Analysis of Anthropometric Compatibility of Agricultural Tractor Cabs

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ABSTRACT

In agriculture, anthropometry has a remarkable relevance above all in design and realization of a tractor cab. The operators spend much time in driving tractors and an uncomfortable cab represents a risk for them. A space too narrow is extremely dangerous in case of overturning, for the collisions with the internal parts of the cab, and it can favour unintentional use of the commands with consequences on the behaviour of the vehicle.
This paper is focused on experimental analysis of the internal dimension of tractor cabs. The main goal is to verify the respect of "the least overall dimensions" of the driver (according to UNI EN ISO 3411 standard), calculated on the biggest driver size, corresponding to the internal cab surface with no visible deformation.
Measurements have been carried out on 15 tractors differently dimensioned and aged, later compared to the provided limits, in order to verify the least overall dimensions.
The results show that all the cabs, also if approved in accordance with OECD standard, don't respect one or more parameters provided by the UNI EN ISO 3411 standard.

Keywords: Ergonomics, Anthropometry, SIP (Seat Index Point), Cab, Agricultural tractors

1. 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. Ergonomics can use this standard 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. cab height), in others, foreseeing the possibility of adjustment depending on the size and characteristics of the driver. 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. 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 ambiance is adaptable to 95% of people (UNI EN ISO 3411:2000).
On tractors and other self propelled agricultural equipments, particular care needs to be taken of the seat, on which an operator may spend sometime the whole working day. In their most comfortable versions the drivers' seats have:

- base large enough, in width and depth (comfortable for the 95% of the population) (Tewari and Prasad, 2000), and horizontal on the resting points of the ischium (the lower pelvis bone) with a light descending gradient (max 14° - Dhingra *et al.*, 2003) and a length inferior to the thigh (femoral arteries are not compressed and the leg can move freely);

- it is considered essential for desirable conditions to reduce low back pain: (1) lumbar support, adjustable in height and convexity to anatomically support the lower vertebrae (subject to discopathy) (2) side support, (3) firmer cushion at the ischial tuberosity region, and (4) soft cushion at the femoral region (Anderson and Ortengren, 1974a, 1974b, Dhingra *et al.*, 2003, Katuraki *et al.*, 1993);
- adjustable inclination of the back rest for a better support of the trunk;
- two arm rests for a better support of the arms;
- a 20º rotation angle in both directions, to facilitate entry and exit and visual check of implements coupled rearly;
- regulation in height (75 mm – ISO 6682:1986) 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 cab floor;
- vertical suspension, to reduce vibrations transmission from the engine, gearbox, implements, etc., adjustable to the operator's weight;
- horizontal suspension to reduce horizontal impulses, felt as shocks to the back (this option actually is present on few models and it can generally be turned on or off on command);
- seat surface material allowing a suitable perspiration.

On agricultural tractors, vertically and longitudinally adjustable seats equipped with parallelogram springs and suspension stiffness based on the driver's weight are nowadays usually available. Cushions, back rests and arm rests are anatomically shaped (and often adjustable) to contain the operator well even on steep slopes.

Anthropometrics regulates also the location of the commands, that once again has to be rationally studied based on:

- the anthropometric working radius of arms and legs;
- the possibility of easy usage based on the easiest movements of hands and feet;
- easy visibility based on sight angle and easy movement of the head;
- the easy recognition of all the machine commands (Biondi and Maraziti, 1998).

Figure 1. View of a modern tractor cab (left - NH tractor) and detail of the joystick for controlling the vehicle mobility (right – Fendt tractor).

On the driver place many handles and commands can be found (figure 1). Essential for the easy and secure use of the commands is their best recognition, which can be improved with a characteristic shape and colour. Some handle commands (for example the handle position of the hydraulic distributors, that is proportional to the actuator effect), for a fine and safe control should have the possibility of a resting point for the hand. The commands controlling the machine mobility (accelerator, clutch, gear levers) usually have all the same colour, so being easily distinguished from the other commands. For this reason the coding for the different light signals (shape, colour and symbol) need to be carefully studied and in some cases is based on international standards. In some cases also acoustic signals are particularly useful to inform the driver of serious malfunctions and/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 signals, with variations from five to nine. Warning signals for the driver therefore will have to be visualized in a clear and simple way, to give only the most important information, necessary to make the quickest and most effective counter-measure (Biondi, 1990).
The driver's place of a tractor, finally, needs to allow for maximum external visibility, theoretically without blind spots and above all visibility of the rear and front machinery. Exactly these needs call for a cab nearly completely made out of glass and a so called tractor with clear or improved sight of the front (with a lowered engine bonnet) for a better view of the implements coupled at the front (Binswanger, 1984).

2. MATERIALS AND METHODS

Tests have been carried out on 15 tractors of different make, models, power engine (from 65 to 200 kW) and age (year of manufacturing from 1983 to 2007). The measurements have been carried out with a wooden device, manufactured in such a way to obtain the maximum precisions for respecting the need of the UNI EN ISO 5353 standard (figure 2).
This device has been used to define the Seat Index Point (SIP), acting as a reference for all the measurements.

Figure 2. Wooden device for SIP determination.

The SIP device was manufactured using various types of wood, to obtain maximum resistance even though the wooden part of the device has a mass of only 2.98 kg which, together with four steel pedestals, comes to a total mass of 6 kg, in accordance with the above described standard. The four steel pedestals are used to support weights added to arrive to the desired final mass (figure 3).

Figure 3. Device for SIP determination, completed with steels pedestals to support the ballasting.

A numeric controlled machinery was used to manufacture the SIP device, to cut hundreds of wedges that later have been glued using a particular mechanic press. The device consists of a horizontal base and a vertical back rest, both having curve made in accordance the UNI EN ISO 5353 standard. The base and the back rest have been joined with a wedge, in such a way the two parts will result perpendicular one in respect of the other.
The Seat Index Point is defined by the intersection of the horizontal straight line passing through the two holes on the upper part of the device with the vertical straight line passing through the hole situated in the centre of the lower part of the device (figures 4 and 5).

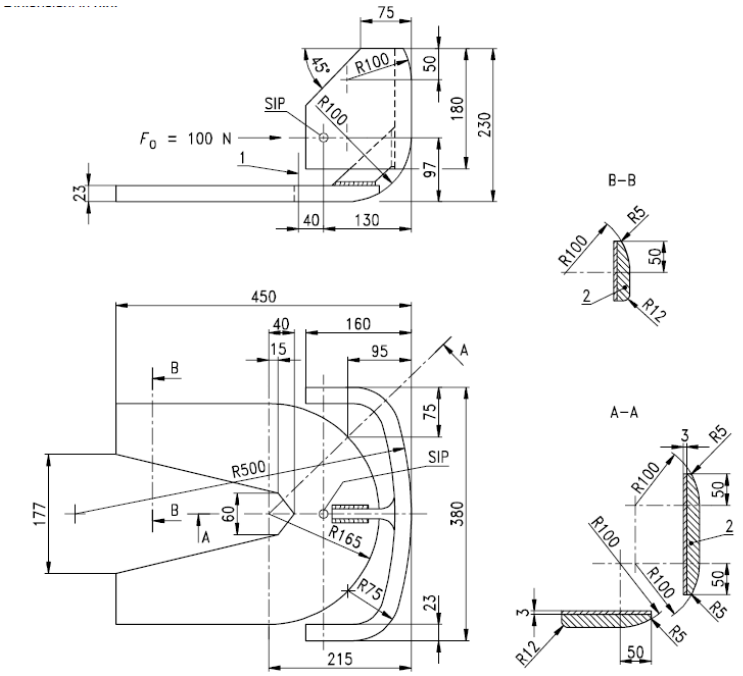


Figure 4. Device for SIP determination: structural arrangement (dimensions in mm) (UNI EN ISO 5353:2000).

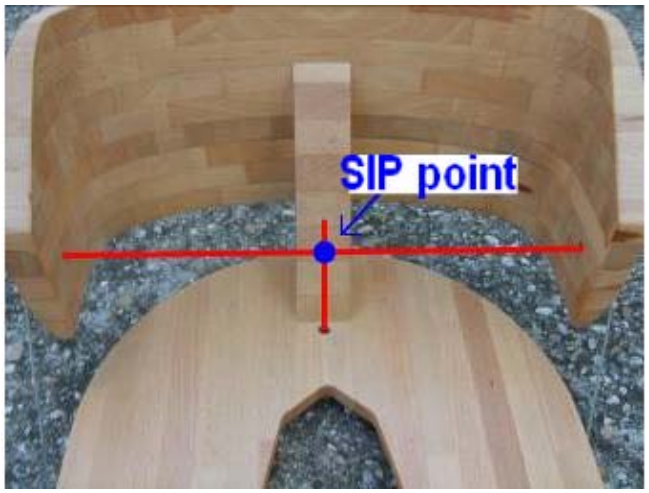


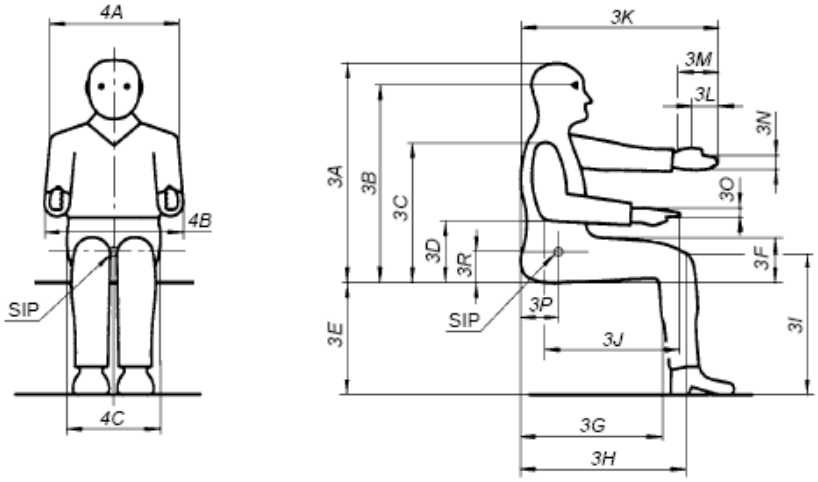
Figure 5. Determination of the SIP.

Other than the already described device, to carry out the measurements were used measuring tape, spring rule, folding meter, bubble level, adhesive tape, paper, and two metal ballasts of 10 kg to come to the final provided mass (26 ± 1 kg).

2.1. Dedicated Form

A dedicated form was prepared to record all the measurements to be analyzed, in accordance with UNI EN ISO 3411 standard, including the maximum and minimum dimensions to be taken into account, completed with three drawings to improve their meaning.

Further measurements have been recorded, with a light modification to the provided methodology, wherever it was impossible to follow the standard because of the ballasts position on the four steel pedestals.
To make the SIP more accessible to carry out the measurements, a practical method has been pointed out, in order to remove the device. Once the device is correctly located on the seat, a thread is passed through the two holes on the vertical back (the upper part) of the device, then stretched and attached to the corresponding points of the internal sides of the cab with adhesive tape, thus carefully forming a horizontal straight line using bubble levels.
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 (cab) of a fully dressed operator (arctic clothes and gloves, parka, hood) refers to the S.I.P. defined in the ISO 5353:2000.
The minimum overall dimension of the operator (figure 6) is based on the dimensions of bigger sized operators (95% percentile). 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 standard UNI EN ISO 3411 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.



3A	990		3K	915
3B	850		3L	85
3C	680		3M	210
3D	260		3N	105
3E	490		3O	45
3F	200		3P	147
3G	500		3R	107
3H	680		4A	540
3I	640		4B	635
3J	535		4C	450

Figure 6. Dimensions of a seated and dressed operator (dimensions in mm) (UNI EN ISO 3411:2000).

The parameters (specified in the UNI EN ISO 3411 standard) that have been measured are (figure 7):
δ1: distance between the cab (considering also the glasses) and all the commands in their closest position to the cab itself. The minimum limit of this value imposed by the standard is 50 mm.
R1: distance between the SIP and the cab ceiling in the transverse plane. The minimum limit value of this distance imposed by the standard is 1050 mm for tractors having a power of 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 sides of the cab and intersection of the internal sides of the cab with its ceiling. The maximum limit value is 250 mm.

R3: distance between the SIP and the rear side of the cab. The gathered measurement needs to be at least b+400 mm, where b is equal to the half of the seat's horizontal adjustment.
h1: vertical distance between the SIP and the lower extremities of the upper side walls of the cab. 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 cab. 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 cab. This distance needs to be at least 500 mm.
L2: distance between the cab and the arctic shoes of the operator which operates a pedal or pedal command in any position. The minimum limit value imposed by the standard is 50 mm.

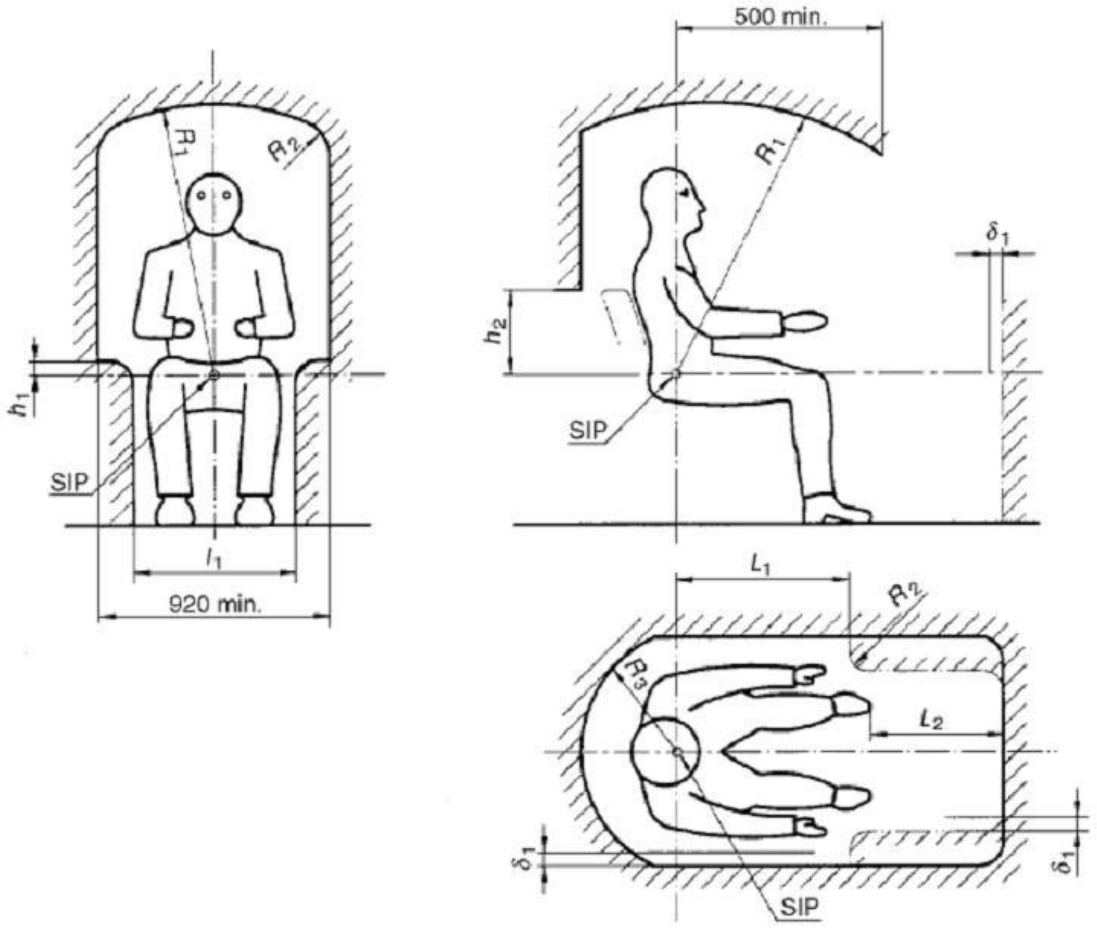


Figure 7. Measured parameters (seated and dressed operator) (dimensions in mm) (UNI EN ISO 3411:2000).

3. RESULTS AND DISCUSSION

In table 1 the gathered results are summarized; parameters not respected on each tractor are underlined. Resulting from the anthropometric analysis carried out in this research, all the analyzed machines, regardless of size and age, have a percentage of parameters that do not

respect the standard. This percentage range between one unconformity (11% of parameters for the Case 1255 XL tractor) and a maximum of five unconformities (56% of parameters for three tractors).
Starting with the "h2" measurement (vertical distance between the SIP and the lower extremities of the upper rear wall of the cab), 14 analyzed tractors (93,3% of tested tractors) result to be below the standard.
Another parameter which is often not respected is "δ1" (distance between the cab and the commands in their closest position to the cab itself). Regarding this parameter, 7 tractors out of 15 (46,7% of cabs) result to violate the minimum safety distance.
Based on the standard, the distance between the cab and the commands should have a minimum of 50 mm to avoid that the operator gets crushed or hits the cab using this command. Seven tractors register variances from -5 to -50 mm (on average -24 mm). Constructors place rarely used commands in the close vicinity of the cab. This can involve for the operator risks of crushing his fingers against the cab walls.

Table 1. Extended table of the respected dimensional characteristics of the analyzed tractors (dimensions in mm). Underlined values show the unconformities to the ISO standard.

Tractor makes and models	**Power kW**	**δ1**	**R1**	**R2**	**R3**	**h1**	**h2**	**l1**	**L1**	**L2**
Landini Globus Top 80	43.25	22	990	50	378	151	138	580	795	70
Steyr 9083	64.7	0	981	60	532	126	95	725	1173	30
John Deere 5615 F	66.1	51	1204	98	360	78	173	560	810	10
Fendt Farmer 309 C	78.6	68	1029	99	477	84	183	966	840	55
Case CS 110	80.9	41	1010	0	448	172	181	730	546	28
John Deere 6330 Premium	86.7	66	915	35	460	50	35	875	740	75
Case 1255 XL International	91.9	99	1130	42	608	258	293	1079	919	142
Hürlimann SX 1500	113.9	70	1004	280	583	146	121	632	1068	69
Same Hercules 160 V	117.6	41	1050	103	420	124	148	818	707	110
Same Galaxi Turbo	122.3	20	1065	38	427	232	146	724	1028	51
Landini Legend Tecno	145	11	942	32	428	138	131	663	1306	265
Ford TW 30	139.7	109	1101	119	584	123	68	973	1072	101
Same Iron 200	147	91	945	70	660	120	56	640	682	12
John Deere 7730	161.7	45	980	80	405	165	0	820	815	80
Case MX 270	188.5	85	1090	58	720	195	33	890	820	140

The “R3” parameter (distance between the SIP and the rear side of the cab) show unconformities in the 60% of the tested tractors, with variances from -7 mm to -114 mm (on average -59 mm).
Other parameters that result unrespected are “R1” (for 6 tractors out of 15: from -10 to -85 mm, average -35 mm) and “h1”, (for 5 tractors: from +1 to +108 mm, average +46 mm). These parameters regard respectively the distance between the SIP and the cab ceiling in the transverse plane (R1) and the vertical distance between the SIP and the lower extremities of the upper side walls of the cab (h1).
Regarding the “R1”, in some tractors, space is occupied by ventilation devices. Some constructors justify the unconformity for the “h1” distance with the need of insert a lateral control console (a device nowadays present in all medium and large sized tractors of the last generation).
The “L2” parameter (distance between the cab and the arctic shoes of the operator) is not conform for 3 tractors out of 15. This distance has a minimum limit of 30 mm and is not respected by those tractors that have a too long pedal travel (the clutch pedal: in this case data show variances from -2 mm to -20 mm).

4. CONCLUSIONS

Considering that the UNI EN ISO 3411 is a “standard” and not a “directive”, constructors of agricultural tractors are not held completely to respect the limits indicated by the standard itself. However they should to motivate and justify an eventual choice in construction which does not respect the standard’s limits (Biondi, 1999).
Tests show that the most critical parameter for agricultural tractors is the “h2” one. This is related to the fact that the agricultural tractors often use machinery attached to the back on a three point linkage 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 terrain. In fact it needs to be underlined that the applied standard refers to ground moving machinery (a similar European standard does not exist for agricultural tractors).
Parameters that seem to give less problems to the tractors cab planners are “l1”, length inside leg space, and “L1”, distance for the forearm inside the upper lateral zones of the cab. In fact all the tested cabs show the respect of such parameters.

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The contribution of this research management must be equally divided to the authors.