NEW APPROACH IN THE AUTOMOTIVE COCKPIT DESIGN

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Abstract: The design of the driving seat position represents the starting point and the control criteria for a new car design process. For each alternative of a new body design proposed by the stylist it is necessary to make an ergonomic evaluation of the cockpit. This is why this stage is recommended to be as simple and fast as possible. Starting from the wide diversity of human dimensions we propose a new algorithm for the research of the cockpit architecture using a 2D virtual anthropometrical model with variable dimensions. The concept is transposed in a new CAD software for the cockpit architecture research.

Keywords: ergonomics algorithm, automotive cockpit architecture, CAD

1. INTRODUCTION

The SAE standard methods proposed for the ergonomic study are using theoretical human models - anthropometrical percentiles. There are few models that have the dimensions resulted from a statistical analysis made on a focused population. The practice demonstrated that the real anthropometrical dimensions are often different from the theory and it is necessary to use a wide diversity of human dimensions.

The design of the driving seat position represents the starting point and the control criteria for a new car design process. The method consist of determining the field in which there are satisfied the driving comfort conditions for the legs and arms and finally for the vision.

2. TECHNICAL REQUIREMENTS

The classic ergonomic methods use two human mannequin templates corresponding to the 95% male percentile and 5% female percentile anthropometrical models (figure 1). The method is useful but it is time consumer, it is not very precise and almost empiric and it is most likely to ignore many real driving situations.

Obvious, the multitude of the driving situations could be well controlled and analyzed with an analytic method. For this reason it is proposed an algorithm and software based on the algorithm that transpose an original method for the cockpit analysis. The method is characterized by a convergent approach of the numerous possible driving situations and guides the investigation to a simple and clear conclusion.

Figure 1: Anthropometrical models
2.1. Contributions concerning anthropometrical mannequins used in the automotive design

To realize an algorithm for determining the driving comfortable positions it was necessary to simplify the geometry of the human body. As an original contribution it was proposed a beam mechanism that reproduce the human body in a simplified manner (figure 2). Thus, the ergonomically analysis will be made by using the well-known mechanism methods.

Figure 2: The beam mechanism that reproduce the human body

The mathematical results will be transposed in a graphic representation in which the mechanism corresponding to the simplified human body will be replaced by a suggestive anthropometrical mannequin.

One of the most important difficulties in ergonomics is to choose the right dimensions for the anthropometrical mannequins. There are plenty studies that use different anthropometrical models obtained from a reference model by proportional scaling of the body elements. However it is proved that in the real life the proportions of the human body are different for each person. It is known that the anthropometrical profiles depend on the sex, race and age. The complete study is laborious and time consuming and will need a lot of attention. This is the reason why it is purposed a virtual (CAD) anthropometrical mannequin that can be modified easily; the length of the body elements can be modified independently by simply introducing the values in a dialog box. The reference mannequin corresponds to the 95% male percentile (figure 3) and it is automatically scaled after introducing the values for the body elements lengths. This is the way it can be obtained any type of anthropometrical mannequins (figure 4).

Figure 3: the 95% male percentile

Figure 4: Different types of anthropometrical mannequins
The experiments made on the ergonomic stands offer the angular values that are recommended in order to ensure optimum comfort driving. One of the conditions refers to the minimum distance between the femur and the bottom of the driving wheel rim. These two objectives must be achieved only if the conditions for a good driving vision are also attained.

The SAE recommendations for the vision field measurements use the hip point position for the 95% male percentile placed in the rearmost driving position (SgRP).

Each of the angles of the human joints has a field of recommended values. This is the reason why, by combining the accepted values (for each of the joints) results a huge number of possible situations to be analyzed in the ergonomics stage. For example, in order to realize a certain movement it is made a modification of the value in a joint angle. This could bring about a new position of the mannequin that must be in accordance with the recommended values of the angles in each of the body joints.

In the figure 5 it is presented the geometry of “the human mechanism” proposed together with the new algorithm and software, and “the human profile” associated with the mechanism.

![Figure 5: The geometry of “the human mechanism”](image)

**2.2. The definition of the comfortable position of the legs**

Using the figure 5 it is written the vectorial equation for the vectors polygon 1-3-4-5:

\[
\vec{l}_1 + \vec{l}_2 + \vec{l}_3 + \vec{l}_4 = 0
\]

The position of the hip point (point 5) results from the above equation according to the recommended values for the angles. The study is made apart for the 5% female mannequin and for the 95% male mannequin (figure 6).

![Figure 6: The hip point for the 5% female mannequin and for the 95% male mannequin](image)
The gap between the two domains (corresponding to the anthropometrical mannequins used) determine the domain in which will be placed the virtual seat during the adjustment - corresponding to the hip point adjusting field.

The proposed method, algorithm and software easily allow a quick verification of the comfortable position for the hip point of any anthropometrical profile and working situation. The hip points have to be placed in the adjustment domain determined.

2.3. The definition of the comfortable position of the arms acting the steering

The comfort of the driver depends on a minimum distance between the bottom part of the steering-wheel rim (12) and the femur (4) (figure 7).

![Figure 7](image)

Figure 7: The geometry for calculating the minimum distance for the bottom part of the steering-wheel rim

The position of the point 12 related to the point 4 results from the vectorial equation written for the polygon 5-9-10-11-12-4:

\[ \vec{l}_4 + \vec{l}_6 + \vec{l}_7 + \vec{l}_9 + \vec{l}_{10} + \vec{l}_{11} = 0 \]

First of all it is necessary to choose the type of the mannequin and to establish the domain of the hip point (5) using the method presented in the previous chapter. Then, it is choosen a hip point (5) in the established domain that provide a confortable position. It is adopted the radius and the bending angle of the steering wheel and the bending angle of the back. Then it is calculated the accepted positions of the bottom part of the steering wheel (12) related to the hip point (5). The calculated position is a function of the arm angles (figure 8).

![Figure 8](image)

Figure 8

![Figure 9](image)

Figure 9
In the figure 9 there is represented the accepted positions of the point 12 for the 5% female percentile mannequin and for the 95% male percentile mannequin. The two domains have a common sub domain in which could be placed the point 12 of a fixed steering wheel. The situation represented is special, usually the two domains are distinct and the steering wheel must be adjustable in the two represented domains.

In the figure 10 it is represented the configuration of the driving position and the two extreme mannequins used for the ergonomic study – 95% male percentile and 5% female percentile. It can be observed the limits of the position of the hip point (5) for each of the mannequins and the fixed position of the steering wheel that respect the comfort condition.

![Figure 10: The configuration of the driving position](image)

2.4. Automation tool for the 2D cockpit architecture research

The ideal helping solution capable to ensure that the finished (car) product meets the ergonomic requirements is to conduct the traditional mock-up stage using the computer graphics. Starting from the working principles, the algorithm and the anthropometrical 2D CAD model presented above, the author conceived a new software (named “MANE”) for the 2D cockpit architecture research. The program is very useful in the early design and styling stages.

The reference point of the mannequin is the heel point. The analyse is made for the two extreme mannequins usually used in the ergonomics – the 95% male percentile and the 5% female percentile. There are imposed angular restrictions for the mannequin joints. In the first stage the program determines the hip domain (of the point 5) for the two mannequins. From the two intersection domains there are chosen two points, one for each mannequin. The “MANE” program automatically represents the two mannequins profile (figure 11). The gap between the two points include any possible seat adjustment.

![Figure 11: The representation of the mannequins using the “MANE” program](image)

By choosing the type of the mannequin and the corresponding hip point 5, the “MANE” program determine and represents the comfortable positions of the steering wheel 12. The positions also depend on the diameter and the inclination of the steering wheel. It is important to notice that it is preferable to find a common subdomain of the points
12 for a given inclination angle and a common diameter of the steering wheel for the two mannequins used and for all possible users. In this sub domain it can be placed the 12 point of a fixed steering wheel. It was noticed that generally the steering wheel must be adjustable. The “MANE” program gives the representations of the possible domains of the steering wheel that provide the comfortable conditions for the arms.

The main dialog of the “MANE” program is a pretty complex dialog box (figure 12). The preview image on the left side and the ‘Show/Hide Body’ button helps the user to identify the requested dimensions.

![Figure 12: The main dialog box of the “MANE” program](image)

All data are saved in an external text file, with a structure similar with the standard AutoLISP lists, to easily read and transform each line in a data list.

3. CONCLUSION

The proposed algorithm can be transposed in different software solutions that allow rapid ergonomic optimization of the cockpit.

The new software is easy to use and also offer enough flexibility to add/modify mannequins with different dimensions, and save them in a database with “human-readable” names.

Using the proposed software the necessary time for the study is dramatically reduced and the correctness of the results is improved.

REFERENCES