New experimental research of the quasi-vertical driving position

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Abstract The paper presents new contributions to the study of the unconventional driving position of the car - called by the author as "quasi-vertical driving position." Firstly the quasi-vertical driving position offers significant advantage of reducing the loads in the buttock (pelvis) area by partially redistributing them to the shins (knee area) and soles. Quasi-vertical position involves a new configuration of the seat of the car and a new architecture of the cockpit. The paper further presents some important elements of the experimental methodology applied, the description of the original equipment (the stand) for determining the distribution of the loads on the driver seat for a large diversity of the body positions and also some significant results of the experiments. Starting from these experimental data it will be possible to formulate new recommendations in the field of the comfort and it will open new research perspectives in the field of unconventional driving positions.

Keywords: Quasi-vertical Driving Position, Future Urban Car Architecture, Experimental Ergonomic Research.

1 Introduction

Over more than a century of evolution, the car has not experienced a radical change in its operating principles, including the working position of the driver / passenger. However, in the last decades marked by a growing concern for the evolution of society in the perspective of sustainable development, there was a spectacular evolution of research into the means of people's mobility. In the context of urban agglomerations, the dimensions and architecture of the automobile has become key factors in optimizing mobility performance. Today, there is a growing need to reinvent the car as an important component of the transport system adapted to the needs of the future [1].

In this respect, the author proposed the concept of quasi-vertical driving / travelling position applicable to urban car [2]. The new concept can strongly influence the architecture and appearance of the future cars, their size, architectural style, how to use them and the level of comfort provided to the users as well as their transport capacity. Thus, the new concept will lead to reducing the specific dimensions of cars and, in particular, the external dimensions related to the number of passengers and thereby increasing their specific transport capacity and indirectly the mobility in crowded urban areas [3]. On the other hand, the quasi-vertical driving position will require the definition of new conditions that must be met to ensure a proper comfort for the driver and passengers. It is possible that the new perspective proposed for driving / travelling posture will stimulate the design and development of new types of cars or other urban transport systems that will contribute to meet the growing need for mobility in the future [1].

2 Quasi-vertical position - a possible driving /travelling posture adopted for the urban automobile. The main features

It is known that the interior architecture of the current car is based on the principles originally formulated during the study of comfort for the cockpit of the WWII hunting planes. Further in-depth studies on car comfort were made over many decades and have led today to a much deeper understanding of the conditions necessary to ensure comfort and the multiple responsible causes that can influence it. So, the resemblance between the sitting posture in the airplane chair and the similar one in the car seat is not accidental.

Much less is known about other possible driving/traveling positions in the car, given the relatively small diversity of the cockpit architecture configurations of the various existing vehicles. Today, the dominant driving/traveling position is obviously the „classic" sitting position in the airplane.

Intuiting an opportunity to reduce the size of the cockpit, the author proposed the original concept of "quasi-vertical driving position" for the driver but also applicable to the passengers. This position is defined by the almost vertical posture of the user's trunk with the back and buttocks supported by a special chair or support device and having the possibility for the soles of the feet to reach the floor. The knees area must also be in contact with a special adapted support. In this way the body weight could be discharged in different proportions on each of these four contact surfaces [3] (Figure 1.a).

3 Testing the quasi-vertical driving position

Based on the previously presented principles, a series of tests were conducted on a testing stand that basically simulates a seat adaptable to very different driving postures - including the quasi-vertical driving position described above.

To explore the possibilities of using new driving / travelling positions it is necessary to determine the multiple interactions between human body and the body support system (the chair) which can influence the comfort. The present study aims at dealing primarily with the mechanical interaction between the user and the chair, initially in static conditions. It seeks to deepen the understanding of how the weight of the human body is distributed on each of the seat support surfaces.

Determining the principles of body weight distribution on the seat support surfaces is difficult because the human body can be considered as a multibody system of great complexity due to the nature and mechanical behaviour of the organic substance it is made of. It is obvious a disadvantage to work with such a multiple undetermined system (the human body), but even here it can be a chance to discover original ways in which the chair provides unprecedented comfort.

3.1 The equipment for testing the quasi-vertical driving position

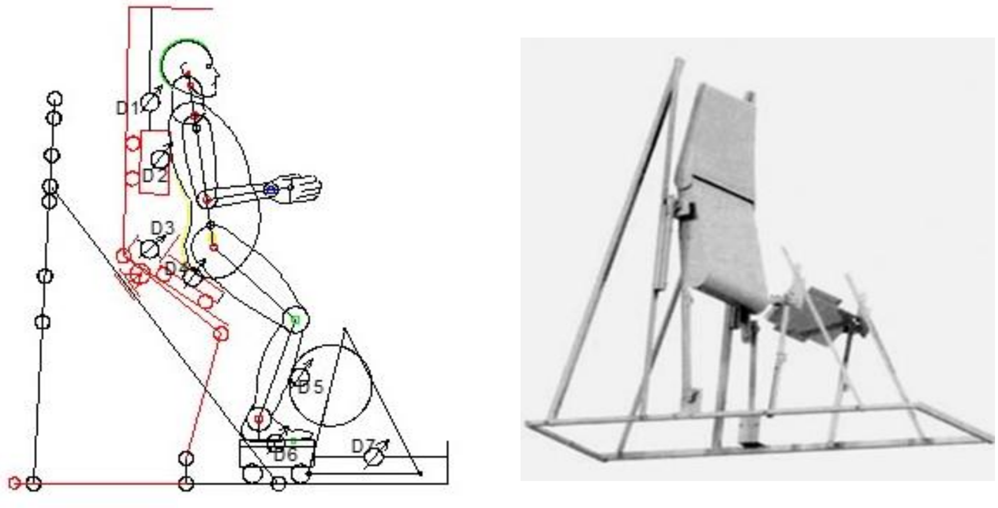
Unlike the usual driving position in which the seat supports the weight of the body predominantly in the buttocks and back of the thighs, the study suggests a quasi-vertical position where, due to the almost vertical position of the body and multiple support surfaces, the weight is distributed on several areas: back, buttocks and back of the thighs, knees area and soles of the feet.

To test this type of multiple support, the test bench simulating a driver's seat adapted to the quasi-vertical driving position was designed to measure the normal and tangential forces with which the user's body acts on the seat. As characteristic features - the stand is provided with a special device that supports the tibia and another device where the soles rest on.

The testing stand has been designed so that its geometric configuration can be modified relative easely according to a wide range of driving postures that should be taken into account during the tests (Figure 1.b).
It provides some important possibilities of adjustment of the seat position such as: seat cushion inclination and height, backrest inclination, the positions of the knee and sole supports in relation to the seat cushion.

The test is carried out in static conditions for various configurations / driving positions, using different human subjects with different anthropometric dimensions.

The seat cushion, the backrest, the tibia / knee support and the sole support are considered supporting elements of the chair. These elements and the dynamometer systems (D1,…,D7) attached to each of them have been designed and adapted so that normal forces (measured by D2, D4, D5 and D6) and tangential forces (measured by D1, D3 and D7) can be measured independently (Figure 1.a).



a) b)

Fig. 1. The functional scheme of the forces measurement system (a) and the basic structure of the testing stand for quasi-vertical driving position (b).

3.2 Principles used to test the quasi-vertical driving position

The mechanical stresses to which the seat is subjected by the user as well as the mechanical stresses to which the user's body is subjected (in return) by the seat will be determined by measuring normal and tangential forces. The way in which the body weight is distributed on the surfaces of the seat is determined directly by the working position adopted through the choice of geometrical configuration of the chair type support.

As an approach, this may be considered as a first step in the study of comfort for the unconventional quasi-vertical driving posture, followed by the study of other physiological and psychological effects on the user's state. The comfort state is also influenced by other factors that may prove important, such as the relative position of the limbs, the general body position, the duration of the test, the test conditions (static, dynamic, vibration, etc.), the place and context in which the test is made (indoor / outdoor, in traffic, in the laboratory), the quality of the contact between the body and the supporting elements. Obviously, the state of comfort is determined by a number of factors, and actually it represents an element of synthesis.

It is desirable to determine the existing relationship between the specific position of the body, the human body loads on the elements of the seat and the corresponding values of the significant parameters responsive for ensuring the comfort state of the user in the quasi-vertical working / driving position in the vehicle. This issue will be the subject of further studies.

One of the most important advantages offered by the testing stand during the experiments is the possibility to make large adjustments of the seat geometry corresponding to the range of driving/working positions studied (Figure 2.a).

An important parameter taken into account when performing the experiments is the angle of inclination of the seat cushion (α_{sc}) because it has the greatest influence on the working posture in direct association with the angle of inclination of the femur. A second important parameter is the inclination angle of the tibia (α_{tibia}). The two angular parameters α_{sc} and α_{tibia} represent the reference elements in the study of the working postures (Figure 2.b).

Thus, the cases determined by the angle α_{sc} (= $12^0 ... 84^0$) were analyzed, taking into consideration for each of them the values of the angle $\alpha_{tibia} = 33^0$, 16^0, 3^0 and -20^0. Positive values for α_{tibia} mean the tibia and the soles are directed backwards (Figure 2.c).

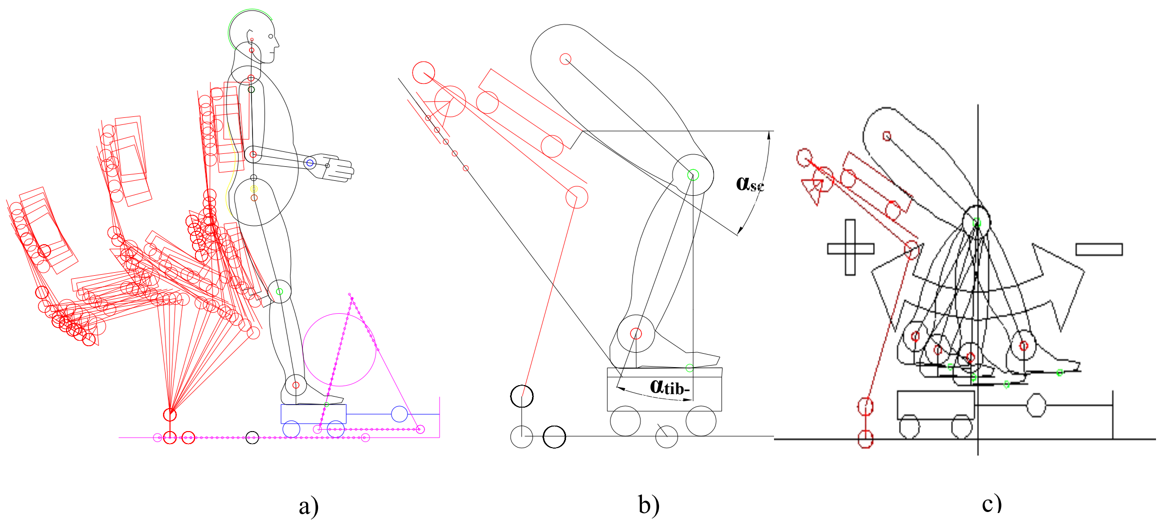


Fig. 2. The range of driving/working positions possible to be studied starting from α_{sc} and α_{tibia}

According to the existing comfort recommendations and following the observations made by the author during the experiments, the quasi-vertical working position implies a low inclination of the backrest. This explains the low values of both normal and tangential body pressure on the back of the seat measured during experiments and thus a seemingly low impact of the backrest in terms of working conditions. This led to the temporary ignoring of the backrest, which does not mean giving up the study of the influence of the backrest in this working position. On contrary, for the future this could represent a new direction of research and an important resource for innovation.

For each of the working positions defined by the parameters α_{sc} and α_{tibia} three working hypotheses were considered (Figure 3):

1 - the situation where the seat cushion is connected to the fixed frame of the seat by means of a dynamometer which records the tangential force with which the seat cushion is actuated - let say “in a passive way” (Figure 3.a);

2 - the situation where the seat cushion is not connected to the fixed frame so that there is no (theoretically) any tangential component of the human - chair interaction force at the seat cushion level (Figure 3.b);

3 - the situation where the seat cushion is operated in a tangential direction with a supplementary “active force” F_{sup}. It will be measured the influence of that supplementary force on the distribution of the human body loads on the chair (Figure 3.c).

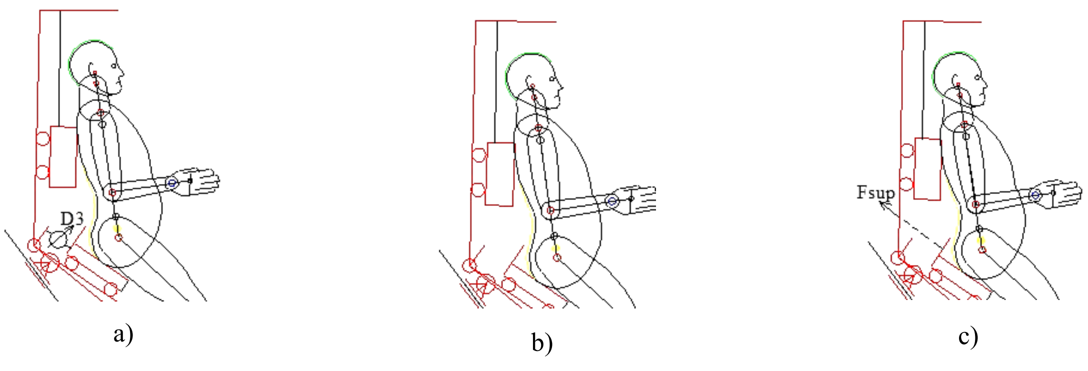


Fig. 3. The working hypotheses for the tests

For each of the cases, measurements of the normal and tangential forces were made on the stand by means of the D3, D4, D5, D6 and D7 dynamometer devices. The forces were represented graphically for a better interpretation of the research results.

As an example, for the first case (seat cushion connected to the fixed frame), if $\alpha_{tibia} = 3^0$ and $\alpha_{sc} = 12^0...84^0$, the following data resulted from the measurements on the testing stand (**Table 1**).

Table 1. Normal and tangential forces measured on the testing stand.

α_{sc}	*D3*	*D4*	*D5*	*D6*	*D7*
12^0	3,5 [kgf]	60,8	12,3	17,7	1,82
20^0	4	57,8	16,6	22,5	1,68
36^0	8	51,8	31,6	21,2	5,1
50^0	8,5	39,2	39	28,7	6,74
71^0	7,5	35,8	45,7	46	9,87
84^0	7	35,6	46	50,9	11,9

Graphically these data can be represented in several significant ways. In the Figure 4 it can be observed the variation of the normal loads (D4, D5 and D6) and tangential loads (D3 and D7) measured on the seat elements as a function of the variable α_{sc} ($\alpha_{sc} = 12^0...84^0$). It can also be observed the share of each load in the set of forces acting on the seat elements, as well as the interdependencies of these represented loads depending on α_{sc} values. The loads are expressed both in absolute value ([kgf]) and in percentage ([%]).

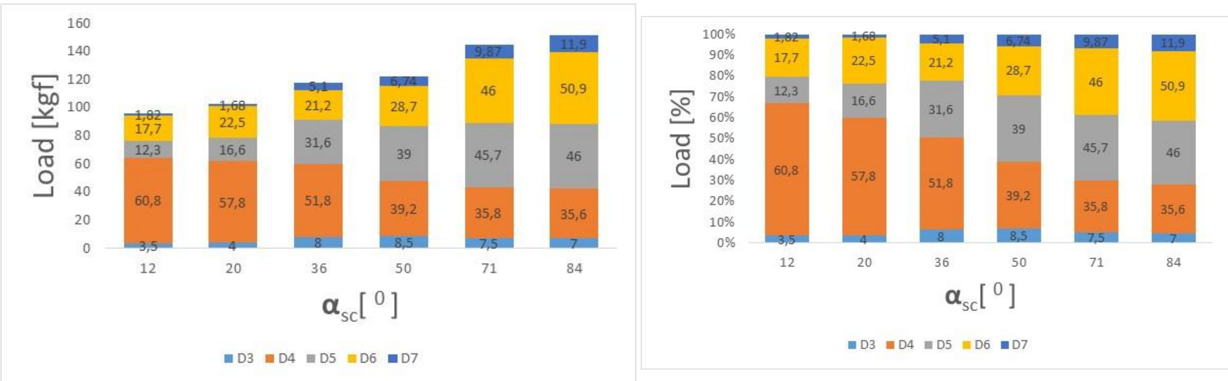


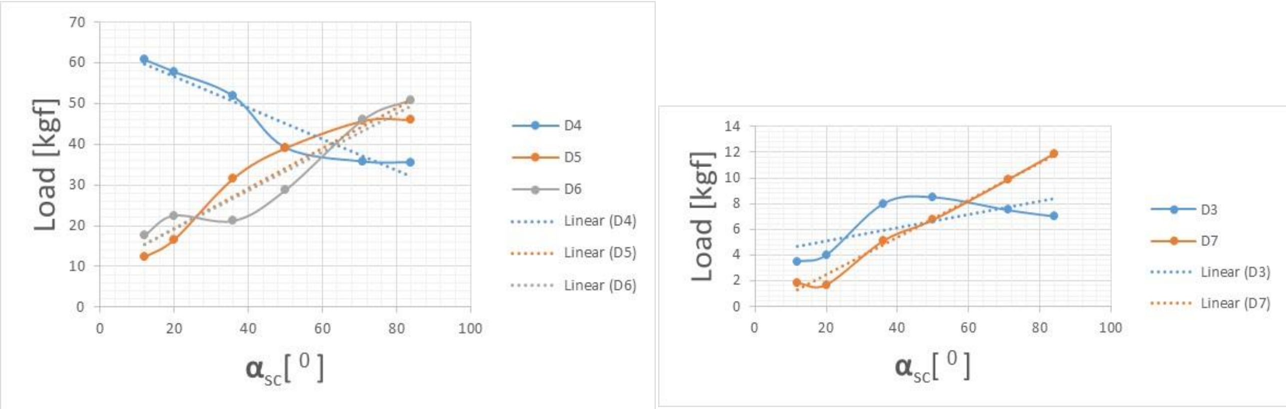
Fig. 4. The variation of the normal and tangential loads measured on the seat elements as a function of the variable α_{sc}

The results of measurements show that the sum of the loads on the seat elements is variable depending on the seat cushion angle and reaches values (151 [kgf]) significantly higher than the weight of the subject (93 [kgf]). This significant increasing may be directly responsible for the comfort or discomfort sensations.

Using another type of chart, the Figure 5.a represents only the normal loads on the seat elements. Similarly, in Figure 5.b are represented only the tangential loads.

As a general trend, it is noticed that the increase of the seat cushion inclination angle ($\alpha_{sc} = 12^0 ... 84^0$) produces a progressive and significant decrease of the normal force on the seat cushion (from 60.8 [kgf] to 35.6 [kgf]) with the progressive increase of both normal forces on tibia (from 12.3 [kgf] to 46 [kgf]) and on soles (from 17.7 [kgf] to 50.9[kgf]).

It is also noted the trend of the total normal forces pressing on the elements of the seat (sum of the normal forces) to increase significantly (from 90.8 [kgf] to 132.5 [kgf]) with the increasing of the inclination angle of the seat cushion α_{sc}. This could mean an extra effort of the body, a more intense aggression on it due to this supplementary interaction with the seat support elements.



a) b)

Fig. 5. The variation of the normal loads (a) and tangential loads (b) as a function of the variable α_{sc}

4. Conclusions

Different ways of acting of the human body on the seat elements generate specific effects on the user's comfort state that have to be checked by tests. It is assumed that by increasing the inclination of the seat cushion and reducing the normal load in the buttock area a beneficial effect on the comfort state occurs, but at the same time there is an opposite effect due to the increase of normal loads in the tibia and the soles. It remains to be determined which are the optimal comfort conditions that can be achieved in the quasi-vertical position depending on the inclination of the seat cushion and the corresponding generated loads. It can be seen in the Figure 5 that, for the angle α_{sc} around of 60^0 the normal forces (D4, D5 and D6) tend to become equal, but the summed forces exceed the value of the user's own weight. Therefore, it is intended to establish by experiment the criterion of choosing the recommended comfortable working position - possibly the situation when the normal loads on the seat elements are approximately equal to each other („uniform pressure distribution criterion"), or when uneven, the normal forces to be inferior to some specific recommended values.

Even if their size is much lower than the normal forces, it is also necessary to carefully test the influence of the tangential forces (D3 and D7) on the comfort state considering their variation depending on the seat cushion inclination angle. As a preliminary observation on the measurements made on the testing stand, the tangential forces measured at the level of the sole and at the level of the seat cushion tend to become equal for α_{sc} around 60^0. For the angle α_{sc} less than 60^0 the measured tangential load D3 is bigger than D7, and for the angle α_{sc} greater than 60^0 the tangential load D7 becomes greater than D3. This could mean that a balanced distribution of the body mass on the seat elements is achieved around the posture corresponding to $\alpha_{sc}=60^0$, suggesting some research perspectives of this position.

Acknowledgments The research work reported here was made possible also by the collaboration of the students Raluca Stoica, Sorin Ivan and Iulia Ciuntu who brought their valuable and enthusiastic contribution to the realization of the testing stand during the elaboration of their license work.

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