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Pedal force determination respect to ride comfort

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Pedal force determination respect to ride comfort

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Abstract. Automotive ergonomics is a set of knowledge which has a task to design a vehicle to make the passengers feel comfortable. Interior packaging represents an important stage in the vehicle design process, in order to enable the driver to every important aspect of movement. During the process of driving, the driver performs various movements of arms and legs, leading to a certain fatigue. Each seating position in the vehicle, contain certain boundary conditions, and for that reason it was necessary to examine how the seating position affects the driver possibilities. In this paper, the pedal forces were determined by application of Ramsis human model. Different human populations were taken into account. Correlation between subjects' anthropometrics measures and the foot pedal force pedal was observed. Obtained results were significant input data for vehicle packaging.

1. Introduction

Car manufacturers design the interior of the vehicle in order to better meet the needs of the driver. Ergonomics is a science that helps manufacturers makes cars as comfortable as possible. Every designer must use certain norms and regulations when designing a car interior. First, it is necessary to increase efficiency and productivity of production, then the improvement of health, and finally the safety and comfort man in his work environment [1]. Using knowledge of this science, there is a possibility to know in advance the possibility of movement during driving. During the driving process, due to certain movements, driver fatigue occurs. This is particularly the result of a long distance driving and often pedal activation. In this study, the force required to press the pedal in a driving position was studied.

This study investigated the ergonomic position of the mannequin in the virtual environment of the interior of the vehicle VW UP! (figure 1). The anthropometric data of male and female of nineteen populations were analysed. The software packages Catia v5 R18 and Ramsis (*Rechnergestutztes Anthropometerisches Mathematisches System zur Insassen-Simulation*) [2] were used. It is a leading program in the field of 3D CAD ergonomics, and more than 70% of all car manufacturers worldwide now use this software, which have ability to set a mannequin at a specific place and to manipulate his movements [3].



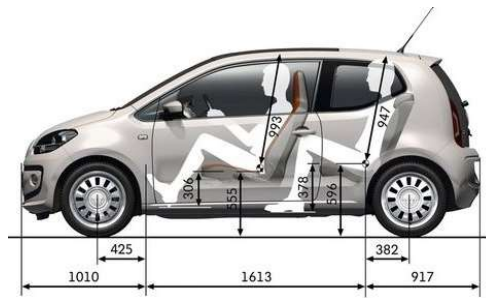


Figure 1. Volkswagen Up! dimensions [4].

2. Literature review

In the automotive industry, a very competitive market forces car manufacturers to develop their products better and faster. Application of computer-aided design (CAD) and numerical simulations is possible to apply ergonomics in the early stage of vehicle creation, using digital human models [5]. The assessment of discomfort was done through a discomfort assessment method such as RULA [6], REBA [7], etc. In the paper published in 2012 in the journal *Applied Ergonomics* [8], it has been shown that near to 105.000 papers were published using the term discomfort in their title, while only a few studies dealt with differences in comfort and discomfort. In the mid-nineties of the last century, three authors [9] suggested that comfort and discomfort are not two opposing concepts on a continuous scale. Discomfort is primarily associated with physiological and biomechanical factors such as fatigue or pain, while comfort is associated with physical ease and well-being. A few years later, in [10] model of comfort and discomfort in which he connects the physical environment to perceived discomfort is proposed.

Pedals of brake and clutch are one of the most used controls used in vehicles. The force exertion capacity depends on the influence of many factors [11], [12]:

- Subject factors (gender, age, anthropometry, etc.),
- Product factors (size, weight, material of contact area, etc.),
- Environmental factors (vibration, temperature, etc.),
- Posture factors (body parts in contact, body parts used for the force exertion, etc.) and
- Task factors (required force level, speed of motion, direction of force, frequency, etc.).

The first research of necessary activation force of a pedal began in the seventies of the last century. Author [13] showed that maximum static pedal force depended on human model position, seat and pedal type. The required force value can be achieved if the backrest is well adjusted and when the pedal is positioned so that there are small flexions of the knee (between 20° and 40°). Also, the authors [14] claim that changes in knee angles significantly affect the value of the maximum force on the pedals. Another group of authors [15] showed that the maximum pedal force can be achieved at the stretched leg position of the observed subject (for the angles of the knee between 35° and 45°). Psychological parameters and characteristics of the passengers in a vehicle can affect the force of effort. A large sample of female and male drivers took part in the measurement of pedal force [16]. It was concluded that women drivers are weaker than men drivers and achieve less force on pedals. The aim of this paper is to determine the force on the clutch pedal using digital models by observing certain boundary conditions, in the case of male and female digital models.

3. Methods

Digital human models have been used for many years in the automotive industry to test how the car's design and the position of the various components meet drivers' needs. In this work the first task was to create a working environment of the mannequin in the vehicle. The Catia v5 R18 software package and the Part Design module were used for seat and interior modeling. The interior of a small city car was used (Volkswagen UP!). A small car was chosen due to the growing crowds in the cities and city

driving regimes required frequent pedal activation. The next task was to place the human model in the seat and set certain boundary conditions (figure 2) using Ramsis software. This software has the option to work with two types of models - kinematic and geometric. The kinematic model takes into account the human skeleton and is wire frame model, while the second represents surfaces. In the paper, the geometric model of the mannequin with five fingers, and foot legs with shoes is used.

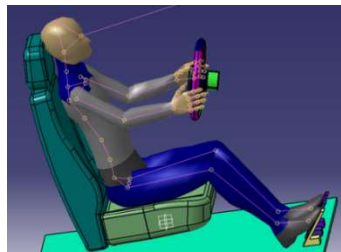


Figure 2. Mannequin in the passenger compartment after setting boundary conditions.

This study included the analysis of activation force on the pedal of nineteen different populations - male and female which anthropometric data are presented in tables 1 and 2 [17]. These populations belong to the age group of 18-70 years old, for the 1% and 99% male and female population.

Table 1. The anthropometric data of male and female 1% population [17].

Population	Height (mm)		Sitting height (mm)		Foot length (mm)	
	male	female	male	female	male	female
Japan	1585	1476	813	760	224	204
France	1607	1481	853	797	237	209
North Africa	1527	1454	807	770	237	217
South America	1608	1478	846	783	227	205
North America	1627	1494	860	803	239	217
West Africa	1507	1402	734	720	234	206
Spain and Portugal	1533	1465	804	780	228	198
North India	1535	1412	800	750	222	199
Eastern Europe	1615	1502	840	814	237	217
North Europe	1668	1541	880	823	232	217
Australia	1607	1521	860	810	244	212
South East Europe	1595	1485	830	790	237	212
Central Europe	1575	1518	870	803	232	212
South East Africa	1545	1442	790	750	232	202
Middle East	1582	1496	813	780	232	214
South India	1485	1351	743	723	217	194
North India	1506	1469	814	780	218	199
South China	1590	1406	770	720	224	204
South East Asia	1495	1402	763	730	214	201

Table 2. The anthropometric data of male and female 99% population [17].

Population	Height (mm)		Sitting height (mm)		Foot length (mm)	
	male	female	male	female	male	female
Japan	1855	1704	1027	960	266	246
France	1933	1779	1007	923	293	261
North Africa	1853	1766	933	910	293	273
South America	1892	1762	1014	937	293	275
North America	1953	1806	1000	957	291	273
West Africa	1833	1658	906	860	286	244
Spain and Portugal	1710	1735	890	920	270	292
North India	1805	1668	940	890	278	241
Eastern Europe	1885	1758	980	926	293	273
North Europe	1952	1839	1020	977	288	283
Australia	1933	1819	1000	950	286	268
South East Europe	1865	1755	970	930	293	268
Central Europe	1845	1802	1010	957	298	268
South East Africa	1815	1698	930	890	288	258
Middle East	1838	1724	967	920	288	266
South India	1755	1649	897	877	273	236

North India	1874	1711	986	920	285	251
South China	1730	1634	910	860	266	246
South East Asia	1765	1658	917	870	256	239

For the better development of an efficient braking system, as well as the clutch mechanism, a good foot pedal design is needed. The activation force on the pedal can be active and passive. The active forces is realized only by muscle activity, while the passive forces is generated by muscle activity and additionally support forces which are generated at the start of the joint chain to the environment [2]. Foot ankle joint load represents torque loads of the individual joints in the chain; in this case joint of the foot ankle. The recommended values for activating pedal brakes are in the range of 25 to 400 N [19]. These are the values recommended in 2006 issue. A change in the anthropometric dimensions of the population affects pedal activation forces. The goal of the car maker is to make vehicles accessible to wider a population. The aim of this work was to investigate proper range values of pedal activation force and foot ankle joint load for different populations in order to design pedal mechanism.

4. Results

The RAMSIS software is able to predict the posture of a digital human model. This is based on statistical analysis of results obtained from the conducted experiments, [18]. By collecting all anthropometric data of the virtual driver population, digital human models were generated with appropriate boundary conditions. By using this software and ECE/TRANS/180/Add.3 regulations [19], the analysis of the interaction driver foot-foot pedal was conducted, in order to determine the activation pedal force. Partial results of performed analysis are given in figure 3, a) analyses conducted for the male driver model of the West Africa 1% population, and b) analyses conducted on the Spain and Portuguese 99% population.

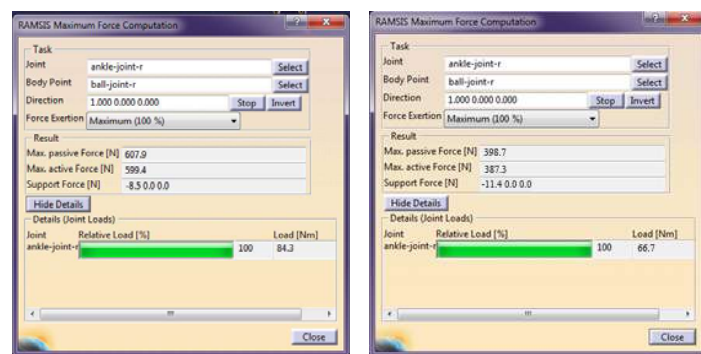


Figure 3. Maximum force of the computation for male driver model; a) West Africa 1% population, b) Spain and Portuguese 99% population.

Table 3 Descriptive statistics of results obtained for male population.

	Height [mm]		Sitting height (mm)		Foot length (mm)		Max. passive force [N]		Max. active force [N]		Torque load [Nm]	
	1%	99%	1%	99%	1%	99%	1%	99%	1%	99%	1%	99%
Max	1668	1953	880	1027	224	298	607.9	398.7	599.4	387.3	84.3	66.7
Min	1490	1710	734	890	214	256	322.3	147.7	297.4	136.3	38.6	24.4
Mean	1568.2	1846.8	815.2	963.3	229.8	283.3	473.3	289.1	461.7	274.6	62.1	47.1
St. deviation	50.3	71.6	42.21	45.9	8.24	11.7	91.28	75.3	94.82	78.3	14.72	12.1

Table 4 Descriptive statistics of results obtained for female population.

	Height [mm]		Sitting height (mm)		Foot length (mm)		Max. passive force [N]		Max. active force [N]		Torque load [Nm]	
	1%	99%	1%	99%	1%	99%	1%	99%	1%	99%	1%	99%
Max	1541	1839	823	977	217	292	244.1	262	231.5	259.9	28.2	41.7
Min	1351	1634	720	860	194	236	150.8	119.6	141.4	114	19.4	18.7
Mean	1402.8	1732.8	772.9	917.5	207.3	261.1	190.6	191.7	182.1	183.6	23.4	28.8
St. deviation	49.2	61.8	33.1	35.1	7.4	15.9	19.3	42.2	18.7	42	2.1	6.4

The result of performed analysis showed that maximum passive force for nineteen male 1% populations (figure 3a) is 607.9 N (West Africa population), while the maximum active force is 599.4 N for maximum effort of 100 %. Foot ankle joint load of nineteen 1% male populations is 84.3 Nm. The same analysis of 99% male population is shown in figure 3b (Spain and Portuguese population). The maximum passive force is 398.7 N, while the maximum active force is 387.3 N for maximum effort of 100 % (table 3). Differences are primarily derived from different anthropometric dimensions.

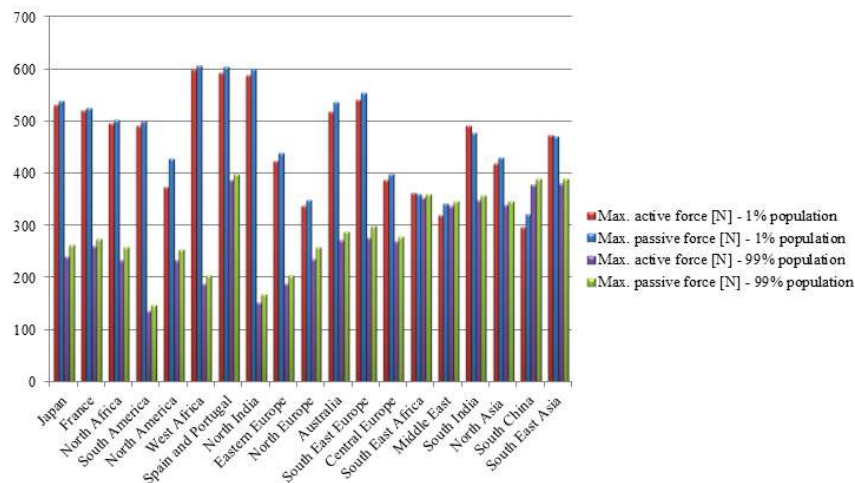


Figure 4. Comparison of the results obtained for male 1% and 99% populations.

The figure 4 showed that the highest values of active and passive forces on the pedal were recorded by the 1% male population from West Africa, Spain and Portugal and North India. The results for 99% male population showed that the highest values of active and passive forces on the pedal were recorded by the 1% male population from Spain and Portugal, South China and South East Asia.

Analysis of these nineteen populations shows that with an increase in the height of the male driver decreases maximum active force that he can achieve on the pedals. Dependency between maximum active pedal force of the male drivers and height was showed of figure 5.

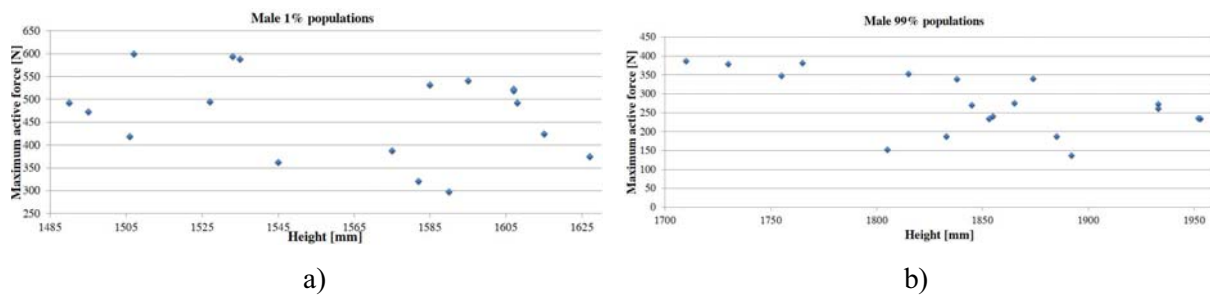


Figure 5. Maximum active pedal force of the male drivers vs. height.

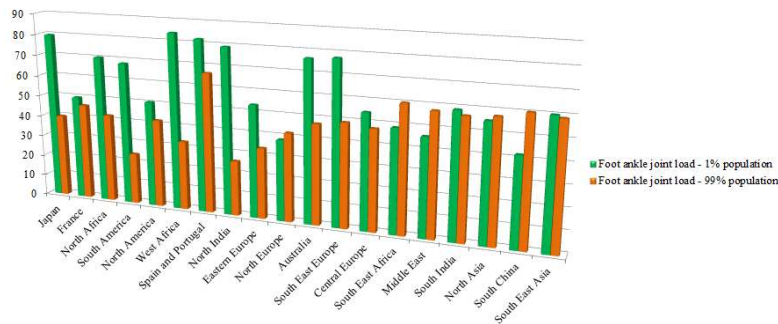


Figure 6. The foot ankle joint load analysis of nineteen male populations.

Figure 7 showed the results of analysis of nineteen female populations, for both cases: 1% and 99% populations. The seat is moved forward so that those feel more comfortable. The result of performed analysis showed that maximum passive force for nineteen 1% female populations is 244.1 N, while the maximum active force is 231.5 N for maximum effort of 100%. Foot ankle joint load of nineteen 1% female populations is 28.2 Nm. These values refer to the female population of South India. An analysis of all 99% female populations is conducted in the same way. The maximum passive force was obtained for the Japanese population and is 262 N, while the maximum active force is 259.9 N for maximum effort of 100%. Foot ankle joint load of nineteen 99% female populations is 41.7 Nm.

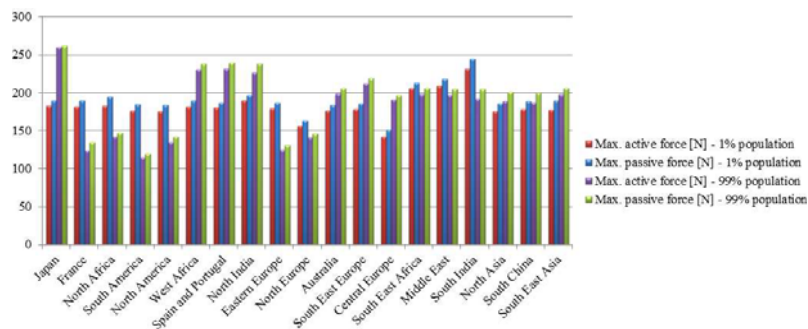


Figure 7. Comparison of the results obtained for female 1% and 99% populations.

This analysis showed that for a certain number of populations, higher force values are obtained in the case of 99% female population, which was not the case with male models. It can be concluded that there are considerably less differences in the results obtained between 1% and 99% of female populations, in regard to the same results of male drivers.

Dependence between height and active pedal force for female driver is showed on figure 8.

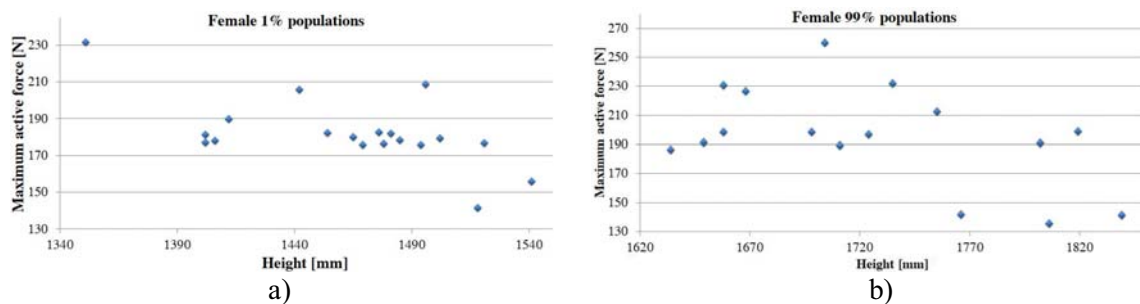


Figure 8. Maximum active pedal force of the female drivers that can be achieved on the pedal vs. height.

Figure 9 showed the results of foot ankle joint load analysis of nineteen female populations. The highest values of foot ankle joint load are obtained for 1% female population of South East Africa and South India and are 38.1 Nm and 28.2 Nm, respectively. In the case of 99% female population, the highest recorded values of this ankle joint load is obtained for female populations of Japan (41.7 Nm), Spain and Portugal (39.5 Nm) and South East Europe (33.7 Nm).

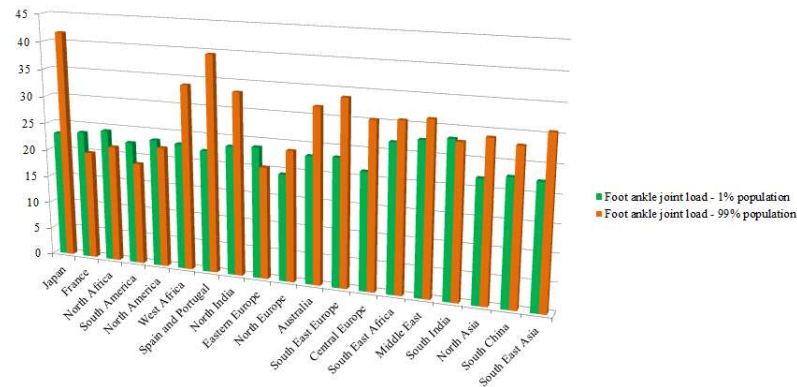


Figure 9. The foot ankle joint load analysis of nineteen female populations.

Poor negative correlation between anthropometric data of analyzed human population between body height and foot pedal forces and ankle joint load is obtained. In the case of the 1% male population negative correlation coefficient between body height and foot pedal forces is -0.384, and correlation between height and ankle joint load is -0.371. Foot length did not correlate with foot pedal forces. Female 1% population has negative correlation coefficient between body height and foot pedal forces -0.607 and correlation coefficient between body height and ankle joint load is -0.440. Analysis of 99% male population shows negative correlation between height and foot pedal forces -0.574 and between height and ankle joint load -0.507. Results obtained for 99% female population, compared to the previous 1% female population, have smaller negative correlation coefficient between body height and foot pedal forces and ankle joint load (-0.522 ÷ -0.387). Foot length did not correlate with ankle joint load, for both populations.

5. Conclusion

The aim of this study was to determine the force required to activate foot pedal in a driving position. The anthropometric dimensions of nineteen 1% and 99% populations - male and female, were used. Testing was performed by application of the software Ramsis. Validation of vehicle interior packaging can be performed, before realization of the first prototype by application of Ramsis. This paper has shown that digital human model, both male and female, in a driving position, can be used to determine the pedal activation force. The increase of the height of the driver male and female decrease a maximum value of an active pedal force as well as passive pedal force. In the case of 1% male population, the maximal active pedal force varied from 297.4 N to 599.4 N, while the maximum active force varied from 141.4 N to 231.5 N for 1% female population. The maximum active pedal force varied from 136.3 N to 387.3 N when male are drivers, while in the case of women drivers, the maximum active force varied from 114 N to 259.9 N. Based on this, it can be concluded that there are considerably less differences in the results obtained between 1% and 99% of female populations, in regard to the same results of male drivers.

Comparison of the results showed that there are less difference between 1% and 99% female population than results obtained for 1% and 99% male population. 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.

Acknowledgment

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