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DETERMINATION OF THE FOOT PEDAL FORCE BY APPLICATION OF DIGITAL HUMAN MODEL

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Abstract

Interior packaging of the car is one of the most important stages of vehicle design. The design of passenger compartment is important with respect to possibility of car driving. Anthropometrics characteristics of the driver has significant role in car design. Research, conducted during PhD studies, concerning the determination of the force required for activating foot pedal in a driving position. In this paper, determination of foot pedal activating force is performed on human model of different populations. The anthropometric data of male and female subjects of twelve populations were analysed. Software package Ramsis [1] was used to perform load analysis of "mannequin" in driving condition. Obtained force values are different for all kinds of subjects. Poor negative correlation was obtained between Poor negative correlation between anthropometric data of analysed human population were noticed between height and foot pedal forces and ankle joint load. Sitting height of human did not correlate with foot ankle load.

***Key words**: vehicle, driver, Ramsis, foot pedal force.*

1 INTRODUCTION

The interior of the car has to fulfil all ergonomic and manipulation requirements during driving task. Ergonomics is the scientific discipline concerned with the understanding of interaction between human and other elements of a system - in this case the driver and the vehicle interior. Ergonomics has several roles. The first is to increase the efficiency and productivity of production, then the improvement of health, and finally the safety and comfort man in his work environment [2]. In the case of cars, ergonomics postulates contribute in passenger compartment packaging. Using knowledge of this science, there is a possibility to know in advance the possibility of movement during driving process. Performing different movements in driving process, driver is fatigued. This study investigates the force required to activate the foot pedal in driving position. Pedals are one of the most used controls in vehicles. Foot pedals often restrict the posture of the user, and inadequate pedal design lead to muscle fatigue and driver`s discomfort [3]. There are a few studies of the comfort of pedal operation [4], [5]. Many studies on comfort/discomfort have been carried out only using a subjective assessment method [5], [6]. Researches attempted to find possible correlations between subjective assessment of comfort/discomfort and design parameters in order to improve driver comfort [7].

In this study, the driving position of all models was investigated in the virtual environment of the Volkswagen VW UP! Interior (Fig. 1). The influence of the anthropometric data of male and female of twelve populations on the foot pedal activation force were investigated. For this purpose, the software packages Catia v5 R18 and Ramsis (*Rechnergestutztes Anthropometerisches Mathematisches System zur Insassen-Simulation*) were used, [1]. Software package enable to set a mannequin at a specific place and to manipulate his movements.

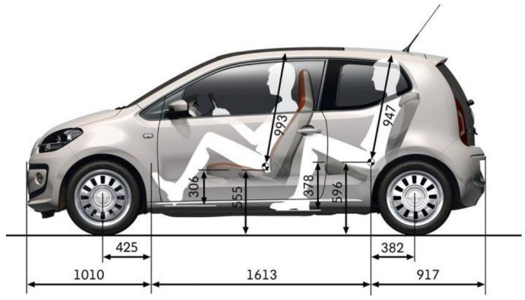

Fig. 1 *Volkswagen Up! Dimensions [8]*

2 METHODS

Definition of the final layout of a vehicle from an ergonomic point of view requires knowledge about body dimensions of the driver. The first task of this study was to create a working environment of the mannequin in the vehicle. The Catia v5 R18 software package and the Part Design module was used for seat modelling. In Fig. 2 the Volkswagen UP! interior, with real dimensions, used in this work is shown.

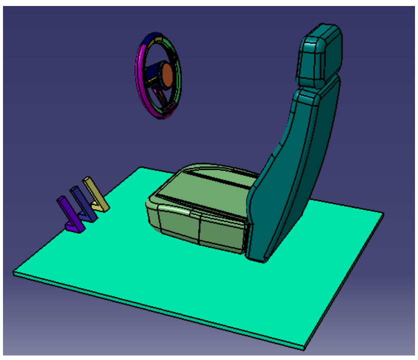

Fig. 2 *Modelled driver`s environment in the vehicle Volkswagen Up!*

The second driver`s task was to analyse the model in driving condition and to calculate the foot pedal force activation. In the Ramsis environment driver`s model was placed. Software Ramsis can manipulate with two kind of human models: kinematic and geometric. Kinematic, or the internal model, takes into account the human skeleton and is wire frame model. The geometric model, or an external model, is simply manikin surface. This is what makes the manikin that looks like a human. Each manikin was modelled with five fingers, and foot legs with shoes. It is necessary to fix a manikin on the seat, and to put hands in the driving position with both hands on the steering wheel. Right foot is placed on the brake pedal (Fig. 3).

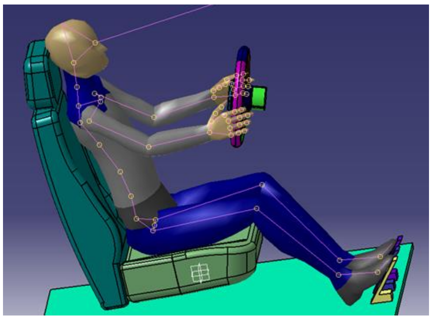

Fig. 3 *Mannequin in the passenger compartment after placing boundary conditions*

This study included the analysis of twelve different populations - male and female which anthropometric data are presented in Table 1 [9]. These populations belong to the age group of 18-70 years, for the 50% populations. Anthropometrics characteristics of male and female subjects are given in Table 1. Height of twelve female populations was between 1530 mm and 1690 mm. Sitting height was between 1170 mm and 1310 mm. Height of male population was between 1670 mm and 1810 mm. Sitting height of human was between 1230 mm and 1405 mm, [9].

Table 1 The anthropometric data of a) male, b) female populations [9]

a)

Population	Height (mm)	Sitting height (mm)	Foot length (mm)	Shoulder breadth (mm)
Japan	1720	1335	245	420
France	1770	1375	265	450
North Africa	1690	1290	265	420
South America	1750	1375	260	450
North America	1790	1375	265	460
West Africa	1670	1230	260	420
Spain and Portugal	1710	1345	270	440
North India	1670	1282	250	380
Eastern Europe	1750	1355	265	450
North Europe	1810	1405	260	460
Australia	1770	1370	265	450
South East Europe	1730	1345	265	450

b)

Population	Height (mm)	Sitting height (mm)	Foot length (mm)	Shoulder breadth (mm)
Japan	1590	1255	225	370
France	1630	1245	235	410
North Africa	1610	1250	245	410
South America	1620	1240	240	400
North America	1650	1290	245	400
West Africa	1530	1170	225	390
Spain and Portugal	1600	1230	245	390
North India	1540	1200	220	340
Eastern Europe	1630	1275	245	410
North Europe	1690	1310	250	400
Australia	1670	1280	240	380
South East Europe	1620	1240	240	405

Design of the foot pedal and transfer mechanism of the brake system is very important task in order to develop safe and efficient brake system. Activation force of foot pedal is input parameter in brake system design as well as a brake booster. The active forces will be evoked only by muscle activity. The passive foot pedal forces are generated by muscle activity and additionally support by floor or support. Ankle joint load represents torque loads of foot joint ankle respect to force of activation.

3 RESULTS

The RAMSIS posture prediction is based on statistical analysis of results obtained from the conducted experiments, [10]. After obtaining the anthropometric data of the virtual driver population, digital human models was generated with appropriate degrees of freedom. By using of Ramsis software the analysis of the interaction driver foot - foot pedal was conducted, in order to determine the activation force of the foot pedal. Partial results of the first analysis, conducted for the male driver model and female driver model off Spanish and Portuguese population are presented in figures 4 and 5.

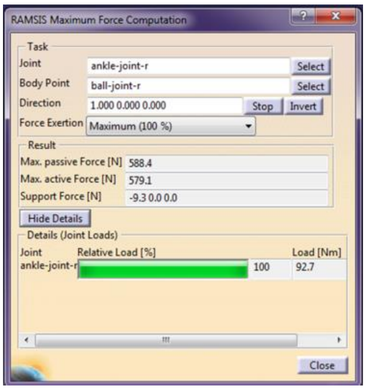

Fig. 4 *Maximum force computation for Spanish and Portuguese male population*

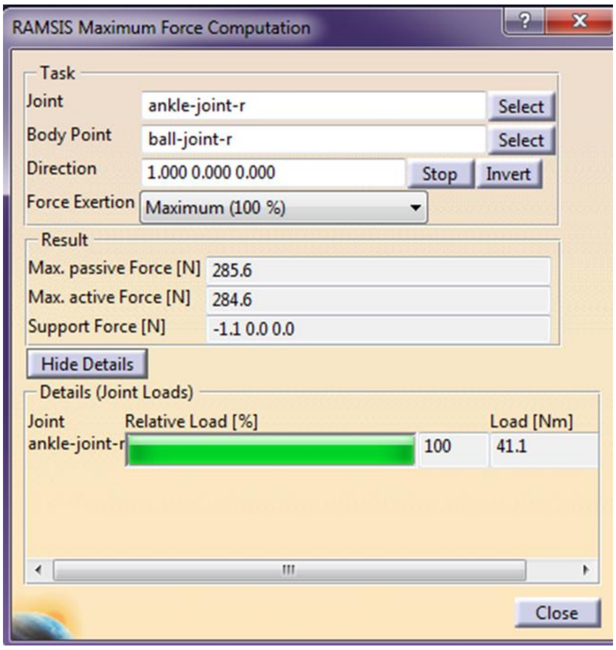

Fig. 5 *Maximum force computation for Spanish and Portuguese female population*

The result of performed analysis showed that maximum passive force for twelve male populations is 588.4 N, while the maximum active force is 579.1 N for maximum effort of 100 %. Maximum foot ankle joint load of twelve male populations is 92.7 Nm and minimum foot ankle load is 47.9 Nm. The analysis of foot pedal forces of male populations are presented in figures 6, 7 and 8.

The maximum value of active and passive foot pedal force as well as ankle joint load correspond to Spain and Portugal male population. Minimum values correspond to French male population, figures 6-8.

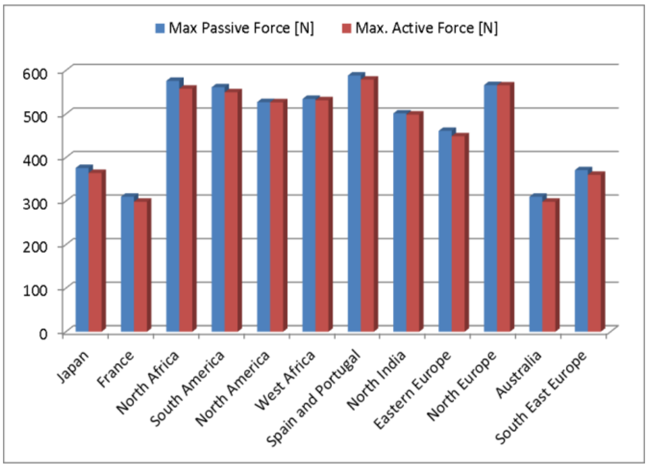

Fig. 6 *The maximum foot pedal force (active and passive) of twelve male populations*

Analysis of these twelve populations shows that with an increase in the height of the male driver decreases maximum active force that he can achieve on the pedals. Fig. 7 shows this dependency.

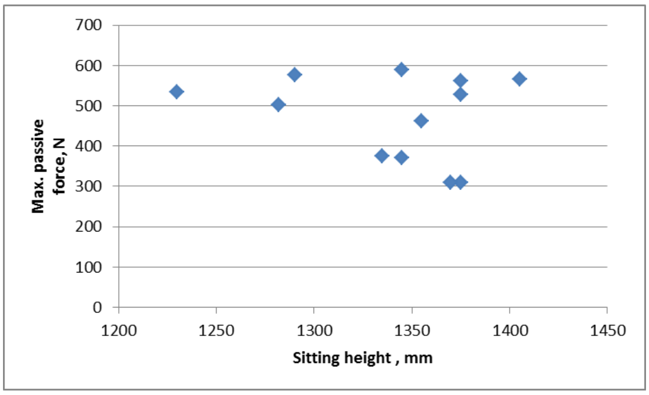

Fig. 7 *Maximum active foot pedal force of the male drivers vs. sitting height*

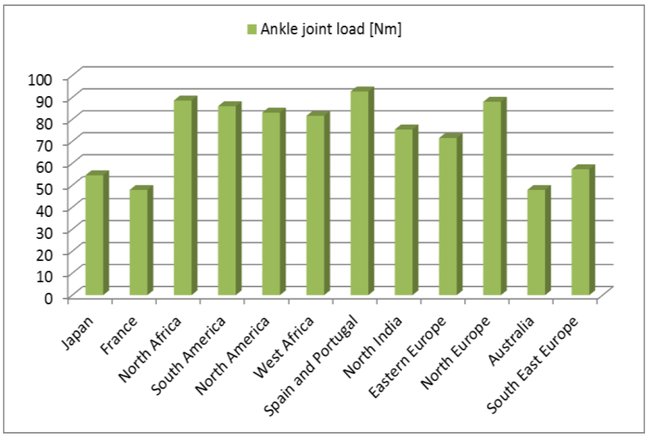

Fig. 8 *The ankle joint load of twelve male populations*

Results of analysis of twelve female populations is given in figures 9 – 11. The maximum value of active and passive foot pedal force and ankle joint load corresponds to West Africa and minimum value corresponds to France female population.

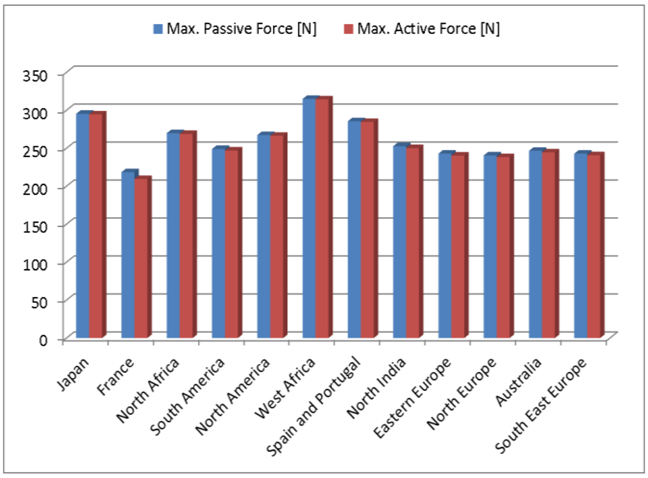

Fig. 9 *The maximum foot pedal force (active and passive) of twelve female populations*

A result of these twelve analyses for the case where the drivers are women also show that with the increase of the height of the driver, there is a decrease of maximum value of an active force which it can act (Fig. 10).

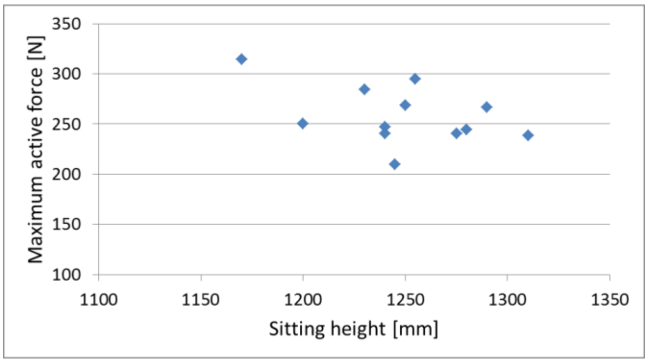

Fig. 10 Maximum active foot pedal force of the female drivers vs sitting height

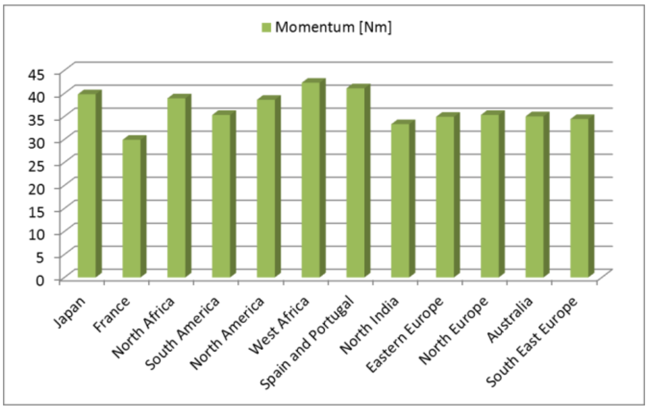

Fig. 11 The ankle joint load of twelve female populations

Maximal value of foot pedal activation force of male and female population is 588.4 N and is lower than force value recommended in [11], 25 N<F_p<400 N for brake pedal design. Analysis were performed for 50% female and male populations. With respect to necessary activation brake force on foot pedal, the same analysis should be performed on 5%-95% female and male population as well as 1%-99% female –male population. Results should be very useful in brake system design process.

Poor negative correlation between anthropometric data of analysed human population can be noticed between height and foot pedal forces and ankle joint load (values between -0.227 and -0254). Sitting height did not correlate with foot ankle load.

3 CONCLUSION

In the presented work, the force required to activate foot pedal in a driver sitting position has been determined. The twelve different human male and female populations - male and female were investigated. Analysis was performed by application of Ramsis software.

Maximal value of foot pedal activation force of male and female population is 588.4 N and is lower than force value recommended in [11], 25 N<F_p<400 N for brake pedal design.

Poor negative correlation between anthropometric data of analysed human population can be noticed between height and foot pedal forces and ankle joint load (values between -0.227 and -0254). Sitting height did not correlate with foot ankle load.

The same analysis should be performed on 5%-95% female and male population as well as 1%-99% female –male population.

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