Higher Education for Prevention, Health and Safety at the Workplace, etc.). We later used the information we gathered to develop a model which enables us to verify and to certify the level of learning quickly, using Forestry Evaluation 1.0 Programme.

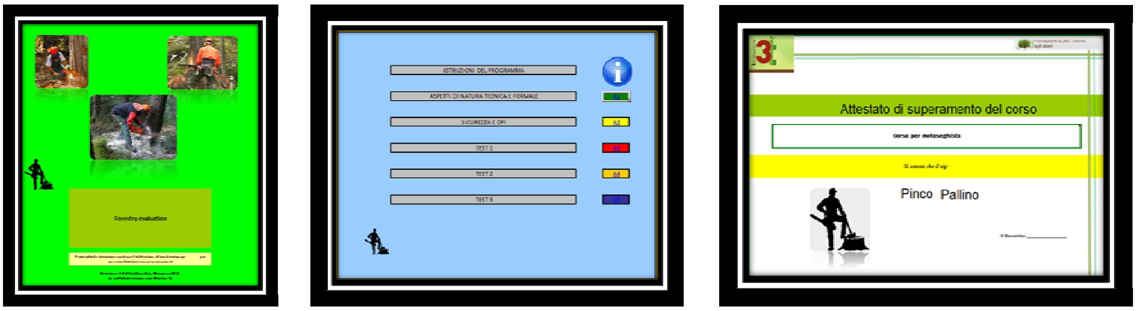
By doing this, whoever is going to use a chainsaw might previously evaluate, through a series of tests, his or her theorical background and technical capabilities before using a chainsaw.

Our aim is to standardise a test in order to validate training and information pertaining the use of this tool in safe conditions.

The programme is made up of five sessions. Those sessions assign a score. This indicates whether the minimum level of knowledge required has been achieved or not in order to be able to use a chainsaw.

After the welcoming screen, you have access to the programme and can choose among the following options:

- programme instructions
- information key
- test on formal, technical aspects
- test on safety and PPI
- test on chainsaw components
- two practical tests.



Picture 1. Introduction, Menu and Certificate of Diploma (in italian)

As previously pointed out, the test is composed of five sections. On the one hand, three sections are theorical and deal with safety, chainsaw and general working methods. On the other hand, the remaining two sections are merely practical and require the implementation of specific tests. The first section is a test for verifying the correct use and maintenance of the chainsaw from an operational point of view. For each test, the candidate has to indicate whether the tree questions are true or false.

After answering each question, the programme indicates if the test has been passed and if the candidate is allowed to have access to the following section.

The following section, containing several questions, aims at evaluating the operators’ level of knowledge on legal aspects, systems of prevention and protection as well as safety of the person who is going to use the chainsaw.

Even in this case, three answers are indicated for each single question. The candidate has to indicate if the questions are true or false. Basing on the number of correct answers, the test will be considered as passed or not.

The third section contains a test for recognising the parts of which a chainsaw is made up: the candidate has to combine words to numbers associated to chainsaw components. After answering the first three sections and passing each test, the candidate undergoes two practical tests.

Both technical tests are evaluated by the instructor through a series of given parameters, which are still present in the programme. By looking at the operation in the section and by analysing the information contained in the handbook on the operations, the tests can be assessed.

After passing all five sections, the candidate will receive a certificate attesting him or her to have passed the tests as well as the level of training he or she has achieved.

This will allow him or her to assess his or her capabilities – both practical and theorical – on the use of the chainsaw, thereby preventing accidents.

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Dynamic simulations to test the protective safety gloves: first results of a new methodological approach

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Abstract

Gloves are largely diffused as work tool in many activities. According to the Italian Law in force concerning health and safety at the workplace, the employer must endow of special PPE (Personal Protective Equipment) the workers (element not always effected) after the risk evaluation in which he has identified the characteristics of the ppe, according to the specifications of the work activities. On the market there are many brands of gloves with technical standards (EN 388 for protection against mechanical hazards and physical). However, there are still many accidents in which gloves didn't have the appropriate technical measures able to protect the worker. This search analyzes, through techniques for the evaluation planned for this study, the effectiveness of the gloves in real working conditions. From a methodological point of view, a protocol has been elaborated in order to test in the real sceneries the efficiency and the effectiveness of these PPE. First results show that the classes of resistance are not very often appraised by the employer and in this way the gloves used in agriculture don't always guarantee good performances in terms of effectiveness. Besides, the protocol defines a new methodic that could directly be gifted in the agricultural firm.

Keywords: PPE, choice, technical standards

Introduction

The use of equipments and tools in the agricultural sector expose the worker to high risks of crushing, perforation and abrasion of the hands, during the work activities. Insofar the first element that can protect and defend the worker is related to the use of specific and proper gloves. The cut performance of articles made of high performance materials is currently evaluated using several norm procedures (Rebouillat S., 2004).

The European EN388 Standard has been designed to assess the performance of a fabric or layers of fabric for their ability to withstand puncture, cuts, tearing and abrasions.

The test procedure includes a separate test for each of these qualities, and a performance level is awarded according to each test result.

The test procedure includes a separate test for each of these properties, and a performance level is awarded according to each test result, for example a material with an abrasion resistance of between 100 and 500 cycles would be awarded level 1.

The minimum test results required to achieve the various performance levels are listed in the table number 1.

TEST/PROPERTY	PERFORMANCE LEVEL				
	1	2	3	4	5
Abrasion Resistance-cycles	100	500	2000	8000	
Blade Cut Resistance-cut index	1,2	2,5	5	10	20
Tear Resistance-Newtons	10	25	50	70	
Puncture Resistance-Newtons	20	60	100	150	

Table 1. Performance level EN388

When a protective glove has been approved for CE marking (Fig. 1) to the EN388 standard, these test levels are quoted as four numbers below the EN388 pictogram, the numbers are always shown in the order in which the tests are described. Please note the progression between the minimum results required to meet the increasing performance levels.

This means, for example, that the increase in test performance required to improve from blade cut index level 4 to index level 5 is eight times that needed to improve from level 1 to level 2. Also, where multiple layers of material are involved, the abrasion and tear resistance levels are derived from the most resistant of the individual layers, not the combination of layers.

It is important to note that blade cut resistance is the only test parameter where a performance level 5 is awarded. We will further discuss, whether even 5 levels are sufficient given the capabilities of new cut resistant technologies.

Figure 1. CE marking

Cut tests have always had tremendous variability, and the ratings can give a false sense of comfort to the user, who might think that since it is a level 5, they are protected. Within the blade cut resistance level of 5, there is a wide range of performance.

We often hear safety professionals and glove manufactures speak of gloves being a "low 5" or a "high 5".(figure 2).

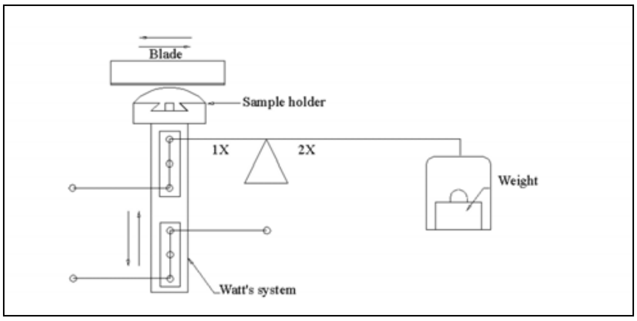

Figure 2. Schematic representation of cut test apparatus in ISO standard 13997 (Lara, 1996)

So, it must mean that there is a need for additional stratification. Then, why don't we add a level 6 and a level 7 so that will allow us to better stratify and qualify the level of protection.

A glove manufacturer can have a product that can withstand just over 2000 grams of cut resistance (most likely qualifying for level 5) and be classified in the same level as a glove that may take well over 5000 grams of cut resistance. It should be clear that cut levels are only a place to start looking, and are not the complete analysis for selecting PPE. The standardized tests can give us a directional indication of where to start looking, and then we can confirm that performance with real application tests in our workplace. Furthermore, real-world tests are needed because, for example, the way materials cut on a standard test machine is very different from the way those materials would cut if used in the palm of a glove that is immobilized under load. Perhaps an even more important performance area is that of puncture resistance.

A safety manager once summed it up, "Why are we considering the results of a test that essentially measures the puncture resistance of a roofing nail [the EN388 probe] when I am trying to protect employees from hypodermic needle threats?" Good question. The EN388 test for puncture resistance has three critical flaws as it relates to testing new material technology and new hazards. First, the probe is not adequate for testing the range of puncturing hazards that are prevalent in the market today. Second, the speed at which the probe moves is not representative of any application that you might find in the market (100mm per minute? Does anything move that slowly?). Third, it doesn't allow for the fact that contact with the glove's protective material can alter the probe and change future results.

So why the disconnect? It is not that the standards were not well developed. A lot of thought was put into the development of a reliable and consistent measurement. The problem lies in the lack of good alternative test probes that are consistently produced and the evolution of new technologies, products and materials that simply don't test the same way that other materials test.

In order to define the appropriate PPE for his workers, the employer needs to know:

- how much weight must be applied on the cutting or puncturing force
- how fast is the moving and how high or low is the impact
- what are the knowledge about the weaknesses of the PPE

The market is changing rapidly. New materials are improving our ability to protect from threats that were previously elusive. There is certainly a need for new standards to help the measure of these threats, but first of all we need to be aware of what the current standard tests are actually measuring.

The aim of the present search is to test different typologies of safety gloves in real conditions (pruning yard) by using three different tools (pruning, electric and manual shears) in order to evaluate the validity of the products commercially available and to study possible solutions.

Materials and methods

From a methodological point of view, the survey has been carried between January 2011 and March 2012.

The protocol required the use of the following equipments:

Three shears typologies:

- *Pneumatic shears*

Technical Information pneumatic model				
model	working pressure	cutting capacity	air consumption	net weight
	bar	mm	lt.min	kg
SLY	08-ott	30	80	0,55

Table 2. Technical data

- *Electroportable pruning shears*

model	Cutting capacity	Size	Net weight	Weight of the battery pack
	mm	mm	kg	kg
FELCO 820	45	290	0,98	2-2,5 kg

Table 3. Technical data

- *Manual pruning shears*

The gloves, classified according to the EN388 and second price elements (Table 4), were tested during the experimental period.

Class	**Level**	**Cost (Euro)**
1 economic class	low	< 6
2 economic class	medium	6 price 12
3 economic class	higth	>12

Table 4. Economic classes

Every typology of glove has been submitted to the cut of the equipments. The effects of the cut are considered according to the impulse of a force and not as repeated cycles (from the normative EN388); this force was constant for the pneumatic and the electroportable shears, while was variable for the manual ones.

To assess the damage, because of the impossibility to detect with load cells (invasive tests that lead to the destruction of the sensors) the fingers and the frame of a hand have been rebuilt by using biological and woody materials very similar to the morphological characteristics and resistance of the fingers of the hand.

Impulse I produced from time t1 to t2 is defined to be[

$$\mathbf{I} = \int_{t_1}^{t_2} \mathbf{F}\, dt$$

For each test, the damage was classified according to three parameters:
1. the cut on the glove;
2. the damage on the finger’s soft tissue;
3. the damage on the bone.

Glove	Soft tissues	Bones	Descriptor
A0	B0	C0	Absence of damage
A1	B1	C1	Slight, insignificant, hardly discernible damage
A2	B2	C2	Significant harm by cutting, tearing or crushing
A3	B3	C3	Total shearing

Table 5. Damage evaluation

Results

The used method has provided ten repetitions for each test. Statistical analysis has not been performed because of the uniformity of the responses, with any variation.

The first graph (figure 3) shows that the responses of the gloves were very poor even with the use of the manual shears: the gloves also G1 and G2 (considered anti cutting), although there were no significant damage to the glove, show a total damage of the soft tissues and of the bone (Fig. 4).

The only positive outcome was related to sample N. G6, in which the soft tissues come significantly damaged, but the bones remain unchanged (Fig. 5).

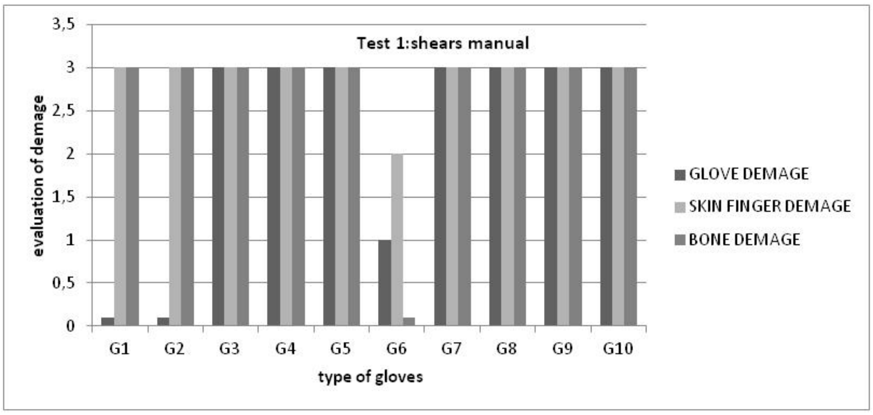

Figure 3. Test n.1

Figure 4. Damage sample for G2

Figure 5. Damage sample for G6

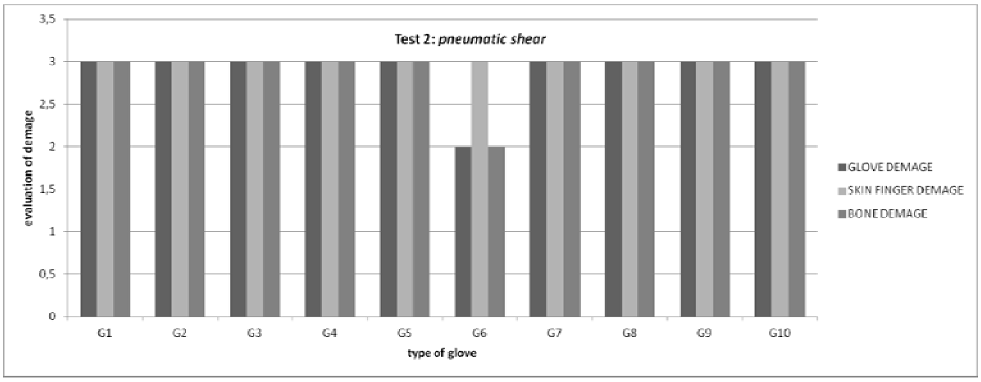

Figure 6. Test n.2

In the use of pneumatic shears, see Test n.2, the result has identified only one element of strength, always referred to the glove G6, nevertheless with significant damage to soft tissues and bones.

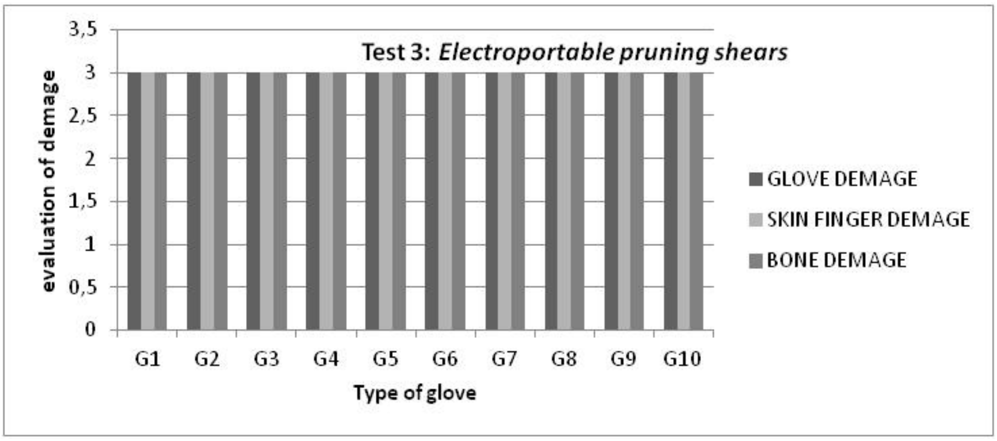

Figure 7. Test n.3

The last test (Fig. 7) has in fact shown as electric shears are the most dangerous of all.

In fact, although they are progressive, and then the operator can intervene on the block of the blade, can cause an impact of greater importance, hardly stoppable also with tissue cutting.

Conclusions

The research has shown that the gloves commercially available are currently not eligible.

These products are in fact designed to be used in static and standardized areas, in which the risk factors are due to known forces and accidental elements with a single effect (only cut, only abrasion or perforation).

Even using gloves with high performance, the result is the same, causing the total amputation of the fingers of the worker. The research, although has shown some positive results on the use of steel mesh gloves, doesn't propose such solution as applicable in the agricultural sector, because of they are very heavy and with very little skill.

Moreover, because of their characteristic, they can easily become entangled in the branches and vegetation. In the future, we must change the current standards for identifying a glove for the agricultural context: only building gloves that consider impulses and energies we can obtain better PPE.

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A software for evaluating the radial eccentricity of agricultural tires for ride comfort test

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Abstract

The agricultural tractors have increased the forward speed for construction, with different development depending from the legislation of the Countries, arriving to 50 km/h.
Already the speed of 40 km/h on road surface has pointed out the attention on comfort and handling performance.
The solicitation originating from tires caused from a non-uniformity roundness is one of the factors of interest influencing the cited parameters.
The phenomena is caused from the revolution of the tires on the road that could excite its resonance frequency. Each complete rotation of the wheel induces a periodical solicitation to the vehicle that is proportional to the amplitude of the tires' eccentricity.
The CRA-ING Laboratory of Treviglio, Italy, has developed a software for evaluating the amplitude of the eccentricity of the tire based on the harmonic analysis of the tire's profile.
It's important to note that the EUWA (Association of European Wheel Manufacturer) has developed a specific standard for the rims: "3.21/2009 High Speed Wheels for Agricultural Tractors - Geometrical uniformity of wheels and first harmonic point".
The software regards only the first harmonic but the considerations are valid and easy to extend also to the superior harmonics.
Conceptually, the measure of the amplitude of the eccentricity of the tire (TI) will be that of the tire with rim, the wheel (WH), less that of the rim (RI). Each single data of the wheel is subtracted to the relevant of the rim so that TI=WH-RI.
Moreover, the software allows to define the correct match-mounting of the low spot of the tire with the high spot of the rim to minimize the value of the eccentricity of the complete wheel.

Keywords: Tractor, agricultural tire, comfort, eccentricity

Introduction

The agricultural vehicle operators are exposed at whole body vibrations (Scarlett et al., 2007; Okunribido, 2006) which interest is growing also in the phase of road transport for the increasing speed for construction of tractors.
The European Parliament Directive 2002/44/EEC (EEC, 2002) defines the minimum safety requirements for the protection of workers from risks to their health and safety due to exposure to mechanical hand/arm vibrations and whole body vibration (ISO 2631/1997). In 2008, Italy adopted a specific national regulation (Decree no. 81/2008).
Several factors influence tires' dumping such as non-uniformity roundness, load, pressure (Sherwin et al., 2004), resonance frequency and elasticity characteristics (Taylor et al., 2000), this research, focused on whole body vibration and on handling performance, defines a software for the evaluation of one of the most important factor defining the non-uniformity: the eccentricity.

Agricultural tires can be considered like a system of springs and dumper and require, during tests, to take into account the solicitation originating from tires caused from the passage of the eccentricity, during revolution of the tires, in their resonance frequency.
The concept is to suppose that each complete rotation of the wheel induces a solicitation on the relevant axle. This approach leads to consider a periodical solicitation that is proportional to the amplitude of the eccentricity.
The CRA-ING has pointed out a methodology for evaluating agricultural tire's eccentricity and peak/peak (Cutini et al., 2011).
In this work the software developed for the measurements is presented.
The question has been considered also by EUWA, Association of European Wheel Manufacturer, by a specific standard for the rims (3.21/2009) regarding the tractor with speed of 50 km/h or more. The standard require marking the rim for match-mounting with tires to minimize the assembly radial force variation of the complete wheel.

Methods

The research is focused on the phenomena of resonance of the agricultural tires (≈ 3 Hz) in the frame of the characteristic tractor speed (≤ 50 km/h), that influences the vertical movement or pitch of the vehicle during transport on road surface: for this reason the mathematical analysis in this work is carried out only on the first harmonic.
The definitions used for the research have been taken from the EUWA standard.
1 - Radial run out – Total Indicator reading (TIR) is taken simultaneously at the two bead seats, for a minimum of one revolution, with the wheel located on the specified equipment.
2 – Equipment – The combination of physical features to locate the wheels during run out measurements.
3 – First harmonic – The magnitude of the sinusoidal component of the radial run out, representing one cycle per revolution of a run out trace (dimension in mm).
4 – High point – Experiences gained from the tractor manufacturers in cooperation with the wheel and tire manufacturers have defined two options for the value to be marked, depending on the tractor characteristics: the worse of the two bead seats first harmonic or, as an option, the first harmonic calculated from the average of two bead seats run out.
5 – Worse of the two bead seat first harmonic – The location on a wheel at which the maximum value of the worse of the two bead seats first harmonic occurs.
6 – First harmonic of the vector average of the two beads run outs. – The location on a wheel at which the maximum value of the first harmonic of the vector average of the two bead seats radial run out occurs.
The harmonic analysis has been used based on the concept that a function or a signal could be considered as a superposition of basic waves called harmonics.
The basic concept is based on the Fourier's theory: it is possible to form any function as a summation of a series of sine and cosine terms of increasing frequency.
For an agricultural tire the aim is to define the sine function approaching the tire profile.
The tire's profile is defined from the position and the number of the lugs' noses.
If the tire has R lugs for each side, the number of reliefs will be 2R.
The measure of the amplitude of the eccentricity of the tire (TI) will be that of the tire with rim, the wheel (WH), less that of the rim (RI). Each single data of the wheel is subtracted to the relevant of the rim so that TI=WH-RI.
This requires the tire mounted on the rim and at the desired pressure, i.e. the nominal.
Fig. 1 shows the example for one side of a tire with 20 lugs.

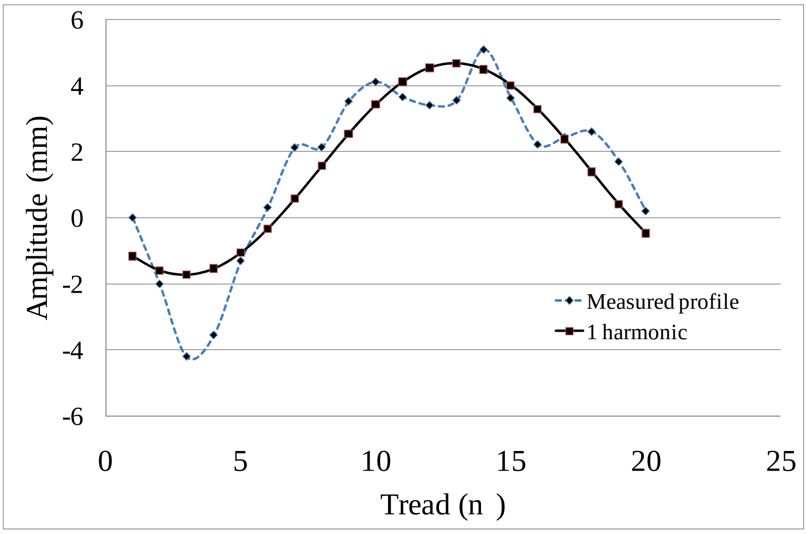


Fig.1: Example of a first harmonic of a measured profile

As TI=WH-RI the amplitude of the eccentricity of the complete wheel (WH) and of the rim (RI) will be directly measured.
Two comparators are positioned on the same radius of the wheel, on the rim and of the relevant nose of the tread (fig. 2).

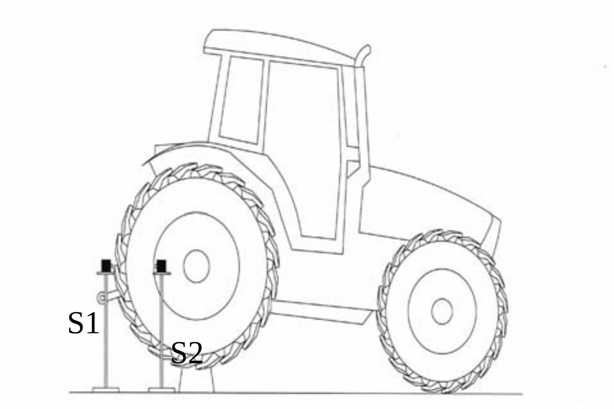


Fig.2: Layout of the position of the two sensors for the measurements at the wheel (S1) and at the rim (S2).

The tread n. 1 is conventionally that closest to the valve position.
As using comparators could be possible to move accidentally the sensor for positioning the feeler pin, a no contact sensor, such as a laser could be adopted.
The accuracy tolerance for both type of sensors was of 0.02 mm.
The versus of forwarding the tread number is that of designed forwarding of the wheel.
Each single data of the rim is subtracted to the relevant of the rim so that:
TI=WH-RI
The results are the values of the tires that we can introduce in the formula for calculating tire eccentricity. With a common software for calculation the data sheet can be filled as follows:

1. The first column is numbered from 1 to the number of lugs (i.e. 20) of one side;

2. The following four columns are filled with the measurement of the wheel (tire + rim) and of the rim, inside and outside.
3. The mean value of the relevant measurements of the wheel and of the rim between inside and outside is calculated; column 5 and 6.
4. Calculate the difference of the wheel and the relevant side of the rim; column 7.
5. One column (8) presenting a sample of sine is filled with a period of 2π of the number of the lugs: $y=O+A*sen(2\pi /N_r*R_n\cdot\varphi)$ where:
    a. O: is an offset
    b. A: indicates the amplitude of the sine
    c. φ: is the phase
    d. N_r = number of the lugs
    e. R_n = number of the lug of the measurement
6. The following column is the square difference between column 7 and 8. At the end of this column the sum is reported (S).
7. At this point is enough to minimize the value of (S) acting on the parameter O, A, φ. Several software have free solver that offers this operation. The offset (O) will result also the mean value of the measurements.
8. The sample of sine is now become the first harmonic of the tire.
9. The same concept will be applied directly to the mean values of the rim and of the wheel to calculate the first harmonic.

The value (A) is the amplitude of the 1° harmonic.
At the end of the radial run out test the obtained values are:

- First harmonic amplitude of the TI; RI; WH.
- Peak/peak of the TI; RI; WH.

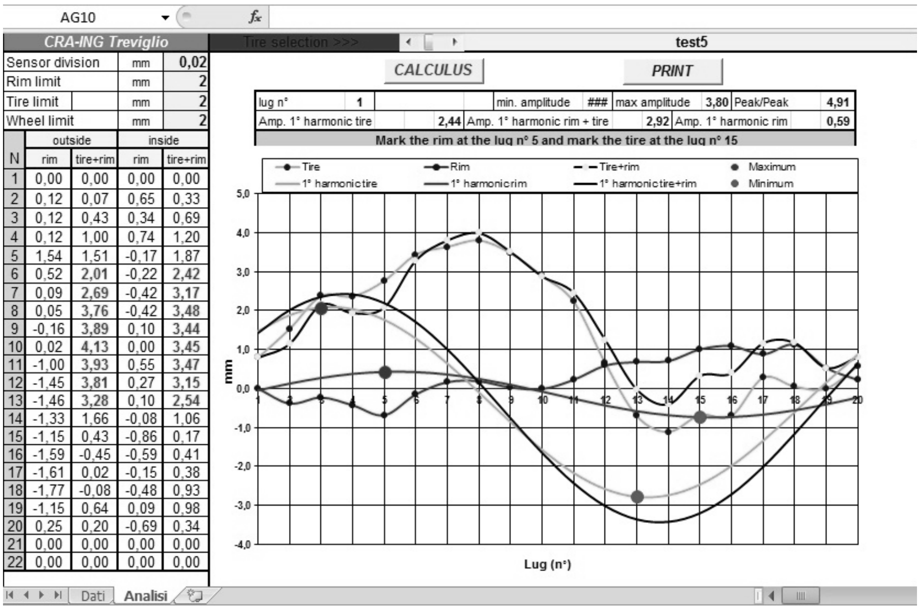
It's important to note that TI and WH are subject to the same error due to the assembly with the hub. This error is not present in the TI so the test is focused for the TI value.
This data sheet is enough for obtaining the main characteristics of the uniformity of the tire.
The following considerations can be reported:

- it's not enough to measure only one side of the wheel;
- it's necessary to check both side of the rim.

The value of the first harmonic amplitude is important because influences directly comfort and handling and has possibility of being minimized.
The layout developed from the CRA-ING of Treviglio is reported in fig. 3 where are presented:

- the four measurements:
    - rim inside
    - rim outside
    - wheel inside
    - wheel outside
- the resultant graphics, both of the measurements both of the harmonics
- the value of the first harmonics and of the peak/peak.

The calculation exposed are in the same data sheet (not shown in the picture).



CRA-ING Treviglio			
Sensor division	mm	0,02	
Rim limit	mm	2	
Tire limit	mm	2	
Wheel limit	mm	2	

N	outside rim	outside tire+rim	inside rim	inside tire+rim
1	0,00	0,00	0,00	0,00
2	0,12	0,07	0,65	0,33
3	0,12	0,43	0,34	0,69
4	0,12	1,00	0,74	1,20
5	1,54	1,51	-0,17	1,87
6	0,52	2,01	-0,22	2,42
7	0,09	2,69	-0,42	3,17
8	0,05	3,76	-0,42	3,48
9	-0,16	3,89	0,10	3,44
10	0,02	4,13	0,00	3,45
11	-1,00	3,93	0,55	3,47
12	-1,45	3,81	0,27	3,15
13	-1,46	3,28	0,10	2,54
14	-1,33	1,66	-0,08	1,06
15	-1,15	0,43	-0,86	0,17
16	-1,59	-0,45	-0,59	0,41
17	-1,61	0,02	-0,15	0,38
18	-1,77	-0,08	-0,48	0,93
19	-1,15	0,64	0,09	0,98
20	0,25	0,20	-0,69	0,34
21	0,00	0,00	0,00	0,00
22	0,00	0,00	0,00	0,00

lug n°	1	min. amplitude	###	max amplitude 3,80	Peak/Peak 4,91
Amp. 1° harmonic tire	2,44	Amp. 1° harmonic rim + tire	2,92	Amp. 1° harmonic rim	0,59

Fig.3: Layout of the datasheet of the CRA-ING for evaluating eccentricity.

At this point is fundamental to optimize the position of the tire on the rim.
Two main approaches are considered:

1. Minimum of the tire (low spot) matched with the highest point of the rim (high spot)
2. Minimum of the tire matched 90° or 180° (worst case) out of phase with the rim's high spot.

Setting 1 is chosen as best fitting for an ideal behavior of the tractor while setting 2 is chosen for soliciting the tire for evaluating the tire behavior in comfort or handling at different speed.
These results allow to simulate, and to define, the rotation between tire and rim that defines the fitting minimizing the value of the amplitude of the wheel.
To obtain this result is enough to consider that the we've measured the rim and the wheel profile and obtained by the previous calculation the tire profile. This means that since now on the tire is not more the variable. The wheel, as the tire + rim, now won't be measured but will become the variable and will be obtained by simulating the rotation of the tire on the rim in the software. It's enough to report:

- the number of the lugs in a first column;
- the profile of the rim in a second column;
- the profile of the tire in a third;
- the sum will be the new profile of the tire that will allow to calculate its first harmonic.

A simple way for obtaining immediately an overview in the data sheet is to make this operation as much time as the number of the lugs. If the lugs are 20 for each side, 20 groups of columns have created. This allows to display all the possible values of the wheel profile.
The selection of the desired position, the lug, of the tire on the rim will display the wheel profile also graphically. This allows easily to select the desired rotation of the tire on the rim.

Without reporting all the data sheet, is possible to show the results of all the tire positions on the rim, as reported in fig.4, that represents the layout chosen from the Laboratory of Treviglio.
It's possible to see the function "Select position" for simulating the rotation of the tire on the rim for each lug position. As reported above, the result is shown in real time also graphically.

AF42

21	0,00	0,00	0,00	0,00
22	0,00	0,00	0,00	0,00

Select position

-4,0

Lug (n°)

POS	amp.min	amp.max	Amp.tot	lug	rmonic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	-0,41	3,99	4,39	11	2,93	###	0,08	0,84	1,66	2,72	2,42	3,20	2,49	1,34	###	###	###	###	###	###	###	###	###	###	-1,18		

11

N	Amplitude min	Amplitude max	Amp.tot min/max	lug in/out	Amp. tire+rim	Lug position 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	-1,11	3,80	4,91	8	3,03	0,00	0,32	0,84	1,50	2,14	1,95	2,59	1,85	1,27	###	###	###	###	###	###	###	###	###	###	-0,41		
2	-0,11	3,83	3,94	11	3,00	###	0,32	1,00	2,08	2,61	2,56	3,22	1,92	1,22	###	###	###	###	###	###	###	###	###	###	-1,17		
3	-0,41	3,99	4,39	11	2,93	###	0,08	0,84	1,66	2,72	2,42	3,20	2,49	1,34	###	###	###	###	###	###	###	###	###	###	-1,18		
4	-0,43	3,97	4,40	11	2,82	###	###	0,61	1,50	2,30	2,53	3,06	2,46	1,90	###	###	###	###	###	###	###	###	###	###	-1,18		
5	-0,52	3,65	4,17	10	2,67	###	###	0,09	1,27	2,14	2,11	3,17	2,32	1,88	0,53	###	###	###	###	###	###	###	###	###	-1,01		
6	-0,89	3,33	4,21	9	2,50	###	###	0,07	0,75	1,91	1,95	2,75	2,43	1,74	0,51	###	###	###	###	###	###	###	###	###	-1,14		
7	-1,12	3,41	4,53	7	2,31	###	###	0,08	0,73	1,39	1,72	2,59	2,01	1,85	0,37	###	###	###	###	###	###	###	###	###	-0,94		
8	-1,08	3,57	4,65	5	2,14	###	###	0,24	0,74	1,37	1,20	2,35	1,85	1,43	0,48	###	###	###	###	###	###	###	###	###	-1,02		
9	-0,93	3,66	4,58	5	1,99	###	###	0,11	0,90	1,38	1,18	1,83	1,62	1,27	0,06	###	###	###	###	###	###	###	###	###	-0,54		
10	-0,95	3,97	4,91	5	1,89	###	###	0,32	0,77	1,54	1,19	1,82	1,10	1,03	###	###	###	###	###	###	###	###	###	###	-0,37		
11	-1,39	4,56	5,95	5	1,86	0,05	0,19	0,23	0,98	1,41	1,35	1,82	1,08	0,51	###	###	###	###	###	###	###	###	###	###	-0,58		
12	-1,80	4,76	6,56	4	1,90	###	0,37	0,71	0,89	1,62	1,22	1,99	1,09	0,50	###	###	###	###	###	###	###	###	###	###	-0,71		
13	-1,54	4,93	6,47	6	2,01	###	0,15	0,89	1,37	1,53	1,43	1,86	1,25	0,50	###	###	###	###	###	###	###	###	###	###	-0,46		
14	-1,39	4,73	6,11	7	2,16	###	0,02	0,67	1,55	2,01	1,34	2,06	1,12	0,67	###	###	###	###	###	###	###	###	###	###	-0,34		
15	-1,50	4,89	6,39	7	2,34	0,07	0,28	0,54	1,33	2,19	1,82	1,98	1,33	0,54	###	###	###	###	###	###	###	###	###	###	0,23		
16	-1,11	4,81	5,92	8	2,53	0,64	0,39	0,80	1,20	1,97	2,00	2,46	1,24	0,74	###	###	###	###	###	###	###	###	###	###	0,20		
17	-1,09	4,51	5,59	8	2,70	0,61	0,96	0,91	1,46	1,84	1,78	2,63	1,72	0,66	###	###	###	###	###	###	###	###	###	###	0,06		
18	-0,70	4,48	5,18	9	2,84	0,47	0,93	1,48	1,57	2,10	1,65	2,42	1,90	1,14	###	###	###	###	###	###	###	###	###	###	0,17		
19	-0,48	4,39	4,87	10	2,94	0,58	0,79	1,45	2,14	2,21	1,91	2,29	1,68	1,31	###	###	###	###	###	###	###	###	###	###	-0,25		
20	-0,39	4,07	4,45	11	3,01	0,16	0,90	1,31	2,11	2,78	2,02	2,54	1,55	1,10	###	###	###	###	###	###	###	###	###	###	-0,41		

Dati | Analisi

Fig.4: Layout of the datasheet for simulating the position of the tire on the rim

As reported above there's a position of particular interest that has the aim to minimize eccentricity. This means to search the rotation, for the software always the lug position, that minimize the eccentricity of the wheel. This software allows to identify this lug both analytically as shown in fig. 4, both graphically, as shown in fig. 5. Fig. 5 is the same tire of fig. 3 with the rotation for the best fitting tire and rim. A sentence indicates automatically the lug of the tire to be matched with the "lug" (position) of the rim (i.e. in the fig.5, "Mark the rim at the lug n°5 and mark the tire at the lug n°15"). It's possible to note as the amplitude of the first harmonic of the wheel is passed from 2.92 to 1.86 mm.

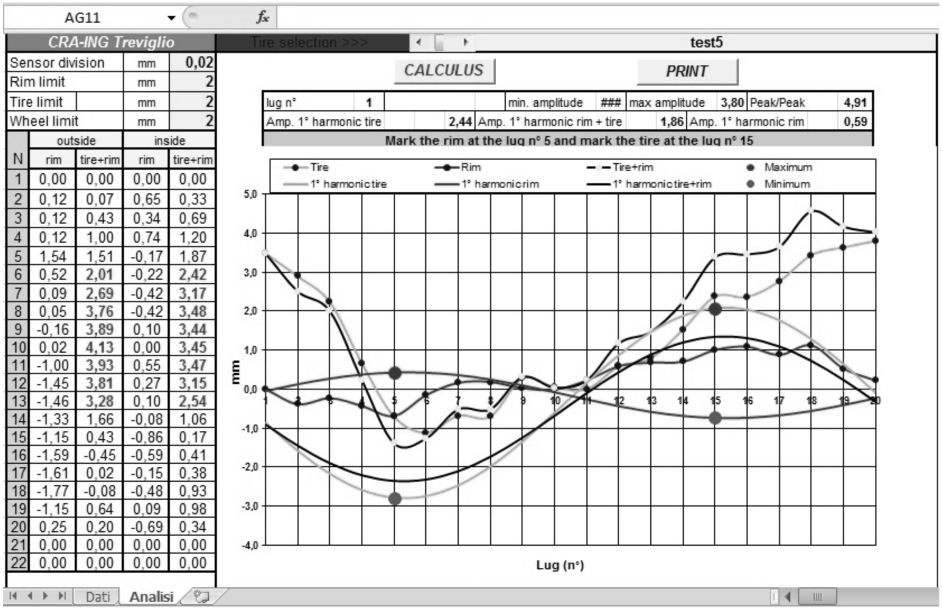


Fig.5: Graphical example of best fitting between tire and rim.

The other cases of interest are reported in fig. 6 and 7 and are the fitting between tire and rim at 90° and 180° out of phase. This last is obviously the worst case scenario where the eccentricity of the wheel has become of 3.03 mm.

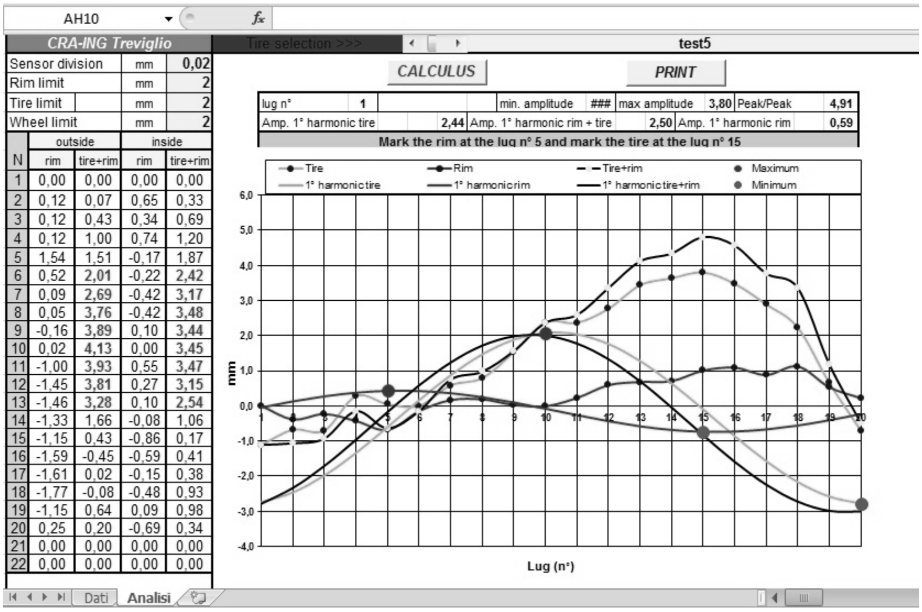
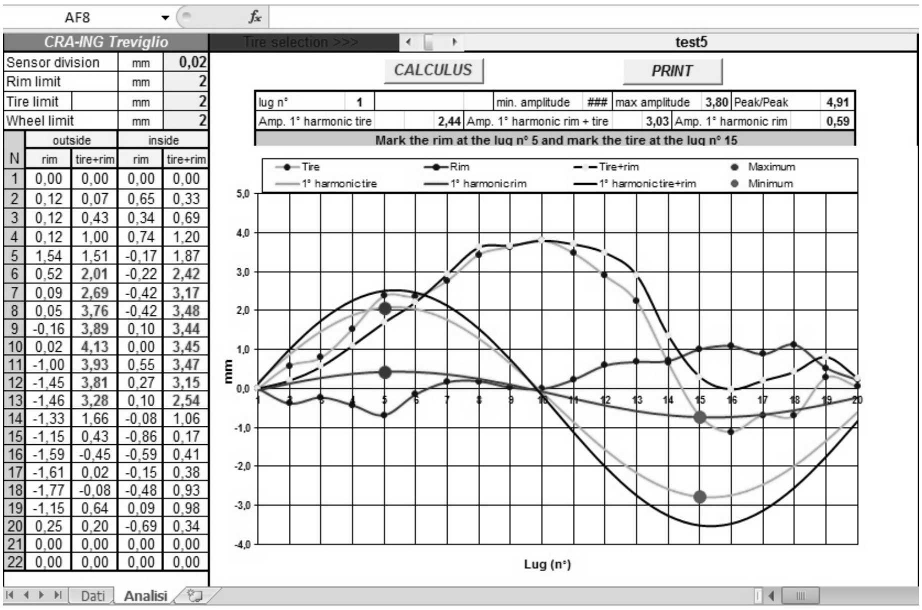


Fig. 6: Graphical example of fitting between tire and rim at 90° out of phase.



	outside		inside	
N	rim	tire+rim	rim	tire+rim
1	0,00	0,00	0,00	0,00
2	0,12	0,07	0,65	0,33
3	0,12	0,43	0,34	0,69
4	0,12	1,00	0,74	1,20
5	1,54	1,51	-0,17	1,87
6	0,52	2,01	-0,22	2,42
7	0,09	2,69	-0,42	3,17
8	0,05	3,76	-0,42	3,48
9	-0,16	3,89	0,10	3,44
10	0,02	4,13	0,00	3,45
11	-1,00	3,93	0,55	3,47
12	-1,45	3,81	0,27	3,15
13	-1,46	3,28	0,10	2,54
14	-1,33	1,66	-0,08	1,06
15	-1,15	0,43	-0,86	0,17
16	-1,59	-0,45	-0,59	0,41
17	-1,61	0,02	-0,15	0,38
18	-1,77	-0,08	-0,48	0,93
19	-1,15	0,64	0,09	0,98
20	0,25	0,20	-0,69	0,34
21	0,00	0,00	0,00	0,00
22	0,00	0,00	0,00	0,00

Fig. 7: Graphical example of fitting between tire and rim at 180° out of phase.

Conclusions

A software for evaluating the eccentricity of the tire based on the harmonic analysis of the tire's profile has been developed from the CRA-ING Laboratory of Treviglio, Italy.
The software requires the measurement of the profile enveloped from the lugs and of the relevant radial point on the rim.
The measure of the amplitude of the point of the tire (TI) will be that of the tire with rim, the wheel (WH), less that of the rim (RI). Each single data of the wheel is subtracted to the relevant of the rim so that TI=WH-RI. The amplitude of the relevant first harmonic is the desired value of the eccentricity.
The software can be applied at each type, model and measure of agricultural tractor tire.
Moreover it allows to check the roundness of the rims before testing and for defining the best fitting between tire and rim for minimizing vibrations that could influence comfort and handling.
The evaluation of the correlation between eccentricity value and non-uniformity exchange of forces with the ground will be the following step of the research.

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A machine to improve the safety during the chestnut mechanical harvest in steep zone

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Abstract
A wire- driven machine able to perform chestnut mechanical harvest in steep zones it has been set up. By mean specific software, it has been possible to perform a simulation of the various runs planning soil slope higher than 25%, spaces wide maximum 80 cm and backs high 30 cm. Subsequently it has been realized the machine prototype. With the aid of the software Solidworks, it has been designed the 3D model to verify the compatibility of the dimensions of the considered machine, with the hypothesized spaces. The vehicle is composed of a tracked wagon surmounted by the aspirator and by the whole equipment of harvest. This machine is completely driven by wire. The operator has only to start the machine and to drive it from remote, avoiding so that the operator has to climb for steep slant exposing himself to danger conditions. The first harvest tests have been performed in only one passage, and they have been aimed to evaluate the functional and operational characteristics, related to the surface of an hectare. The tests of the machine prototype have been conducted with a speed of 1,8 km/h, with a soil moisture of 12%. Under these conditions, in the first tests series, the working operational capacity of the considered machine has been satisfying.

Keywords: chestnut mechanical harvesting

1. Introduction
The greatest part of the zones where is performed the chestnut cultivation, is characterized by slopes higher than 15%. The harvest machines available on the market still have notable operational limits as it regards the soil slope (steep zone), sensibly reducing their performances with soil slopes higher than 15%. In such cases aspirating machines are used with aspirating tubes managed by operators that climb them along the steep slant to perform the chestnut harvest. This is a danger situation, in how much the worker can slip on the steep slant (because of the soil slope and/or moisture). In fact the steep zones also result particularly insidious for how much it concerns to the safety on the work, and the accident risk it is always present to the point to strongly discourage the chestnut harvest with a further damage for the economy of the agricultural compartment already penalized by contingent factors of financial recession. The chestnuts harvest is a rather onerous practice, that requires for a big quantity of manpower. For this, with the purpose to decrease harvest cost, many farmers prefer to wait that all the fruits spontaneously fall from the trees, for natural falling, for then to pick up them with brushing and aspirant machines. Recently, machines for the chestnut mechanical harvest have been set up. They are suitable to operate on wide surfaces with small slopes (<10%). Most quantities of chestnut tree plant, nevertheless, over that for the farm property extremely fragmented, they are characterized by surfaces with high slope values (>15%) and by high difficulty of access to these areas, because the impossibility to create penetration footsteps.

In these zones, mechanization methods are not, currently, used and all the cultivation operations, in particular the soil cleaning before the harvest, must be performed by hand, with evident additional costs not always sustainable from the farmers . In the most quantities of the chestnut tree plant soils, because the high slope value, the harvest and the cleaning workmanships pre-harvest are performed completely by hand. The periodic pruning represent additional manpower costs. Indeed the aim of this research program has been to test innovative machine able to perform the chestnuts harvest in the steep zones. The innovation to be introduced will have to allow, an advantageous manpower saving for the harvest activities, considered also that to have available temporary workers, in the short period of the chestnut harvest, becomes more and more difficult. Further particular attention has been devoted to safety problems to eliminate the danger conditions.

2.Materials and methods

A wire- driven machine able to perform chestnut mechanical harvest in steep zones it has been set up. By mean specific software, it has been possible to perform a simulation of the various runs planning soil slope higher than 25%, spaces wide maximum 80 cm and backs high 30 cm. Subsequently it has been realized the machine prototype. With the aid of the software Solid-works has been designed the 3D model to verify the compatibility of the considered dimensions of the same with the hypothesized spaces. The vehicle is composed of a tracked wagon surmounted by the aspirator and by the whole equipment of harvest. This machine is completely driven by wire. The operator has only to start the machine and to drive it from remote, avoiding so that the operator has to climb for steep slant exposing himself to danger conditions.

Fig. 1 Chestnut Mechanical harvest by aspirant pipes.

The prototype is constituted by a rigid loom realized with C profiled steel with dimensions 40x80x25 mm. On the loom, there is a graft system to hook the further specific equipments. The tracks transmission is realized by back driven wheels, located on the loom, that are located at higher quote in comparison to the idle wheels. In this way, surely an angle is guaranteed, (angle of attack) allowing the vehicle to overcome obstacles in reverse. The transmission wheel, is connected to the loom by turnbuckle mechanism for track that allows the regulation of the stretch of the track. The tracks are in rubber and with width 130 mm. The UTV kinematics is allowed by a couple of brushless engines, opportunely connected to the driven wheels, managed, by mean opportune driver with a microchip located on board the vehicle. As it regards the engine feeding, it has been possible to hypothesize to feed them by electric cable, without batteries on board the machine. In fact, because the considered machine has to be connected to the aspirator machine by mean a pipe (30-40 m long), it is possible to feed the engine by a cable connected to the pipe up to the generator of the aspirator machine.

UTV On board - Electronics
The used microchip on-board is the "Arduino Mega2560" with processor ATmega2560. ATmega2560 has 256 KB of memory flash to memorize the code (of which 8 KB are used for the boot-loader), 8 KB of SRAM and 4 KB of EEPROM (that is possible to read and to write with the bookstore EEPROM). The controller can be programmed by mean software owner open-source in Arduino environment, and with Matlab program.
For the on board sensors and transducers, the under-wagon has been endowed with ultrasounds sensors SRF05 that can denote obstacles up to 4 meters distance

Tele-control
The UTV can be managed by the operator, by tele-control joystick. A specific graphic interface, allows to check and to manage, from remote, the vehicle in the place in which it is located.

Autonomous control
The UTV can be programmed to manage operations in autonomous way, once defined the necessary parameters to the controller, what:
-information on the soil operative condition, where it will have to operate;
-possible paths predetermined that the vehicle has to perform;
-possible parameters required for the chestnut harvest operations.
For the considered machine it has been performed the risk analysis.

2.1 Risk analysis
The Directive CEE and law 626/94 and following integration, define *Danger* an ownership or intrinsic quality of a determined factor (work material, raw material or intermediary, work method, machine and tool) able to cause damages to the people or to the environment.
The term *Risk is* used instead for pointing out the concrete probability that, under the use conditions or exposure, the potential level of damage and the possible dimensions of the possible damage is reached.
The formula with which this concept is represented is:

$$R = P \, X \, M \qquad (1)$$

where *R is* the risk, *P* the probability that happens the event and *M* the magnitude, that is the gravity of the event on the people.
It is evident, therefore, that not all of this that represents a *Danger* also constitutes a *Risk.*
Difference can be born from the quantities of substances in game, from the time or from the frequency of exposure, from the measures precautionary takings, from the major or minor evidence of the same danger.
The working risks can be classified as:
-risk for machines,
-risk for the users;

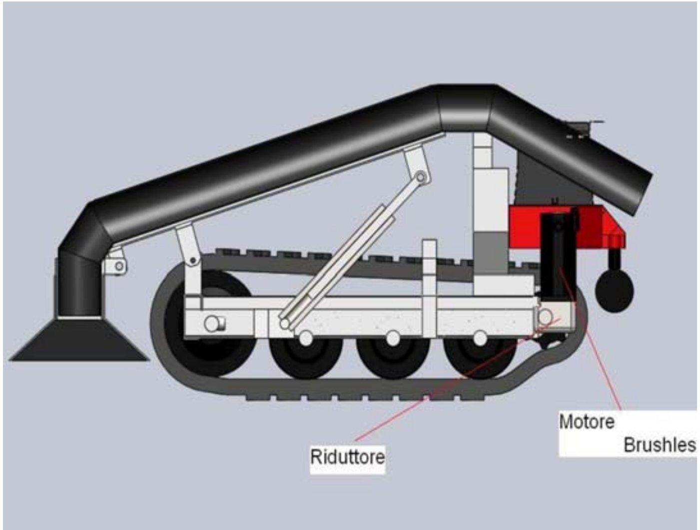

Fig.3 UTV scheme

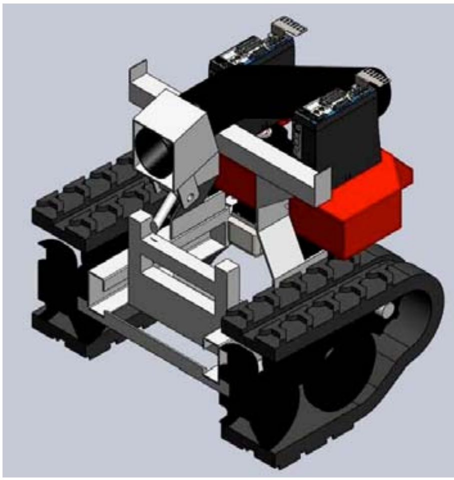

Fig.4 UTV scheme

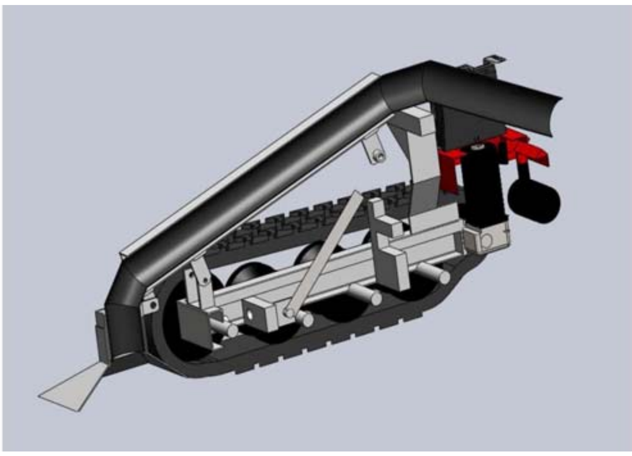

Fig. 5 UTV scheme

- risk for environment;

All that concerns users that work, in a working place in which are present machines or simple or complexes plants. On the base of all that exposed, the following shrewdness have been prepared to increase the safety of the machine.

3. SAFETY DEVICES ON BOARD MACHINE

Direct management of the machine by the user placed to the handlebar:

-Between the engine and the track, on the right side of the machine, with point of view by the guide seat, there is a metallic carter that has the function to protect the user from the mechanisms in movement: the transmission strap and the pulleys.

-There is an idle-brake handle that, only if it is managed, it allows the working of the machine, but in case of release it causes the immediate arrest of the machine. This device results very useful in case of immediate danger.

-On the considered machine, there are protective carters to avoid the contact with warm or incandescent parts of the engine.

The vehicle has been designed for the automatic harvest of the chestnuts and not for improper uses what the transport of people or things. To avoid this circumstance has been realized a structure over the machine in way that it occupies all the empty spaces and to avoid plane potential to support or to grip able to allow the transport of people or things. All that could provoke direct accidents to people or things and to influence the stability of the machine during the operative conditions.

It has been used, as safety measure, a suitable arrangement designing, specific for the considered machine, that has kept into account both of the data inferred by the professional experience matured in the sector of the agricultural mechanization and of the respect of the followings principles:

-mechanical safety and sizing

-safety to the fire

-safety of the accesses

-safety of the users

As it concerns the mechanical safety and sizing, the machine has been designed in way to obtain a remarkable reduction of the direct human intervention in the activation of the different operative functions of the considered machine. In fact, they have been avoided, as already underlined above, no-protected rotating parts with the aim to avoid entangling and dragging; the oleo-dynamic plant is provided of special safety valves; it has been turned particular attention to the turnover of the machine, in fact the barycenter quota, it has been the lower possible.

As it regards the machine *sizing*, the different parts have been designed according to the following rules:

-the stresses are generally limited to the 70% of the elastic limit and we have kept into account of a 15% dynamic increase coefficient applied to the vertical loads on the structures of the considered machine.

Noise: The noise level of the machine is nearly equal to that of the mechanical wheelbarrow from which it derives the over-truck considered, with the addition – in regime condition- of the noise produced by the aspirator machine.

INDICATIONS ON THE LEVEL OF DAILY EXPOSURE TO THE NOISE (LEP,D) OF THE WORKERS:

To evaluate the level of daily exposure to the noise, the considered method has been followed that has these phases:

1.subdivision of the working phases and evaluation of the level of noise in the single working places;

2.the workers' subdivision in homogeneous groups according to the performed activities and measurement of the noise level referred to every considered group;

3.calculation for every homogeneous group, of the level of personal exposure.

Once performed the above mentioned evaluation, the workers have been separated in 4 categories:

-workers submitted to a personal exposure lower than 80 dB(A) for which no prevention activity is required.

-workers submitted to a personal exposure ranged between 80 and 85 dB(A) for which is required the sanitary control, on demand. While the information is obligatory.

-workers submitted to a personal exposure ranged between 85 and 90 dB(A). Here we are to a watch level: the workers must have submitted to periodic medical check; they have to be endowed with devices for the protection individual and informed on the risks caused by the noise exposure.

-workers submitted to a personal exposure higher than 90 dB(A). The risk becomes real and they must be used specific shrewdness : annual medical checking and obligation of use of the devices of individual protection.

For the considered chestnut tree plant :

Working Typology: chestnut mechanized harvest Working group: machine operator and assistant (installation working place)		
ACTIVITY	EXPOSURE AVERAGE %	ENERGETIC AVERAGE Leq dB(A)
Start of the machine engine and the aspirator engine	5	83
Machine Movements on the working site	76	68
Movements of the aspiration pipe	14	68
Physiological	5	0
Lep =	72	dB(A)

Machine management by remote (with special radio-control)

In alternative to the direct use, the machine can also be managed by remote by radio system. In this formality the machine offers greater safety guarantees in how much the operator results distant from the same one, and therefore the risk of interferences is sensitively reduced. The following safety measures are been applied.

It has been complianced, the norm EN 300-220-2 related to the electric equipment of the considered machine. To pursue this aim, the management system by remote it has been realized in way to guarantee the followings conditions:

1.the safety of the people and of the things;

2.the congruence of the answers to the input commands;

3.the facility of the maintenance;

Besides the plant works in low voltage;

It has been used a radio-control, of the type "marsupium pouch", to allow to operate with both the hands. Such equipment has n° 06 functions, for the management of 6 controls in safety. The push-buttons is of ergonomic type and it is provided of an emergency button for the instant annulment of all the active functions.
Further guarantee is offered by the possibility to get the turning off of the engine, with the stop of all the functions in action when the system goes to damage.
Besides, the plant is provided of a hydraulic actuator constituted by an unique block with four controls, provided of proportional electronic-valve with mechanical retroaction, that has the function to manage the machine movements in gradual way, that is it performs the command according to the linear law of the movement, to avoid abrupt and dangerous movements.
All these arrangements are in compliance to the CE requirements on the electromagnetic Compatibility and items related to the radio wave (ERM); Short Range Device (SRD) particularly to the norm **EN 300-220-2**
The user that manage the maneuvers has to make use of special shoes accident-prevention. It results besides necessary to wear gloves in leather to protect the hands and in the sunny days it is opportune that the users wear fit headgear and sunglasses, while in the cold days they must be uses protective garments suitable to the climate.

4.RESULTS AND DISCUSSION

The harvest tests have been performed in only one passage, and they have been aimed to evaluate the functional and operational characteristics, related to the surface of an hectare. The tests of the machine prototype have been conducted with a speed of 1,8 km/h, with a soil moisture of 12%. Under these conditions, in the first tests, the working operational capacity of the considered machine has been satisfying.

Experimental tests

The tests have been performed in a chestnut tree plant of about 23 years of age, with distances of plant of 8,0 x 8,0 m. The regulations of the aspirating machine prototype with the purpose to set-up it, in optimal order of job, has been effected by technical personnel of the farm, and they have concerned the regulation of the job height of the aspiration anterior heading and the working speed. The harvest has been performed in only one passage, and they have been therefore determined the functional and operational characteristics, related to the surface of an hectare. The tests of the aspirating machine have been conducted with a speed of 1,8 km/h. Under these conditions, the working operational capacity of the considered machine results equal to 434 m^2/h, thanks also to the low incidence of the times accessories of turning on the total time. From the analysis of the losses happened during the tests, it has resulted that the operative machine is able to pick up the chestnuts with a percentage of lost product equal to 1,4%. The analysis of the picked product has been effected, to the purpose to underline the working quality performed by the operative machine considered. It is been noticed as in the picked product there were impurities equal to 2,2%. Such level of cleaning can also be defined good in consideration of the washing operation in water of the chestnuts that is performed as a rule subsequently in the farm center. The tests of the aspirating machine have been conducted in a chestnut tree plant, with a maximum slope values of 25%. The picked production during the tests has resulted equal to 201 kg/h, in consideration of the optimal conditions of preparation of the soil, that has also allowed an high working speed in presence of a notable quantity of product on the soil (0,264 kg/m^2).
Further the use of the machine in formality "manual", with operator to the handlebar has been examined, and indications on the use of the lever-friction brake to automatic return has been

furnished: if pressed it able to the movement the considered machine, if released it allows the parking of it.

Conclusions

Insofar it has been designed and realized a machine able to perform the mechanical harvest of the chestnuts in the steep zones. With the aid of a specific software it has been possible to perform a simulation of the different runs planning soil slopes higher than 35%, on spaces with maximum width of 80 cm and backs high 30 cm. Subsequently with the aid of the software Solidworks has been drawn the model in 3D to verify the compatibility of the dimensions of the considered machine with the hypothesized spaces. For such machine, once it goes on, the operator can manage all the functions by remote, simply maneuvering by wire. In such way it is avoided that the operator has to climb on steep slant, all of this to advantage of the operator safety.

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Environment safety and people health protection through innovative changing in making agricultural production using nanotechnology

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Introduction

Nowadays for effective making animal husbandry production in agriculture economically developed countries are more and more wildly using synthetic substance considerably increasing efficiency of farming sector for the purpose of deriving the highest possible income. This process is getting dangerous not only for animal health but also for people who take these products. For making environmentally safe production without decreasing economic effectiveness of the sector it is offered to change synthetic preparations to vegetable ones.

Methods

In order to do this in «Novgorodskiy Agrotechnical College» a scientific educational production laboratory was created. This laboratory is used for design and production overcritical *carbonic acid* extracts – feedstock for feeding-stuff production, veterinary, food, pharmacological and cosmetic industry. Growing in region cultivated and wild plants such as beet, carrot, calendula, vetch, mugwort, fir and pine needles, leaves of birch etc. serve as raw materials for the laboratory. Derived extracts practically imitate input materials at that substances are in proportion, peculiar to a vegetable. One of the way of using them efficiently is feeding-stuff production. Adding them to feeding blend allows not only speed up the growth, development and fecundity but also increase immunity of livestock and poultry to infections, stimulate immune response to vaccine, activate metabolism.

Conclusions

To date laboratory is certified for doing tests according to European techniques, production is also certified. Main experts had gone through a course in Europe, India, China. Collaboration is maintained with European companies: Flavex naturextrakte GmB H (Germany), Prozesstechnologie Gesmb H (Austria) and also Novo Agritech (India).

Proximal optical tester for precision agriculture and environment protection

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Keywords: vegetation index, N rate, wheat crop

Objectives

The diagnostic of plants state is carry out in precision agriculture to apply N rate fertilizers, maintain of soil fertility to receive of high crops, improvement of their quality and environmental protection in connection with nitrogen over application. The special field optical instruments are widely using for this diagnostics. Russian field active proximal optical tester with built - in artificial illumination allow us to make measurements reflectance in visible Rv (0.4-0.7mkm) and near infrared Rir (0.76-1.1mkm) ranges with uncertainty 0,5%. We used the simple vegetation index VI = Rir / Rv to evaluate plants state. It is known that over application on N leads to low N recovery efficiency and risk of N pollution of soil and ground water. The main problem is to define the N threshold level N* and its optical indicators.

Methods

The spring wheat growing on sod-podsol soil on the field of Leningrad region was studied.
Using regression method we constructed a number of Response functions (RF) on the special reference plots with different N rate fertilization in soil.
Analysis of variation the main RF as a dependence VI from N rate **VI (Nr)** we could to define ecological soil N-threshold **(N*)** and an optimal N rate fertilizer when RF have maximum value and the best plants state **VI*** (main optical threshold).
From RF (dependencies **Rv (Nr)** and **Rir (Nr)** we received the information about threshold levels **Rv*** for chlorophyll **Chl*** and **Rir*** for crude protein **Pr*** content in leaves.
We suppose that the using of numbers of the optical thresholds **VI*, Rv*** and **Rir*** a more full describes ecological state of crop on the ontogenesis stages.

Expected results

Using complex of our testers (proximal and contact) allows us to increase the accuracy of definition of the optical thresholds.
We search for partners for testing our instruments in Russia and abroad.

Evaluation of mechanical and rheological aspects of the malaxed olive paste

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Abstract

A malaxer prototype has been developed and it is able to control the oxygen both in the head space and in the paste. Besides, an innovative system to inject oxygen has been introduced on this machine. To investigate on the mechanical parameters a torque monitoring system was implemented on this prototype. In this research has been studied the correlations among oxygen dissolved in the malaxed olive oil paste and rheological properties. The torque and viscosity correlation is important to define an in line parameter directly detectable during kneading to understand when the paste is ready to get the next phase. Experimental tests were done. In the trials, the malaxer prototype was filled with olive paste. A different malaxing condition were chosen (Nitrogen; 15' injecting air; 30' injecting air; air). During the malaxation process the torque on the reel were measured using a rotating torque transducer RT2 (AEP). Rheology measurements were carried out using a Brookfield rotational rheometer (R.v model; Brookfield DV-II+Brookfield Engineering laboratories, Inc., Stoughton, MA, USA). This study examines the mechanical and rheological aspects of different olive oil malaxed paste. The results indicates that the oxygen inject during malaxation is a factor that influence the torque and the viscosity of the paste. The viscosity of the investigated olive oil paste shows dependency on the oxygen concentration. As regarding as the data of the torque a progressive decrease of the torque during malaxation process is observed too. The lower viscosity and torque value are observed when oxygen is inject in the olive paste.

Keywords: apparent viscosity, malaxer, oxygen

Introduction

The malaxation is a phase of the olive oil extraction process. After the crushing of the olive the olive paste obtained is kneaded and heated to achieve the right properties to optimize the extraction yields in the next phase, which is the process of solid-liquid separation by centrifugation. The malaxing phase can be considered as an important phase of the extraction process for its influence on the yield and the quality of the olive oil. There are essentially some main effects generated during the malaxation process, which make the process not only a mechanical process but also biochemical and physical-chemical process. The first effect of the mixing of the paste is to promote the breakage of the unbroken cells containing oil; the tissues and cells of the olive in fact are broken with contact to the pieces of stone formed during the crushing process, this allows the release of drops of oil and at the same time allows the occurrences of the coalescence phenomena. The minute oil droplets come together forming jet larger droplets this renders an easier and more complete separation of the oil and thus influences the yield. The main effect of this phenomena is the decrease of the viscosity of the paste. But, during malaxation process the oil is in contact with the aqueous phase in which various lipases and oxidases (such as Polyphenoloxidase, Peroxidase and Lipoxygenase pathways) are active. The different enzymatic reactions cause both the formation of a great number of compounds responsible of the aromatic fraction of the oil and the oxidation of the phenolic compounds resulting in reduced phenolic concentration of the oil (Kalua et al., 2007). The enzymes are triggered by the crushing phase and are active during the malaxation step.

Mixing conditions and the malaxer machine model can both influence the activity of these enzymes, which affect the volatile and phenolic composition of virgin olive oil, and as a consequence affect its sensory qualities and beneficial properties for human health. Several research have been carried founding the best malaxing conditions to improve the olive oil quality. Low temperatures are recommended for the malaxation step (i.e., $\leq$30 °C), whereas the optimal malaxation time should be between 30 and 45 minutes; this satisfy yield and a good quality. This time, according to rheology of the olive pastes, seem to satisfy these requirements, because compounds responsible for attractive perceptions, such as esters, are still present at high level, and concentrations of those giving unpleasant sensations such as trans-2-hexen-1-ol and hexan-1-ol are rather low. In addition, the amount of secoiridoid compounds is great enough to assure a suitable shelf-life of the pro-duct and the content of branched aldehydes is in the range typical of olive oils of high quality (Angerosa et al., 2001). Thus, the right temperature and the time of malaxation is important in order not to inactivate the LOX pathway and in order to reduce activity of PPO and POD, combined with good oil extraction yields. Several studies have been carried out on the effect of O_2 on the olive oil quality (Servili et al., 2003a; Servili et al., 2003b; Amirante et al., 2006; Servili et al., 2008; Amirante et al., 2008a; Tamborrino et al., 2010). Malaxer machine that included the use of inert gas processing and oxygen concentration control have been used. Malaxation under N_2 flush seemed to inhibit PPO and POD activities, resulting in an increase in the phenolic concentration. Using a malaxer machine with hermetic cover cap it is possible to work at low oxygen level without the use of N_2 flush. As a result of a decrease in the oxygen content, PPO activity was slowed down and, consequently, a reduced degradation of phenolic compounds occurred. The LOX pathway was affected by decreasing the oxygen content; the total C6 compound content was reduced, and, at the same time, the enzyme activity was increasingly addressed to the formation of aldehydes, especially trans-2-hexenal (Migliorini et al., 2006).

The research carried out until now have always considered the control of the oxygen in the headspace through the reduction of it using a malaxer machine able to do it. In a previous research the use of oxygen in the paste, during malaxation has been introduced and a preliminary study has been conducted on a malaxer prototype machine. A malaxer prototype was able to control the oxygen both in the head space and in the paste. Moreover, the malaxer prototype included an innovative system, never used before: a set of micro-oxygen injectors able to inject oxygen by two distributors in sintered steel directly in the paste, on real time. (Tamborrino et al., 2011). If the oxygen plays a important role for the quality of the resulting olive oil, undoubtedly it could influences the rheological behaviour of the malaxed paste. One of the fundamental parameter characterizing olive paste behaviour is viscosity. In fact, viscosity affects velocity gradients, and therefore the motion of suspended solid particles. (Amirante and Catalano, 1995).

Current, the olive extraction equipments do not have devices to assess this important parameter, so the evaluation of the viscosity is approximate and based on the experience of the operator. The malaxer prototype has been also equipped with a torque monitoring system on the reel to evaluate the torque measured on the paste. The torque and viscosity correlation is important to define an in line parameter directly detectable during kneading to understand when the paste is ready to get the next phase. Changing the processing conditions an influence of olive paste rheological properties was implied and thus, the knowledge of the a relationship between the rheological behavior of the olive paste and the mixing conditions could be of fundamental importance to optimize decanter performances (Amirante et al., 2008b). In this research are showed the results of the experimental tests carried out to investigate the rheological behaviour of the olive paste in different processing conditions and a torque measurements for the different conditions were investigated too. A correlation between torque and apparent viscosity value (η) are showed.

Materials and methods

Plant material

Olive fruits (*Olea europaea*) cvs. Coratina at medium ripeness were harvested during the 2010-2011 season in the Foggia area (Apulia-Italy) and transported the same day to the mill. A hammer crusher was used for the olive oil crushing phase; a malaxer prototype was used for the olive oil malaxation phase; a solid/liquid horizontal centrifugal decanter (two-phase) was used for the centrifugation phase. A liquid/liquid vertical plate centrifuge completed the plant.

Malaxer prototype

A malaxer prototype machine was an industrial tank having a capacity of 350 litres, with a circular spiral shape. The tank had a length of 1250 mm. The hermetic sealing was enclosed with three separated doors. These doors enabled to directly access the interior of the tank if required. Stainless steel material was used for the prototype machine. A window enabled to continuously monitor the conditions of the paste during the scutching phase. The polycarbonate was used to made the window. The prototype was also equipped with a valve for inert gas processing and equipped with the paste and water temperature probes; they enabled to accurately monitor the trend of temperature both in the paste as well as in the jacket of the tank, where hot water circulated. All the data were show on the LCD screen. The malaxer prototype was completed with a PLC. The software of this PLC allowed to the signals to be received and to provide the conversion of these electrical measurements into physical measurements and their visualization on the LCD display. The system allowed monitoring of the acquired data and it also allowed the setting of the parameters. The parameters set were: the on/off engine, the paste temperature and water temperature, the reel speed.

An oxygen supply system Ossigena is used. It provide for the supply of oxygen during the malaxation process using different regulations. It is able to supply oxygen continuously, or in single dose, or in a way that provides a very high flow for a very short time.

To measure the torque in real time a rotating torque transducer RT2 (AEP) was fixed between the motoreducer and the reel. The output was 2mV/V or ±10Vdc, the nominal Speed: 4000 rpm and a contact transmission has been used.

The prototype machine has been also equipped with a series of sensors which continually measure the quantity of oxygen both in the air of the head space and in the liquid phase of the paste (Oxygen measurement sensors - Mettler Toledo)

Experimental tests

The olives were processed into paste with the hammer crusher machine. Thus, the malaxer prototype was filled with olive paste. Different operational processing conditions were carried out for O_2 concentration in the paste. Each trial was performed in duplicate by processing homogenous olive batches (400 kg), under the same malaxation temperature and malaxation time conditions; the experimental tests have been carried out setting 27 °C as paste mixing temperature and 30 minutes as mixing time. The oxygen dissolved in the paste was the parameters controlled during processing. During malaxation, oxygen dissolved in the paste was measured using a Mettler Toledo Oxygen Sensor. Results are expressed as ppm of O_2. Four different conditions were studied: (P30): injecting continuously air in the paste using a flow equal to 80 mg/sec for all the malaxation time; (P15): injecting continuously air in the paste using a flow equal to 80 mg/sec for the first 15 minutes of malaxation time; (PN): saturating with N_2 the malaxer before to fill the paste using a nitrogen cylinder connected with a manometer (max 2 - 3 % of oxygen); (PA) under air for the entire time malaxation, leaving the doors opened.

Samples

Paste during mixing were sampled after 0, 15, 30 min. The samples taken were conditioned to the same temperature (27°C). The viscosity measurement was done. Rheology measurements were carried on the 36 samples of 600 mL olive paste. Three replicate trials have been done for each samples.

Torque measurements

During the filling of the tank torque measurements were done as well as during the entire malaxation process. Besides, data gathering were done on the paste when the machine was on going. The measurements were showed on the LCD display and express as *N m*.

Rheology measurements

Rheology measurements were carried out using a Brookfield rotational rheometer (R.v model; Brookfield DV-II+Brookfield Engineering laboratories, Inc., Stoughton, MA, USA) equipped with interchangeable disc spindles, 1–6 (model RV/HA/HB; Brookfield DVII + Brookfield Engineering laboratories). The spindle was driven by a synchronous motor through a calibrated spring; the deflection of the spring was indicated by a pointer on a dial. By utilizing a multiple speed transmission and interchangeable spindles, a variety of viscosity ranges were measured. The samples were directly loaded into the 1000 mL glass containers, where interchangeable spindles were inserted and an equilibrium time of a particular shear rate was ca. 40 s. A controlled temperature bath circulated water through the jacket surrounding the rotor and cup assembly to kept the temperature at the chosen thermal level chosen (27°C). The readings of the apparent viscosity were taken at rotational speeds from 0.5 to 100 rpm. To interpret the experimental results in terms of viscosity, the torque-speed data and scale readings were converted into shear stress–shear rate relationships using numerical conversion values (Mitschka, 1982). An empirical power-law model was used to calculate the apparent viscosity and the flow behaviour index from the shear rate (XUEWU et al., 1996) which is frequently used for engineering applications. It is given by the following equation (1):

$$\eta_{app} = k \gamma^{(n-1)} \qquad (1)$$

where η_{app} is the apparent viscosity, γ is the shear rate (s^{-1}), *n* is the flow behaviour index (dimensionless) which is less than unity for pseudoplastic behaviour, *k* is the consistency index (Pa s^n).

Statistical analysis

Statistical analysis was carried out using Microsoft Excel software. Significant differences between treatments were determined using one-way ANOVA.

Results and discussion

Regarding the data of the torque a progressive increase of the torque during the filling phase of the malaxer has been registered. After that, during the malaxation process a decrease of the data of the torque was observed. The air seems to have an influence on the torque; the lowest torque values were observed for the samples P30 and P15. The highest torque values were observed for the samples PA. As regarding as the viscosity, the experimental data, consisting of apparent viscosity values (η) and the related shear strain rate (γ), were collected. These data were processed by means of a linear regression in logarithmic scale in order to verify the consistency of the power law model for olive paste rheological behaviour, according to the equation (1) where *k* is the consistency coefficient, and *n* is the flow index (table 1). The Figure 1 shows the correlation between the torque values and the apparent viscosity. The correlation degree (R^2), for all the conditions studied, highlights that the variables are highly correlated except for sample PA. This could be due to the high difficulty in controlling air - paste mixing during malaxation: further investigation will be necessary in order to asses other parameters influencing torque and viscosity measurements.

Conclusion

This study examines the mechanical and rheological aspects of different olive oil malaxed paste. The results indicates that the oxygen injected during malaxation is a factor that influence the torque and the viscosity of the paste.

The viscosity of the investigated olive oil paste shows dependency on the oxygen concentration, as well as on the time of malaxation according with Di Renzo e Colelli, 1997. The viscosity decreases when the malaxation time increases. As regarding as the data of the torque a progressive decrease of the torque during malaxation process is observed too. The lower viscosity and torque value are observed when oxygen is injected in the olive paste. The main advantage of the introduction of the torque monitoring system is that the torque value is directly read on the display in real time and when the machine is ongoing and highly correlated with viscosity. This device could be associated at the routine equipment of the malaxer machine since that it is easy to handle for the operator. More data should be acquired to better correlate torque and viscosity in the different tested conditions. This is necessary in order to use torque measurements as an evaluation parameters for paste consistence during malaxation.

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Table 1. Experimental data and linear regression results of olive paste rheological analysis.

Sample	Sample description	Consistency Coefficient (*k*)	Flow index (*n*)	Correlation Degree R^2
$PN_{0'}$	Hammer crusher outlet	113965	-0,831	0,95
$PN_{15'}$	Malaxed: extracted after 15 minutes	89299	-0,634	0,98
$PN_{30'}$	Malaxed: extracted after 30 minutes	76552	-0,811	0,97
$P15_{0'}$	Hammer crusher outlet	133864	-0,833	0,99
$P15_{15'}$	Malaxed: extracted after 15 minutes	127423	-0,798	0,99
$P15_{0'}$	Malaxed: extracted after 30 minutes	108294	-0-751	0,99
$P30_{0'}$	Hammer crusher outlet	98206	-0,779	0,99
$P30_{15'}$	Malaxed: extracted after 15 minutes	62207	-0,854	0,99
$P30_{30'}$	Malaxed: extracted after 30 minutes	42681	-0,815	0,99
$PA_{0'}$	Hammer crusher outlet	185402	-0,625	0,94
$PA_{15'}$	Malaxed: extracted after 15 minutes	80362	-0,761	0,99
$PA_{30'}$	Malaxed: extracted after 30 minutes	119073	0,799	0,98

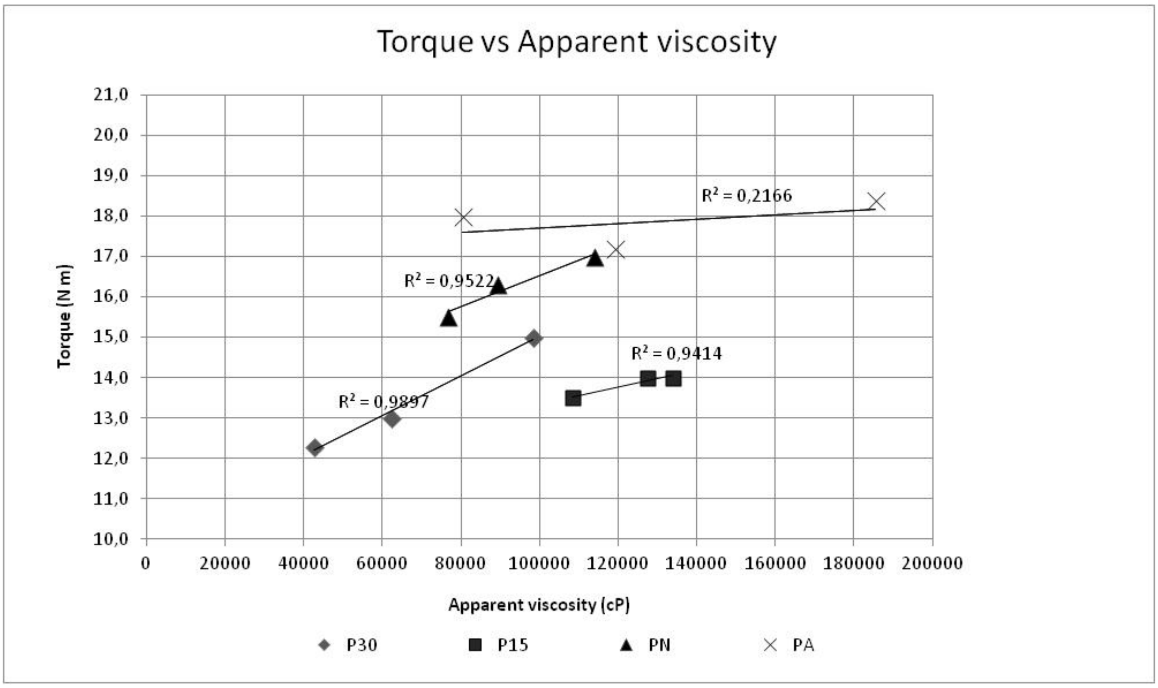

Figure 1. Variation of torque with apparent viscosity during malaxation

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