Application of digital human models in determination of the pedal force while driving

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Application of digital human models in determination of the pedal force while driving

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Abstract. One of the most important tasks of the car manufacturer is the design of the interior space of the vehicle. Anthropometric characteristics of drivers are also important for designing cars. In this paper the determination of the pedal force has been performed. The force determination was made on digital human models for different populations, a total of 11 different populations of men and women. Analysing was done in the software package Ramsis and subjects were presented using "mannequin". The obtained force values were different for different populations. The correlation between the anthropometric measures of the subjects and the force on the pedals was observed. By calculating Pearson R coefficient in both populations, female 5 % and male 95 %, it can be concluded that there is a good correlation between active foot pedal force and driver's height (R^2 = 0.84 and R^2 = 0.72, respectively). In the case of maximum values of passive forces R coefficient in both populations also have a good correlation between passive pedal force and driver's height (R^2 = 0.89 for female 5% population and R^2 = 0.69 for male 95 % population). The obtained results are important for designing the interior of the vehicle.

1. Introduction

The interior of the car can have a significant impact on both the mental and the physical health of drivers and passengers. Car manufacturers design the interior of the vehicle in order to better meet the needs of the driver. Ergonomics is the scientific discipline concerned with the understanding of interaction between human and other elements of a system, in this case - a vehicle [1]. The role of ergonomics is to increase the efficiency and productivity of production, improvement of health, safety and comfort man in his work environment. This paper explores the necessary force to activate the pedal while driving. Inadequate pedal design often leads to fatigue and discomfort of drivers [2]. Many studies have dealt with the determination of discomfort during driving. This is mostly done by subjective assessment methods. Studies have shown that the realization of the maximum force depends on the position of the seat, the type of seat and pedal [3]. Mortimer [4] suggested that the maximum pedal force for 5% female population should not exceed 400 N. According to [5] changes in the angles of the knees influenced the maximum force on the pedals. The smaller the knee flexion angle (from 20° to 80°) is, the greater the foot strength is. Mehta [6] concluded that the maximum force was achieved when the leg was in an almost elongated position, that is, the angle of bending the knees was between 35° and 45°.

In this research, all digital human models were placed in the virtual environment of Volkswagen UP! [9]. The anthropometric data of the male and female population are useful for the examination. The software packages Catia V5 R18 and Ramsis (Rechnergestutztes Anthropometerisches Mathematisches System zur Insassen-Simulation) were used [7]. With the Ramis software package,

models can be set up and manipulated with their movements. This approach is the most important stage in the process of developing a new vehicle.

2. Methods

In order to examine how the design of the car and the position of the vehicle controls affect the inconvenience of drivers, certain digital human models are used. In this paper, the work environment of the driver in the vehicle was first created. The Catia V5 R18 software package is used to model the interior of the vehicle. Setting the model in the seat and defining the boundary conditions was done using the Ramsis software package. The vehicle seat is fixed and adjusted to the highest population.
Two types of human models can be used in Ramsis, kinematic and geometric. The kinematic model takes into account the human skeleton and the model is a wicker frame. The geometric model represents the surface of the model. In this paper, a mannequin (geometric model) with 5 fingers and shoes on the feet was used.

This study included the analysis of eleven different populations, men and women [11]. Their anthropometric characteristics are in Table 1. These populations belong to the age group 18-70 years for 5% and 95% of women and men. When designing a vehicle, manufacturers define a vehicle for a population of 5% to 95%, where 5% is defined in relation to female population, and 95% in relation to male population, with the aim of achieving a larger universality and placement of passenger cars on the market regardless of the geographical climate.

Good design of foot controls has an impact on the better efficiency of the braking system. The activating force on the pedals can be active and passive. The active force is only triggered by muscular activity, while the passive force is generated by muscular activity and additionally relying on the floor. The recommended values for pedal-force activation range from 25 to 400 N [10]. The change in anthropometric dimensions has an effect on the values of the activated pedal force.

Table 1. The anthropometric data of 5% female and 95% male population [11].

	Height (mm)		Sitting height (mm)		Foot length (mm)	
Population	*5%*	*95%*	*5%*	*95%*	*5%*	*95%*
West Africa	1440	1785	741	881	212	278
North India	1450	1765	771	919	205	270
Eastern Europe	1540	1845	831	959	225	285
North Europe	1585	1910	846	999	227	280
Australia	1565	1885	831	979	220	280
South East Europe	1525	1825	811	949	220	285
Central Europe	1560	1805	826	989	220	288
South East Africa	1480	1775	771	909	210	280
Middle East	1529	1800	801	944	222	280
South India	1395	1715	746	874	200	265
North Asia	1504	1820	801	961	207	275

3. Results

The Ramsis software package is based on a statistical analysis of the results obtained experimentally [7], [12]. On the basis of the collected anthropometric data of the subjects, digital models of man with boundary conditions were generated. With this software, the analysis of foot - pedal interaction was performed. Based on this, the pedal activation force was determined. The lowest value of active and passive force of the female population have the populations from Central Europe and North Europe, 138.1 N and 156.9 N, respectively for active force, and 149.2 N and 165.6 for passive force. The populations of West Africa, South India and North India have the highest values of active and passive

forces (Figure 1). Maximum value of active force was 219.7 N (West Africa female 5% population), while the maximal passive force was 223.1 N.

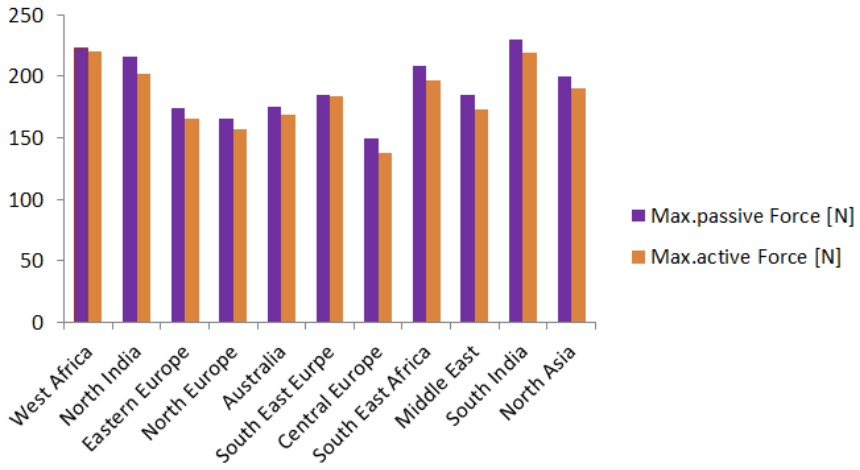

Figure 1. The maximum foot pedal force (active and passive) of eleven female 5% populations.

Figure 2 shows the values of active and passive forces of the male 95% population.

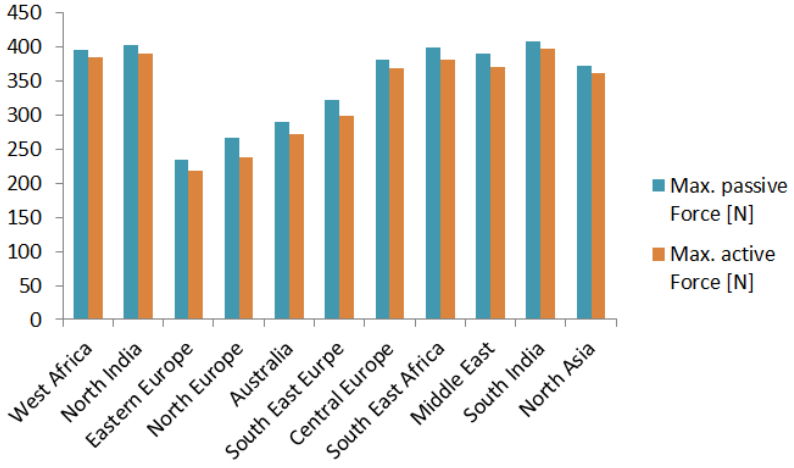

Figure 2. The maximum foot pedal force (active and passive) of eleven male 95% populations.

The smallest value of the active and passive force have population from Eastern Europe and North Europe 218.1 N and 238.5 N, respectively for active force, and 233.8 N and 266.2 N for passive force. The South India, North India and West Africa populations have the highest values of active and passive forces. Maximum value of active force was 397.1 N (South India male 95% population), while the maximum value of passive force was 408.7 N. With this value exceeding 400 N, the male 95% population of South India exceeds the permitted value of pedal passive force, so this position is uncomfortable.

By increasing the height of the male/female drivers, it can be noticed that there is a decrease in the active force values required to activate the pedal (Figure 3 and Figure 5), as well as passive force values (Figure 4 and Figure 6). By calculating Pearson R coefficient in both populations, female 5 % ($R^2 = 0.84$) and male 95 % ($R^2 = 0.72$), it can be concluded that there is a good correlation between active foot pedal force and driver's height. Also, in case of maximum values of passive forces R

coefficient in both populations also have a good correlation between passive pedal force and driver's height ($R^2 = 0.89$ for female 5% population and $R^2 = 0.69$ for male 95 % population).

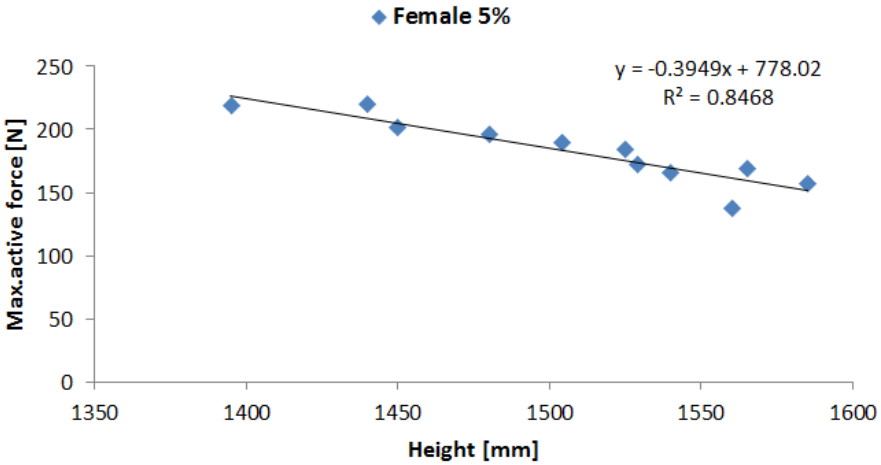

Figure 3. Maximum active foot pedal force of the female driver's vs. height.

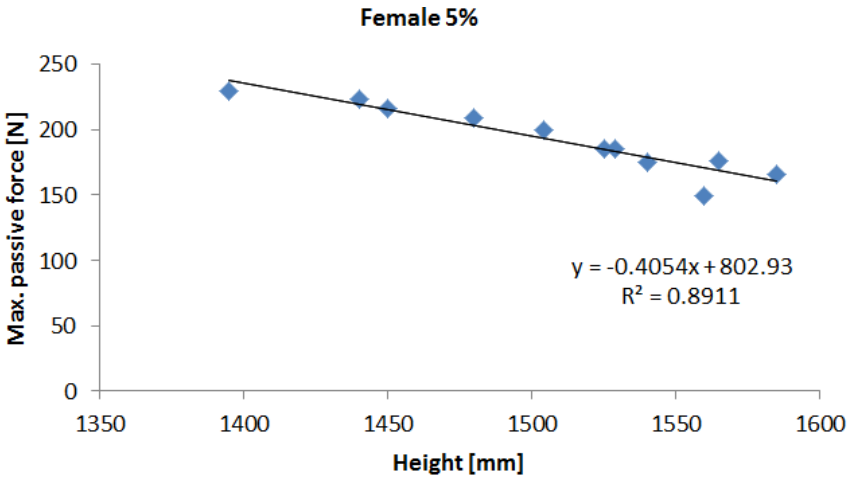

Figure 4. Maximum passive foot pedal force of the female driver's vs. height.

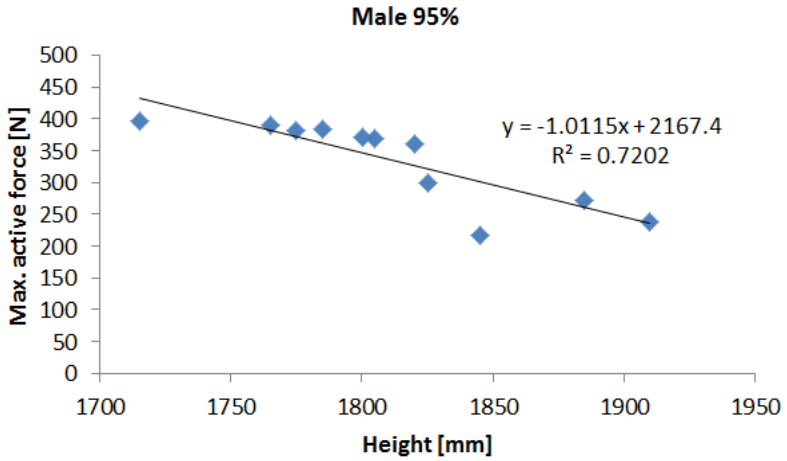

Figure 5. Maximum active foot pedal force of the male drivers vs. height.

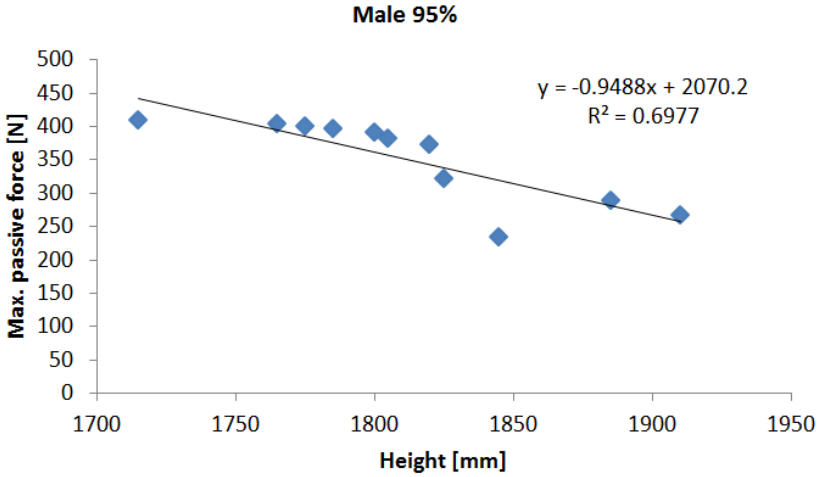

Figure 6. Maximum passive foot pedal force of the male drivers vs. height.

4. Conclusion

In this paper, the force required to activate the pedal from the driver's seat is determined. The study was conducted on eleven different populations, men and women. Ramsis software package is used for analysis and determination of force. Using this software package, car makers have the opportunity, before the first prototype, to graphically display how the model interacts with its environment inside the car. Results show that the smallest value of the active and passive force have population from Eastern Europe and North Europe 218.1 N and 238.5 N, respectively for active force, and 233.8 N and 266.2 N for passive force. The South India, North India and West Africa populations have the highest values of active and passive forces. Maximum value of active force was 397.1 N (South India male 95% population), while the maximum value of passive force was 408.7 N. By increasing the height of the male or female drivers, it can be concluded that there is a decrease in the active and passive force values required to activate the pedal. By calculating Pearson R coefficient in both populations, female 5 % (R^2 = 0.84) and male 95 % (R^2 = 0.72), it can be concluded that there is a good correlation between active foot pedal force and driver's height. Also, in case of maximum values of passive forces R coefficient in both populations also has a good correlation between passive pedal force and driver's height (over 0.69).

The significance of this research during the development and production of vehicles can save a money and time, and also lead to the final product driver friendly designed. The influence of position and indication angle of pedal activation force will be analysed in further research.

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