Ergonomics analysis of automobile seat comfort

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Abstract—**Modern car buyers, in addition to style and safety, also require seating comfort. The most important aspect of the ergonomic posture analysis is a biomechanical study of the position of the vehicle driver. Car manufacturers must adapt seats to almost all populations that may be the prospective owners of these cars. The aim of this research is to analyze the driver's comfort, in the case of the German car production, which is sold for the Japanese market. Using the Ramsis software package, which represents the leading program for the design and analysis of ergonomics inside the vehicle, defining boundary conditions and interaction of the manikin with parts of the vehicle, it is possible to analyze the model sitting position and check the index of health. In this way, car designers can acquire the exact information about their car agreement with anthropometric characteristics of any population, before the actual car-making process.**

Keywords-seating comfort; ergonomics posture analysis; Ramsis; manikin; health index

I. INTRODUCTION

Contemporary literature contains more papers focusing on office and industrial than automotive seating because of the economic costs associated with discomfort and injury in the office and factory. However, the environment of a vehicle is also a workplace, with the difference between the situations of an ordinary and a professional driver while perform process driving. Ergonomics is the scientific discipline concerned with the understanding of interaction between human and other elements of the system. The application of ergonomics is reflected in the design of all means of transport, production processes, agricultural machinery and equipment, traffic system, working environment, as well as devices for everyday use [1]. The role of ergonomics is to increase the efficiency and productivity of production and improve health, safety and comfort of people in their work environment. Ergonomics relies on a large number of scientific disciplines including physiology, biomechanics, psychology and anthropometry. An important component of ergonomic research of a vehicle is a prediction and development of a passenger's space in the vehicle [2]. The interior of the car can have a significant impact on both mental and the physical health of drivers and passengers. Seats in the vehicle are one of the main issues during the design because they determine the position of passengers in relation to all other components in the vehicle [3]. During driving, especially in long periods, seat comfort is very important. Comfort is defined as a condition where the traveler feels relaxed and where you do not feel pain, heat, cold, etc. Lose Loosely designed seats could negatively affect the passengers, and even lead to serious injury [4], [5]. The author [6] shows that it is very difficult to investigate seating comfort because of a large number of interactive factors including the driver, the seat, and all the tasks that must be performed while driving. These factors can be categorized as follows:

- Vehicle/Package factors (seat height/eye point, pedal/steering wheel position, head/knee room, transmission type),
- Social factors (vehicle nameplate, purchase price of vehicle),
- Individual factors (demographics, anthropometry, culture, posture),
- Seat factors (stiffness, geometry/contour, breathability, style).

Almost all manufacturers of automobile seats usually make prototypes for testing the comfort in order to achieve the requested results. Testing with prototypes is an expensive procedure and it requires a lot of time [7]. Implementation of new software products for virtual modeling of a vehicle structure, as well as software products for simulation of processes and system behavior reduce the time for testing a new product. Testing of new vehicles starts with the first phase - virtual testing of virtual models, using virtual humans. This phase reduces errors and inconveniences. Also, time and price for testing new or improved vehicles are reduced. It the end, tests results are applied on real models – prototypes.

Good and precise definition of vehicle sitting comfort /discomfort requires that seat and package geometries, driving postures and visual demands are set close to actual driving situations. Ergonomic analysis of the passenger compartment of cars is carried out by means of specific software packages. In this study, we used the software

packages Catia v5 R18 and Ramsis (ger. *Rechnergestutztes Anthropometerisches Mathematisches System zur Insassen-Simulation*). Ramsis software package is the leading 3D CAD ergonomic tool, which the user can utilize to manipulate the model and place it in different positions. More than 70% of all car manufacturers worldwide now use this software. With this software package, one can include all phases of car designing. Also, Ramsis can be used for a large number of tests in the laboratories of virtual car manufacturers [8]. In this study, we investigated the ergonomic position of the male model (Japanese population) in the virtual environment of the interior of the vehicle VW UP! (Fig. 1).

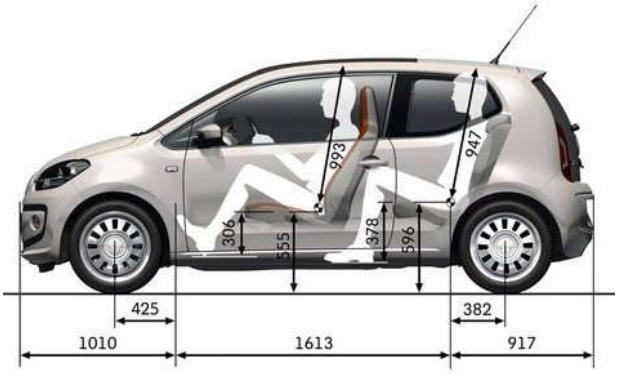


Figure 1. Volkswagen Up! dimensions [8]

II. METHODS

Packaging is the name used in the automotive industry to describe the placement and design of the various components and systems in the vehicle space. Furthermore, packaging is not only concerned with fitting these components into the vehicle itself but with doing so in a harmonious way and most importantly in a way that considers the ergonomic needs of the driver and passengers. The seating package design entails a number of factors including the positioning of the driver and all other occupants, various reach, clearance and visibility zones (e.g. hand reach envelopes, head clearance contours and fields of view), and other relevant vehicle details (such as pedals, steering wheel, seats, arm rests, gear shifter, parking break, mirrors, hard points) and dimensions (Fig. 2).

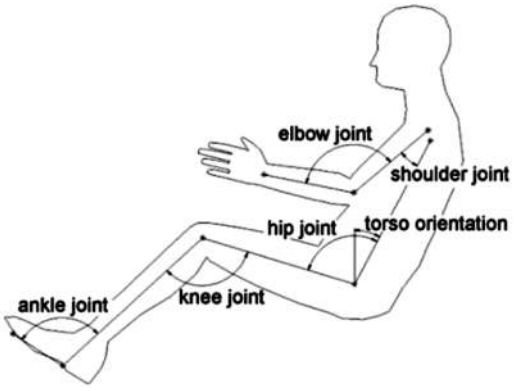


Figure 2. Parameters of driver's work position [9]

In order to define the final layout of an automobile from an ergonomic point of view, it is necessary to have knowledge about body dimensions of the person using the vehicle. The first task of this study was to create a work environment manikin in the vehicle. For seat modeling software package Catia v5 R18 and Part Design Module were applied for the entire interface. Fig. 3 shows the vehicle seats dimensions, used in this paper.

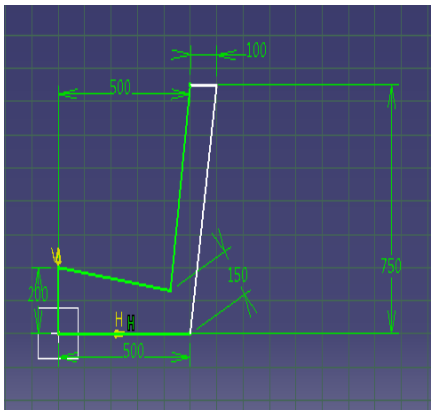


Figure 3. Initial sketch with dimensions of seat

In the same way the whole environment was made, and then Assembly Design module was used, in order to set the seat into the interior of the vehicle.

The second task was to analyze the sitting posture models, and check the index of health in this position. Health index represents a set of measurements designed to detect short-term fluctuations in health of members of a population. These measurements usually include physical function, activities of daily living, feelings, etc. For ergonomic analysis, software package Ramsis [10] was used through which the manikin was placed in the internal environment of the vehicle. The most probable posture can be predicted using this software. Software Ramsis was manipulated with two manikin models - a kinematic and geometric. Kinematic, or the internal model, is an account of the human skeleton. Basically, these are the lines that define the skeleton of a male model. The geometric model, or an external model, is simply manikin surface. This is what makes the manikin that looks like a man.

Big crowds in traffic and fewer parking spaces provide a good reason for people in Japan to increasingly opt for smaller vehicles. In this paper we used a geometric model of a Japanese, male sex, age group 18-70, body height 1720 mm, height of siting part 920 mm, length 245 mm and feet shoulder width 420mm [11]. The hands are modeled with five fingers, feet with shoes (Fig. 4). According to data from 2014, VW was in the top ten manufacturers in the Japanese market [12].

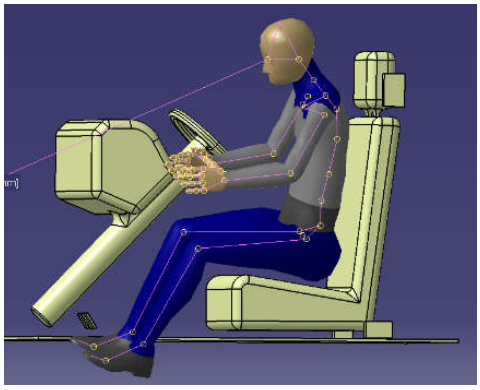


Figure 4. Manikin in the passenger compartment before placing boundary conditions

After setting a manikin in a sitting position, it is necessary to define the boundary conditions of the manikin. First, it is necessary to fix a manikin on the seat, and then bring the hands in the position where both hands are holding the steering wheel. Right foot is placed on the accelerator pedal.

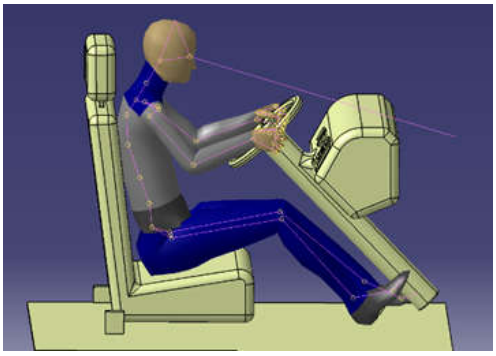


Figure 5. Manikin in the passenger compartment after placing boundary conditions

Settings manikin from the previous figure is ready for ergonomic analysis. The Ramsis posture prediction is based on statistical analysis of results from the conducted experiments. Properly defined boundary conditions create the possibility of accurate analyses sitting position, as well as health assessment of the spinal.

III. RESULTS

The aim of this paper was to analyze the seated position and the index of health manikin. Based on the analysis of the manikin in seated position relevant information were obtained concerning the health of the manikin. Fig. 6 presents discomfort assessment.

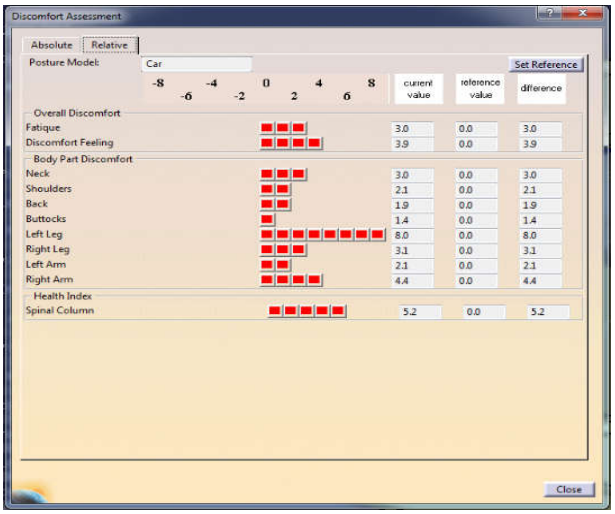
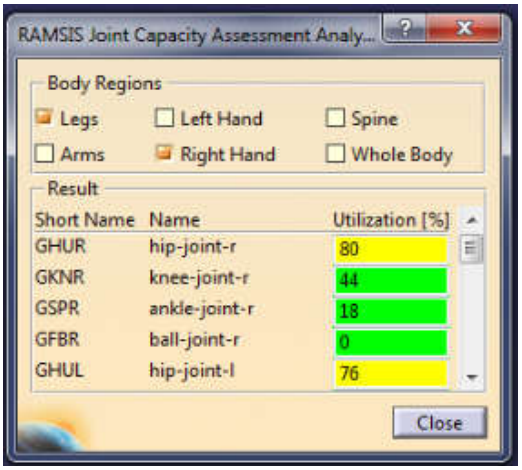
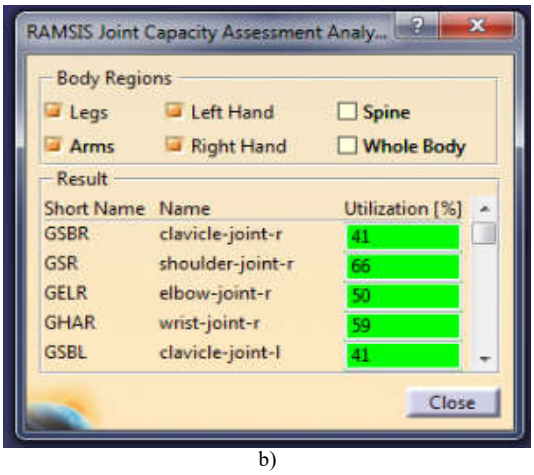


Figure 6. Dialogue of discomfort assessment

It is based on the experimental analysis of more than 100 respondents in a given vehicle seat [11]. Value to 2.5 represent good positions body segments. Values from 2.5 to 5.5 are medium-loaded parts of the body, while values above 5.5 can be uncomfortable and harmful to health. Fig. 5 shows that the left leg suffers greatest discomfort, value 8.0, while the other parts of the body put up with load within acceptable limits. Spinal column has a value of 5.2, and that part of the body is a medium-loaded part. Fatigue has a value of 3.0, while discomfort feeling has 3.9, which represents allowed values. The same load can be displayed as the following procedures, only by the second option (Fig. 7).



a)



b)

Figure 7. Joint capacity assessment analysis

Green color represents the allowed value, and it is moving in the range of 0% - 75%, yellow color represents tolerance value of 75% - 90%, while red color indicates the unallowable condition, or a condition in which the driver should not (in this case a male manikin) be found. Its value ranges in the range of 90% - 100%. From the previous figure, H point has tolerated the load, while other parts of the body were within the permitted load.

Software Ramsis has the ability to calculate the maximum force, tolerant force and force that can be continuously carried out in a given situation. For this case the right leg was chosen to show the force. The maximum value of force for this part of the body is shown in Fig. 8.

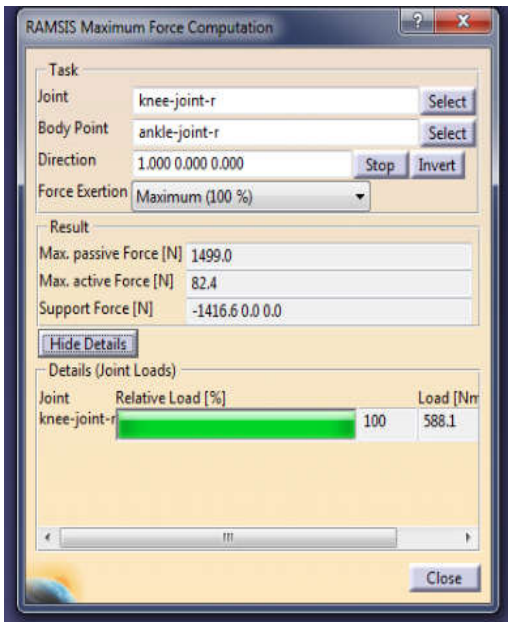


Figure 8. Maximum force computation

From the previous image, we can see that the maximum value of the force, which is realized on the right leg, is 588 N, which is far below the maximum passive force. In this way, it is verified that the resulting value of the force is acceptable for a male manikin.

IV. CONCLUSIONS

Software package ”Ramsis" helps car manufacturers to graphically display the car's interior and thus determine the dimensions of certain components that are needed in the design i.e. for the design of the passenger compartment. In addition, this software performs checking the health index of drivers and passengers, indicating the positions that are comfortable or uncomfortable for users while driving. The present paper included checking the health index of Japanese drivers in vehicles of German manufacturer. The driver is represented by a male model who had all the anthropometric characteristics of a Japanese driver. Using various options for analysis in the software package Ramsis, we obtained the answer of loads of individual body parts. In this way it is possible to examine the spinal stresses of real word condition, as well as the determination of maximum force with which the driver can operate the brake pedal in a given situation.

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