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 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.

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

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