Analysis of anthropometric compatibility of several tractor cabin guide

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Abstract
Anthropometry is a part of ergonomy responsible for measuring human body in its totality and components. The design of every handmade good concerning working sphere (but not only), needs the information supplied by this science.
In the agriculture sector, anthropometry has a remarkable relevance above all in designing and realization of tractor's cabin guide. This is due to the fact that many agricultural workers spend the most part of day driving tractors. A tractor with an uncomfortable cabin guide represents a risk for the driver. A space too narrow is extremely dangerous in case of overturning, collision with the inner side of the cabin, unintentional use of a control and consequent accidental movement of the tractor. The present paper is focused on experimental analysis of the inner dimension of tractor's cabin guide. The main goal is to verify the respect of "the least overall dimensions" of the driver and, according to UNI EN ISO 3411 standard, is calculated on big size drivers; it corresponds to the inner surface of the cabin with no visible deformation [4].
The experimentation has been realized on 15 tractors of different dimensions and year of production. The results have been then compared to verify the least overall dimensions inside the cabin guide. On the basis of the results, the analysis shows that all the tractors don't respect some parameters of the standard.

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

Introduction

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

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

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

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

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

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

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

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

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

Material and methods

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

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

Figure 2. Wooden instrument for determination of the SIP

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

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

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

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

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

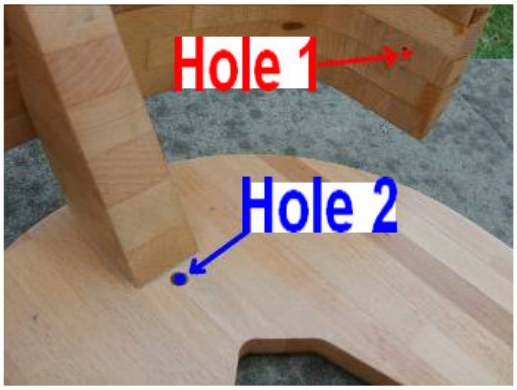

Figure 4. Holes situated on the upper part of the instrument (hole1) and hole situated on the lower part of the instrument (hole 2)

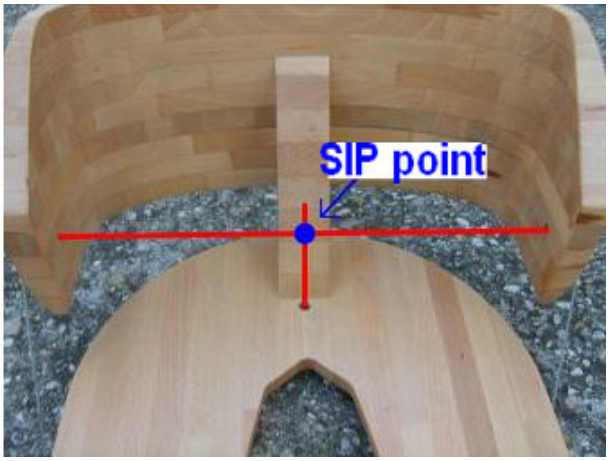

Figure 5. Determination of the S.I.P. point

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

Form for the transcription of measurements

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

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

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

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

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

Results

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

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

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

Conclusions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References

[1] Biondi P., Meccanica Agraria, UTET, Torino, 1999.

[2] Binswanger H.P., Agricultural mechanization. A comparative hystorical perspective. World Bank Staff Working Papers number 673, Washington, 1984.

[3] Biondi P., Meccanizzazione agricola passato e futuro. Macchine e Motori Agricoli, 1990.

[4] Biondi P., Maraziti F., Drawbar pull performance of tractors based on italian type-approval data (1960-1989). Journal Agricoltural Engineering Research 1998 (69): 189-198.

[5] UNI EN ISO 3411/2000 "Earth-moving machinery - Human physical dimensions of operators and minimum operator space envelope"

[6] UNI EN ISO 5353/2000 "Earth-moving machinery, and tractors and machinery for agriculture and forestry - Seat index point"

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