OTEKON 2018

9. OTOMOTİV TEKNOLOJİLERİ KONGRESİ

INTERNATIONAL AUTOMOTIVE TECHNOLOGIES CONGRESS

ULUSLARARASI OTOMOTİV TEKNOLOJİLERİ KONGRESİ

07 - 08 Mayıs / May 07th - 08th 2018
Sheraton Hotel / BURSA

PROCEEDINGS / BİLDİRİLER KİTABI

Editors / Editörler

Dr. Öğr. Üyesi Erol SOLMAZ, Prof.Dr. Necmettin KAYA, Prof.Dr. Ferruh ÖZTÜRK

Uludağ Üniversitesi Mühendislik Fakültesi
Uludag University Engineering Faculty
Otomotiv Mühendisliği Bölümü
Automotive Engineering Department

www.otekon.org

Uludağ University Engineering Faculty

Automotive Engineering Department

OTEKON 2018

ULUSLARARASI 9. OTOMOTİV TEKNOLOJİLERİ KONGRESİ BİLDİRİLER KİTABI

Proceedings of the International 9th Automotive Technologies Congress May 7-8, 2018, Bursa, Türkiye

Editörler / Editors :

Dr. Erol Solmaz,

Prof. Dr. Necmettin Kaya

Prof. Dr. Ferruh Öztürk

BURSA – 2018

İÇİNDEKİLER / CONTENTS

Disclaimer:

No responsibility is accepted for the accuracy of information contain in the text, illustrations and advertisements in this Proceedings. Editors, Organization Committee and BURKON do not have any responsibility for the accuracy of the information and opinions expressed in OTEKON 2018 Proceedings.

Kongre Bildiriler Kitabı metin içerikleri ile ilgili bütün sorumluluk yazarlara aittir. Editörler, Düzenleme ve Danışma Kurulları ve BURKON için bağlayıcı nitelik taşımazlar.

BURSA
Mayıs, 2018 / May, 2018

OTEKON2018 Kongresi Organizasyonu

BURKON TURİZM & KONGRE

444 9 443

burkon TURİZM & KONGRE

Çekirge Cad. No: 51/C 16050 - BURSA

Uludağ University Engineering Faculty

Automotive Engineering Department

Proceedings of the International 9th Automotive Technologies Congress

May 7-8, 2018, Bursa, Türkiye

Editors:

Dr. Erol Solmaz,

Prof. Dr. Necmettin Kaya

Prof. Dr. Ferruh Öztürk

ISBN: 978-605-68414-2-2

KURULLAR / COMMITTEES

Onur Kurulu / Honorary Committee
Prof. Dr. Yusuf ULCAY (Uludağ Üniversitesi Rektörü)

Kongre Başkanı / Congress Chair
Prof. Dr. Ferruh ÖZTÜRK

Kongre Sekreteri / Congress Secretary
Dr. Öğr. Üyesi Erol SOLMAZ

Düzenleme Kurulu / Organizing Committee
Prof. Dr. Necmettin KAYA
Doç.Dr. Rukiye ERTAN
Doç.Dr. Hande GÜLER
Dr. Öğr. Üyesi Zeliha KOCABIÇAK

Bilim ve Danışma Kurulu / Scientific and Advisory Committee

Prof. Dr. Avinash Kumar AGARWA	AGARWAL INDIAN INSTITUTE OF TECHNOLOGY KANPUR	INDIA
Prof. Dr. Orhan ALANKUŞ	OKAN UNIVERSITY	TURKEY
Ahmet ALTEKİN	TOFAŞ-TURKISH AUTOMOTIVE COMPANY	TURKEY
Kerem ALPTEMOÇİN	İSTANBUL ERKURT HOLDING	TURKEY
Prof. Dr. Günay ANLAŞ	BOĞAZİÇİ UNIVERSITY	TURKEY
Prof. Dr. Istvan BARABAS	TECHNICAL UNIVERSITY OF CLUJ NAPOCA	ROMANIA
Assoc. Prof. Dr. Çağlar BAŞLAMIŞLI	HACETTEPE UNIVERSITY	TURKEY
Günal BAYLAN	BUSİAD	TURKEY
Volkan BAYRAKTAR	AUTOMOTIVE TECHNOLOGIES R&D COMPANY	TURKEY
Prof. Dr. Ali BAYRAM	ULUDAG UNIVERSITY	TURKEY
Prof. Dr. Shuming CHEN	JILIN UNIVERSITY	CHINA
Prof. Dr. Giorgio CHIANDUSSI	POLITECNICO DI TORINO	ITALY
Prof. Dr. Takemi CHIKAHISA	HOKKAIDO UNIVERSITY	JAPAN
Baran ÇELİK	BEYÇELİK	TURKEY

Prof. Dr. Can ÇOĞUN	ÇANKAYA UNIVERSITY	TURKEY
Prof. Dr. Julian F DUNNE	UNIVERSITY OF SUSSEX	UNITED KINGDOM
Prof. Dr. Aytül ERÇİL	SABANCI UNIVERSITY	TURKEY
Prof. Dr. Murat EREKE	İSTANBUL TECHNICAL UNIVERSITY	TURKEY
Prof. Dr. Metin ERGENEMAN	İSTANBUL TECHNICAL UNIVERSITY	TURKEY
Prof. Dr. Mustafa GÖKLER	MIDDLE EAST TECHNICAL UNIVERSITY	TURKEY
Dr. Akif GÖKSU	DTA DESIGN TEST ANALYSIS	TURKEY
Prof. Dr. Ali G. GÖKTAN	AUTOMOTIVE TECHNOLOGIES R&D COMPANY	TURKEY
Erkan GÜNGÖR	KOSGEB	TURKEY
Ergün GÜRASLAN	FORD AUTOMOTIVE INDUSTRY CORP.	TURKEY
Prof. Dr. Levent GÜVENÇ	OHIO STATE UNIVERSITY	USA
Prof. Dr. Carlos GUARDIOLA	UNIVERSITAT POLITECNICA de VALENCIA	SPAIN
Assoc. Prof. Dr. Muhamed HADZIABDIC	INTERNATIONAL UNIVERSITY OF SARAJEVO	BOSNIA AND HERZEGOVINA
Dr. Mustafa HATİPOĞLU	BURSA CHAMBER OF COMMERCE AND INDUSTRY	TURKEY
Prof. Dr. Murat HOŞOZ	KOCAELİ UNIVERSITY	TURKEY
Prof. Dr. Bilgin KAFTANOĞLU	ATILIM UNIVERSITY	TURKEY
Prof. Dr. Mehmet KANIK	ULUTEK	TURKEY
Prof. Dr. İhsan KARAMANGİL	ULUDAG UNIVERSITY	TURKEY
Dr. Ahu Ece Hartavi KARCI	UNIVERSITY OF SURREY	UNITED KINGDOM
Prof. Dr. Osman KOPMAZ	ULUDAG UNIVERSITY	TURKEY
Asst. Prof. Dr. Dimitris KOULOCHERIS	NATIONAL TECHNICAL UNIVERSITY OF ATHENS	GREECE
Prof. Dr. Nusret Sefa KURALAY	DOKUZ EYLÜL UNIVERSITY	TURKEY
Dr. Recep KURT	MARTUR	TURKEY
Prof. Dr. Tae Hee LEE	HANYANG UNIVERSITY	KOREA
Asst. Prof. Dr. Xianke LIN	UNIVERSITY OF ONTARIO INSTITUTE OF TECHNOLOGY	CANADA

Prof. Dr. Jovanka LUKIC	UNIVERSITY OF KRAGUJEVAC	SERBIA
İbrahim MART	UNION OF CHAMBERS OF TURKISH ENGINEERS AND ARCHITECTS	TURKEY
Ozan NALCIOĞLU	FORD OTOMOTİV SANAYİ A.Ş.	TURKEY
Prof. Dr. Abdullah MİMAROĞLU	SAKARYA UNIVERSITY	TURKEY
Prof. Dr. Wojciech MOCZULSKI	SILESIAN UNIVERSITY OF TECHNOLOGY	POLAND
Prof. Dr. Henk NIJMEIJER	EINDHOVEN UNIVERSITY OF TECHNOLOGY	NETHERLANDS
Prof. Dr. Valyo NIKOLOV NIKOLOV	TECHNICAL UNIVERSITY OF SOFIA	BULGARIA
Dr. Tarık ÖĞÜT	FİGES	TURKEY
Prof. Dr. Melih PAPİLA	SABANCI UNIVERSITY	TURKEY
Prof. Dr. Kazuhiro SAITOU	UNIVERSITY OF MICHIGAN	USA
Prof. Dr. Dan SCARPETE	UNIVERSITY DUNAREA DE JOS OF GALATI	ROMANIA
Osman SEVER	AUTOMOTIVE MANUFACTURERS ASSOCIATION	TURKEY
Prof. Dr. Wojciech SKARKA	SILESIAN UNIVERSITY OF TECHNOLOGY	POLAND
Erhan KÜÇÜKSÜLEYMANOĞLU	TOFAŞ-TURKISH AUTOMOTIVE COMPANY	TURKEY
Gökhan TUNÇDÖKEN	BOSCH	TURKEY
Ergun TÜRKAY	BUSİAD	TURKEY
Dr. Mustafa UYSAL	TEKNO DESIGN	TURKEY
Prof. Dr. Deniz UZUNSOY	BURSA TECHNICAL UNIVERSITY	TURKEY
Asst. Prof. Dr. Erdem UZUNSOY	BURSA TECHNICAL UNIVERSITY	TURKEY
Prof. Dr. Samim ÜNLÜSOY	MIDDLE EAST TECHNICAL UNIVERSITY	TURKEY
Prof. Dr. Anatoli VAKHGUELT	NAZARBAYEV UNIVERSITY	KAZAKHSTAN
Prof. Dr. Jac WISMANS	SAFETEQ AUTOMOTIVE SAFETY CONSULTING	NETHERLANDS
Prof.Dr. Michael WORSWICK	UNIVERSITY OF WATERLOO	CANADA
Prof. Dr. Recep	ULUDAG UNIVERSITY	TURKEY

YAMANKARADENİZ		
Prof. Dr. Ali R. YILDIZ	ULUDAG UNIVERSITY	TURKEY
Oya YÖNEY	COŞKUNÖZ	TURKEY
Prof. Dr. Serdar YÜCESU	GAZİ UNIVERSITY	TURKEY
Mustafa ZAİM	HAYES LEMMERZ INDUSTRIAL. CORP.	TURKEY

SPONSORLAR / SPONSORS

Altın Sponsorlar / Gold Sponsors

Katkıda Bulunan Diğer Sponsorlar / Other Sponsors and Supporters

ÖNSÖZ / PREFACE

The International 9th Automotive Technologies Congress was held at the Sheraton Hotel from 7 to 8 May, 2018, in Bursa, Türkiye. It is our pleasure to express gratitude to all those who attended this congress and made this event a great success with 587 attendees. The International 9th Automotive Technologies, OTEKON 2018 took place in Bursa with technical papers, posters, keynote speeches and exhibitions.

We do express our sincere thanks to all of keynote speakers, authors presented their works, reviewers, scientific and advisory committee members and sponsors for their great support to make this event a great success.

The first Automotive Technologies Congress (OTEKON2002) was organized in Bursa in 2002, subsequent seven OTEKON Conferences were held in every two years in Bursa. In the past decades, Türkiye has achieved remarkable growth and enhancements in automotive industry and has become one of the important automobile manufacturers. Bursa is the city of one of Turkey's leading automotive industry region where there are several automotive production factories in Bursa and in the near region of Bursa. Bursa is the city which is also known for its rich history and culture.

OTEKON 2018 Congress was a unique platform to gain an insight on the latest research activities and discuss the trends that related to the latest automotive technologies and their applications in automotive industry.

Focused on automotive technologies and their industrial applications, Proceedings of The International 9th Automotive Technologies Congress consist of technical papers and posters through the theoretical works and industrial applications.

The International 10th Automotive Technologies Congress (OTEKON 2020) will be held in April, 2020 in Bursa, Türkiye. We look forward to welcoming you to OTEKON2020 Congress, join us at this major event in beautiful city Bursa.

Congress Chair
Prof. Dr. Ferruh Öztürk
Automotive Engineering Department
Uludağ University

BİLİMSEL PROGRAM / SCIENTIFIC PROGRAM

07 MAY 2018, Monday

08.30 **Registration**

09.30 - 09.45 **Opening Ceremony**

Ergun Türkay (BUSİAD President)

Baran Çelik (UİB President / Beyçelik Holding CEO)

Prof.Dr. Yusuf Ulcay (Uludağ University Rector)

09.45 - 11.00 **Keynote Speakers**

Prof.Dr. Jac Wismans (SAFETEQ, The Netherlands and SAFER / Chalmers University of Technology, Sweden)

Prof.Dr. Thomas Tröster (Paderborn University, Institute for Automotive Lightweight Design (LiA), Germany)

Prof.Dr. Giuseppe Carbone (Politecnico di Bari, Dipartimento di Meccanica, Matematica e Management, Italy)

Prof.Dr. Orhan B. Alankuş (Okan University, ARPROGED Coordinator Engineering Faculty, İstanbul)

Moderator
Doç.Dr. İbrahim Korkmaz (TOFAŞ Türk Otomobil Fabrikası A.Ş., Bursa)

11.00 - 11.15 **Coffee Break**

11.15 - 13.00 **Keynote Speakers**

Erkan Polat (TOFAŞ - R&D Product Engineering Director)

Çağlayan Altınok (OYAK-RENAULT – R&D Director)

Ozan Nalcıoğlu (FORD Otomotiv Sanayi A.Ş. – Engineering Director)

13.00 - 14.00 **Lunch**

14.00 - 15.30	TECHNICAL SESSIONS
15.30 - 16.00	**Coffee Break**
16.00 - 17.30	TECHNICAL SESSIONS
17.30 - 18.00	**Coffee Break**
18.00 - 20.00	TECHNICAL SESSIONS

08 MAY 2018, Tuesday

09.00 - 10.30	TECHNICAL SESSIONS
10.30 - 11.00	**Coffee Break**
11.00 - 12.30	TECHNICAL SESSIONS
13.00 - 14.00	**Lunch**
14.00 - 15.30	TECHNICAL SESSIONS
15.30 - 16.00	**Coffee Break**
16.00 - 17.30	TECHNICAL SESSIONS
17.30 - 18.00	**Coffee Break**
16.00 - 17.30	TECHNICAL SESSIONS
18.00 - 20.00	TECHNICAL SESSIONS
20.00	**Closing Ceremony**

BİLDİRİLER / PAPERS

POSTERLER / POSTERS

ASSESSMENT OF THE HUMAN BODY DISCOMFORT IN THE VEHICLE

Slavica MAČUŽIĆ[1], Jovanka LUKIĆ[1]

[1] University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia
Correponding Author: Slavica Mačužić, macuzicslavica@gmail.com

ABSTRACT

Driver comfort is one of the most important tasks of vehicle manufacturers. In the design stage and vehicle seat development, a posture of vehicle drivers is a critical factor that has to be considered carefully. Long-term driving can affect driver performance, especially in an inadequate posture. In this paper, different angles of the seat back are considered, with the aim of determining the optimal positions of the driver. Position while driving and resting condition, hands on the body, are also examined. Anthropometrics characteristics of the driver has significant role in vehicle design. The anthropometric data of male and female subjects of eleven populations were analyzed; 1% and 99% of the population were used. Software package Ramsis was used to perform posture analysis of "mannequin" in driving and resting condition. The obtained values of fatigue and discomfort, as body parts discomfort, were different for all kinds of subjects.

Keywords: vehicle, driver, Ramsis, fatigue, discomfort

1. INTRODUCTION

Vehicle manufacturers design their product to fully meet the needs of passengers, both for safety and comfort. The description of comfort has been widely studied, but a clear definition could not yet be established. Comfort is a subjective phenomenon (Looze, continued, 2003). Many researchers have studied factors that influence subjective comfort (Helander and Zhang, 1997), (Vink, 2005), (Kuijt-Evers, 2007), (Zenk, 2008). Factors include posture, muscular activity, pressure, stiffness and suspension of the seat cushion and backrest. These studies concluded that there is a relationship between comfort and measured factors (age, anthropometry, vibration, body parts in contact, etc.).

It is necessary to know certain knowledge in order to fulfill all the requirements in the right way. Ergonomics is a science that helps manufacturers makes vehicles as comfortable as possible. This science 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 (Bridger, 2009). There is a possibility to know in advance the possibility of driver movement during driving process, using knowledge of this science and modern technology, such as computer-aided design and numerical simulations. Using digital human models (Duffy, 2008) the assessment of discomfort is done through a discomfort assessment method such as RULA (McAtamney and Corlett, 1993), REBA (Hignett and McAtamney, 2000), etc.

Performing different movements in driving process, driver is fatigued. Driver posture is one of the most important issues to be considered in the vehicle design process. A review of contemporary literature shows that physical fatigue is mainly caused by driving posture (Porter and Gyi, 1998). Appropriate seat backrests proved to decrease loads on the spine (Hirao, continued, 2006), (Graf, 2004), (Lapa, continued, 2000). The optimal seatback inclination ranges between 100 and 110 ° to horizontal (Schmidt, continued, 2014).

In this paper, the digital human models are used in order to enable determination of the fatigue and discomfort, as well as body parts discomfort, for different sitting positions. Eleven different male populations were analyzed. The driving and resting condition of all models were investigated in the virtual environment of the lower medium class vehicle (Fig. 1). The influence of the anthropometric data of male of eleven populations on the fatigue and discomfort, in two different sitting conditions, were investigated. For this purpose, the software packages Catia v5 R18 and Ramsis (Rechnergestutztes Anthropometerisches Mathematisches System zur Insassen-Simulation) were used, (URL 1). Software package enable to set a mannequin at a specific position and to analyze its environment.

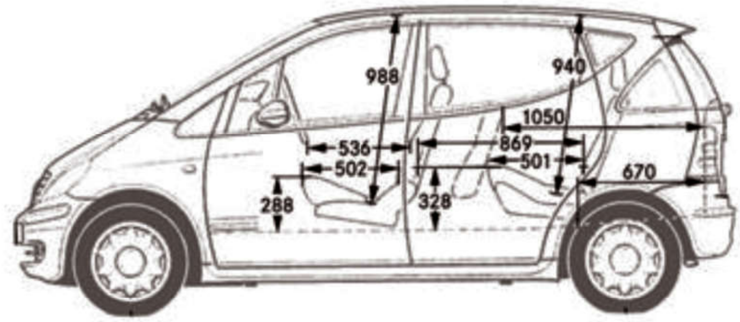
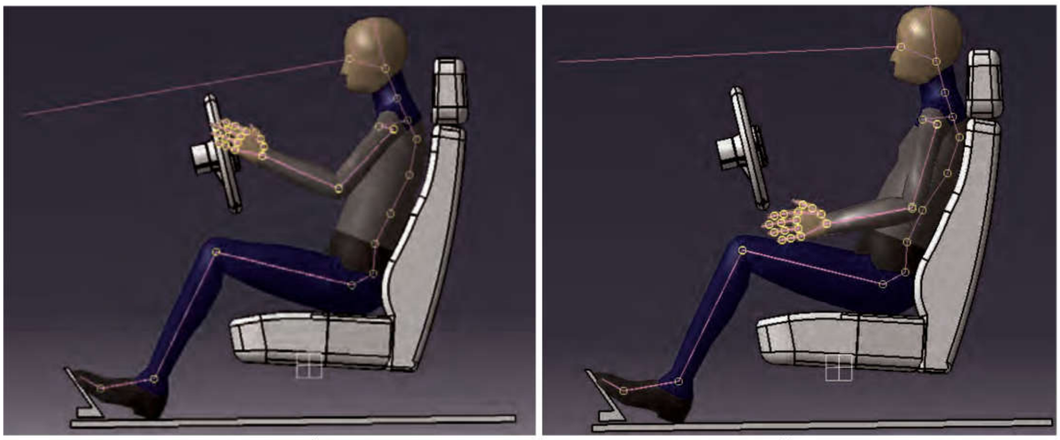


Figure 1. Dimensions of the vehicle

2. METHODS

For many years in the automotive industry digital human models have application for testing purposes. This way show how the vehicle's design and the position of the various components meet driver's needs. 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 (Part Design and Assembly modules) was used for vehicle interior modeling. The next task was to set the mannequin in the sitting position and to set boundary conditions (figure 2) by application of Ramsis software. This software has the option to operate with two types of human models - kinematic and geometric. The first takes into account the human skeleton and it is wire frame model, while the second represents surfaces. Geometric model of the mannequin with five fingers, and foot legs with shoes were used in this paper.



a) b)

Figure 2. Modeled environment inside the vehicle: a) driving condition, b) resting condition

Eleven different male and female populations which anthropometric data are presented in Tables 1 (URL 2), are analyzed in this paper. These populations belong to the age group of 18-70 years, both for 1% female and 99% male populations. Seat backrest angle was determined with respect to horizontal plane and angles of 80°, 85°, 90°, 100° and 105° were analyzed. Passengers were in driving and resting conditions (figure 2 a and b),

Table 1. The anthropometric data of analyzed 1% female and 99% male populations [16]

	Height (mm)		Sitting height (mm)		Foot length (mm)		Shoulder breadth (mm)	
Population	1%	99%	1%	99%	1%	99%	1%	99%
West Africa	1402	1833	720	906	206	286	341	462
North India	1412	1805	750	940	199	278	305	429
Eastern Europe	1502	1885	814	980	217	293	354	506
North Europe	1541	1952	823	1020	217	288	353	514
Australia	1521	1933	810	1000	212	286	331	506
South East Europe	1485	1865	790	970	212	293	358	499
Central Europe	1518	1845	903	1010	212	298	357	509
South East Africa	1442	1815	750	930	202	288	348	479
Middle East	1496	1838	780	967	214	288	348	486
South India	1351	1755	723	897	194	273	318	449
North Asia	1469	1874	780	986	199	285	341	479

The goal of the vehicle manufacturer is to design vehicles comfortable to wide a human population for 1% female and 99% male population. The most vehicle designers are focused on 5% female and 95% male population. Widening of vehicle users populations enable more massive vehicle production. Besides vehicle safety, improvement of the vehicles ride comfort is very significant task for vehicle designers. Determination of ride comfort or discomfort in vehicle in the sitting condition can be conducted in field conditions, laboratory conditions and it is confronted with expensive and long lasting investigations on humans. The RAMSIS software, enables vehicle comfort analyzes and assessment by application of different human manikin in different vehicles interiors. Assessments of discomfort respect to whole body and different human body parts can be performed. The data for comfort assessment was acquired through experiments conducted on more than 100 subjects in sitting conditions (Ramsis, 2012). Discomfort and fatigue is defined by numeric values based on performed experiments. Comfortable sitting and driving is valued as 2.5. Discomfort value assessed higher than 5.5 represents very uncomfortable conditions.

The health assessment of the spinal column is based upon an assessment model which converts the posture-related angular misalignment of vertebral bodies against one another into increased pressure loads on the intervertebral disks, from which in turn the model derives a damage assessment. In line with medical findings, the load in the area of the lumbar spine is the most intensive. The posture of the lumbar spine has therefore the most influence by far on health assessment in RAMSIS, followed by that of the cervical spine - the thoracic spine has the least influence of all (Ramsis, 2012).

3. RESULTS

The RAMSIS posture prediction is based on statistical analysis of results obtained from the conducted experiments, (Ramsis, 2012). After obtaining the anthropometric data of the virtual driver population, digital human models was generated with appropriate degrees of freedom. By application of abovementioned software and ECE/TRANS/180/Add.3 standards (URL 3), the analysis of the interactions between driver and seat, driver and steering wheel, and driver and pedal were conducted, in order to determine the fatigue and discomfort. Example of the obtained results is given in figure 3. The red column shows the results while driving, while the yellow column shows the assessment in the resting condition. Difference column represents the difference between red and yellow columns.

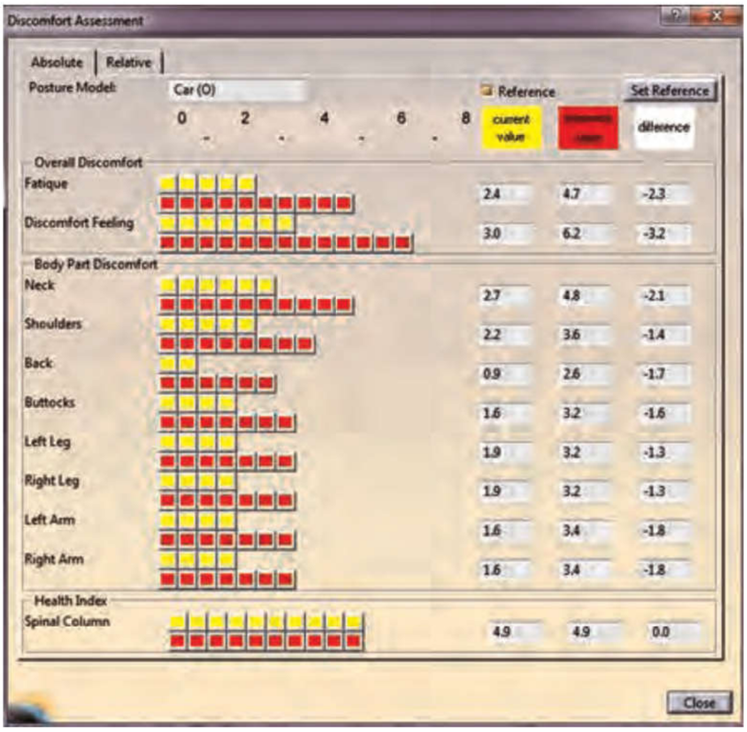


Figure 3. The results of discomfort assessment in the case of West Africa 99% population

Partial results of the discomfort analysis for different seat backrest angles in different sitting position are given in figure 4 and figure 5. Descriptive statistics of fatigue values for both populations are given in table 2. The lowest fatigue values are for 90° seat backrest angle. For 1% female population fatigue and discomfort values are the lowest for angle of 85° respect to mean value of data, Table 2 and Table 3.

Increase of seat backrest angle caused increase of discomfort in both sitting condition. Driving condition is more discomfortable than resting position of human for both populations. Discomfort values are higher than recommended 5.5. Observed female population feels higher discomfort than male population.

Table 2. Descriptive statistics data of fatigue values of 1% female and 99% male populations

Seat backrest angle ,°	Fatigue [-]									
	mean		standard error		Median		mode		standard deviation	
	1% female	99% male	1% female	99% male	1% female	99% male	1% female	99% male	1% female	99% male
80	3.69	2.74	0.213	0.079	3.25	2.65	4.5	2.5	0.999	0.375
85	3.45	2.55	0.159	0.075	3.6	2.5	2.4	2.3	0.746	0.355
90	3.48	2.41	0.137	0.052	3.6	2.35	4	2.3	0.644	0.244
100	4.42	2.54	0.091	0.191	4.45	2.20	4.50	2.00	0.427	0.897
105	4.48	4.32	0.305	0.094	4.35	4.40	4.60	4.40	1.432	0.441

Table 3. Descriptive statistics data of discomfort values of 1% female and 99% male populations

Seat backrest angle,°	Discomfort [-]									
	mean		standard error		median		mode		standard deviation	
	1% female	99% male	1% female	99% male	1% female	99% male	1% female	99% male	1% female	99% male
80	4.93	3.63	0.318	0.124	4.45	3.45	6.4	3.4	1.492	0.585
85	4.66	3.11	0.254	0.115	4.95	3	2.9	2.6	1.194	0.540
90	4.77	2.98	0.227	0.072	5.05	2.9	5.9	2.9	1.066	0.338
100	5.68	3.20	0.164	0.263	5.60	2.80	6.30	2.50	0.771	1.234
105	5.83	5.56	0.239	0.161	5.50	5.35	4.80	5.20	1.123	0.775

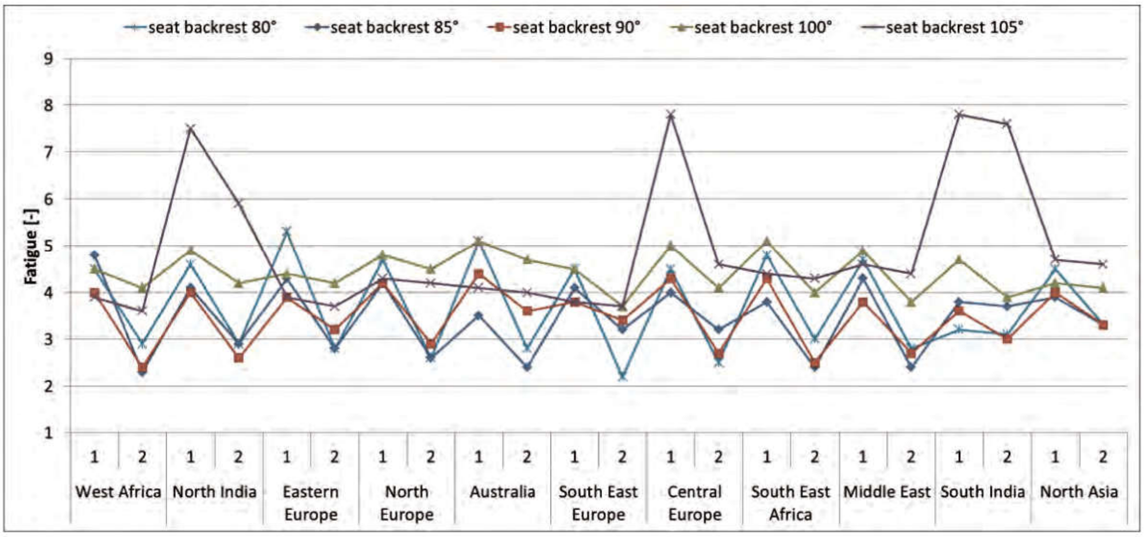


Figure 4. The discomfort analysis of 99% male population in driving (1) and resting position (2) under different seat backrest Angle

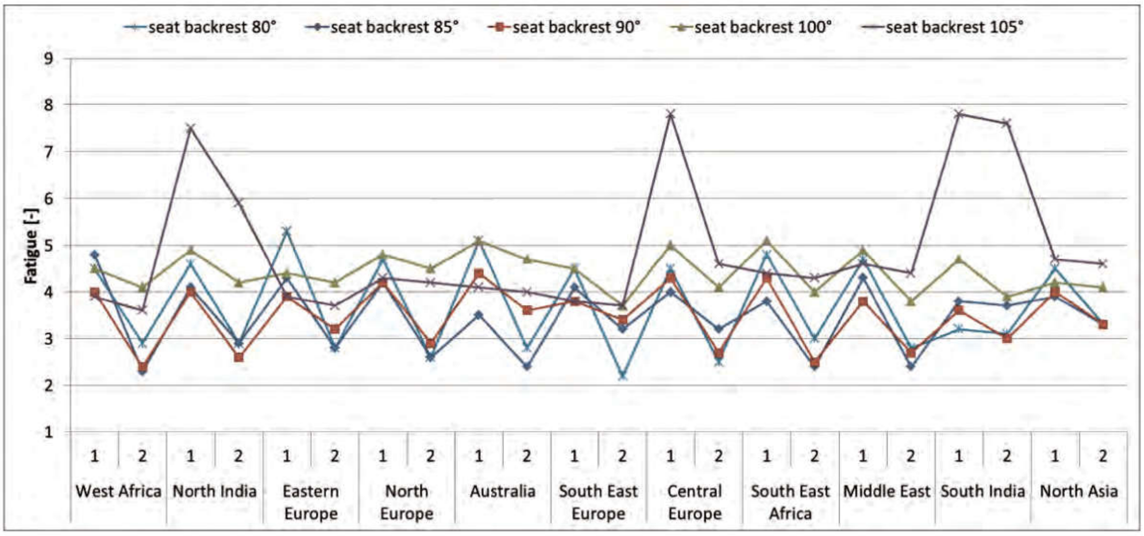


Figure 5. The discomfort analysis of 1% female population in driving (1) and resting position (2) under different seat backrest angle

Based on data partially presented in figures 4 and 5 can be noticed that fatigue values for female 1% population is higher than for male 99% population for both sitting condition.
The most uncomfotable sitting position is with seat backrest angle of 105°. In worst seat backrest angle condition (105°) maximum values of discomfort and fatigue for both human populations is driving condition (1), Table 4.

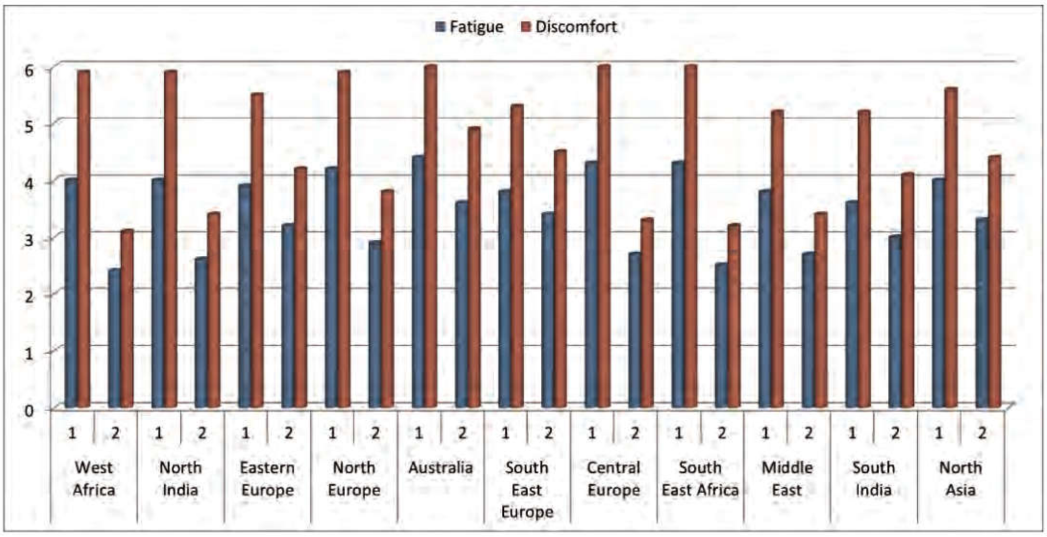


Figure 6. The discomfort and fatigue analysis of 1% female population in driving (1) and resting position (2) under 90° seat backrest angle

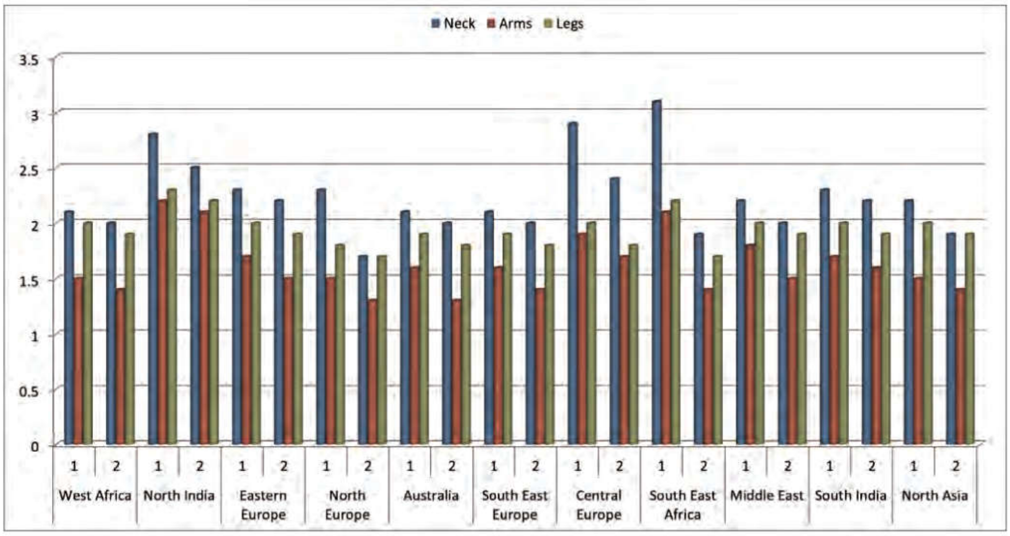


Figure 7. The discomfort body part assessment of 99% male population in driving (1) and resting position (2) under 90° seat backrest angle

Correlation coefficients between discomfort and fatigue values are height and sitting height are determined for seat backrest angle 105° and are given in Table 5.
There is negative correlation between fatigue and discomfort and height of female population is given in Table 5. Positive and strong correlation can be observed between height of male population and discomfort.

Table 4. Descriptive statistics of discomfort values of 1% female and 99% male populations for seat backrest angle 105° in driving position (1) and resting position (2)

	Fatigue		Fatigue		Discomfort		Discomfort	
	1	*2*	*1*	*2*	*1*	*2*	*1*	*2*
	Female	Male	Female	Male	Female	Male	Female	Male
Mean	5.164	4.536	4.600	4.109	6.045	6.227	5.627	5.091
Standard Error	0.499	0.128	0.356	0.108	0.377	0.192	0.300	0.087
Median	4.400	4.600	4.300	4.100	5.600	6.400	5.500	5.200
Mode	3.900	4.600	3.700	4.400	4.800	6.300	4.600	5.200
Standard Deviation	1.655	0.425	1.182	0.359	1.250	0.637	0.995	0.288
Sample Variance	2.741	0.181	1.396	0.129	1.563	0.406	0.990	0.083
Kurtosis	-0.815	-0.256	3.955	-1.602	-1.141	1.677	0.112	-0.749
Skewness	1.085	-0.423	1.958	-0.391	0.747	-1.453	0.957	-0.473
Range	4.000	1.400	4.000	0.900	3.100	2.100	3.000	0.900
Minimum	3.800	3.800	3.600	3.600	4.800	4.800	4.600	4.600
Maximum	7.800	5.200	7.600	4.500	7.900	6.900	7.600	5.500
Sum	56.800	49.900	50.600	45.200	66.500	68.500	61.900	56.000
Count	11.000	11.000	11.000	11.000	11.000	11.000	11.000	11.000
Largest(1)	7.800	5.200	7.600	4.500	7.900	6.900	7.600	5.500
Smallest(1)	3.800	3.800	3.600	3.600	4.800	4.800	4.600	4.600
Confidence Level(95.0%)	1.112	0.285	0.794	0.241	0.840	0.428	0.669	0.193

Applied software enables assessment of discomfort level for part of the human body, figure 7.
The neck is exposed to the highest level of fatigue and discomfort. Left and right legs, as well as left and right arm have the same level of discomfort and fatigue. Also, both legs is subjected to higher level of discomfort than arms.

Table 5. Correlation coefficients Descriptive statistics of discomfort values of 1% female and 99% male populations for seat backrest angle 105° in driving position (1) and resting position (2)

		Fatigue		Discomfort	
		(1)	(2)	(1)	(2)
Female	Height	-0.41626	-0.66435	-0.36831	-0.59346
	Sitting height	0.088812	-0.34878	0.092169	-0.27216
Male	Height	0.760445	0.697349	0.539407	0.277367
	Sitting height	0.453327	0.477271	0.166879	0.006908

Discomfort differences between sitting in driving position and resting position are presented in Figure 8 for 99% male population under 105° of seat back rest angle. Correlations between human body height and discomfort difference are small and there are no significant correlation for both population.

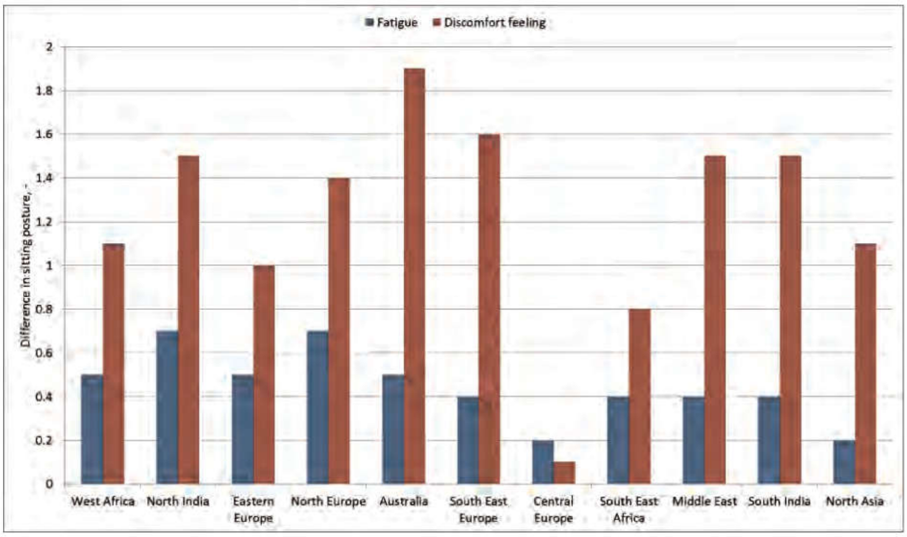


Figure 8. The difference in sitting posture respect to discomfort and fatigue for 99% male population in driving (1) and resting position (2) under 105° seat backrest angle

4. CONCLUSIONS

The aim of this study was to determine the driver fatigue and discomfort in a different seating position. In this paper, digital human models of driver and passanger,are used in order to assess the fatigue and discomfort. Also, discomfort of body parts, for two different sitting posture were analysed. Eleven different populations withr anthropometric dimensions of 1% female and 99% male populations were used. Investigations were conducted by application of the software package Ramsis. Theobtained results showed that all eleven populations have a permissible fatigue value below 5.5.

The most sever discomfort and fatigue are noticed in driving conditions under 105° seat backrest angle for both male an female population.

Application of Ramsis software is very suitable in vehicle design phase especially in the vehicle packaging. Obtained results are conducted for 1% female and 99% male population, which is tendecy in vehicle design phase in order to enable usig vehicle to wider population. Presented results an applied method enable discomfort and fatigue assesment and to sve time in vehicle design.

ACKNOWLEDGEMENTS

This research supported by the Ministry of Education, Science and Technological Development of Republic of Serbia through Grant TR 35041.

REFERENCES

[1] Looze, M.P. de., Kuijt-Evers, L.F.M., Dieen, J. van. (2003) "Sitting comfort and discomfort and the relationships with objective measures", Ergonomics; 46: pp.985-997.

[2] Helander, M.G. and Zhang, L. (1997) "Field studies of comfort and discomfort in sitting", Ergonomics; 40: pp.895–915.

[3] Vink, P. (ed). (2005) "Comfort and design: principles and good practice", Boca Raton: CRC Press.

[4] Kuijt-Evers L.F.M., (2007) "Comfort in handtools", PhD thesis, TUDelft,.

[5] Zenk, R. (2008) „Objektivierung des Sitzkomforts und seine automatische Anpassung", PhD TUMunchen, Herbert Utz Verlag,.

[6] Bridger, R. S., (2009) "Introduction to Ergonomics", Boca Raton: Taylor & Francis Group, LLC.

[7] Duffy, V. G., (2008) "Handbook of Digital Human Modeling: Research for Applied Ergonomics and Human Factors Engineering", CRC Press Inc. Boca Raton FL USA.

[8] McAtamney, L. and Corlett, E. N. (1993) "Rula: a survey method for the investigation of workrelated upper limb disorders", Applied Ergonomics 24 (2) pp 91–99.

[9] Hignett, S. and McAtamney, L., (2000) "Rapid entire body assessment (REBA)", Applied Ergonomics 31 (2) pp 201–205.

[10] Porter, J.M., Gyi, D.E.,(1998) "Interface pressure and the prediction of car seat discomfort", Int. J. Vehicle Des. 19 (3),255–266.

[11] Hirao, K., S. Kitazaki and N. Yamazaki, (2006) "Development of new driving posture focused on biomechanical loads", J. SAE Int., 100: 5-10.

[12] Graf, M.C., (2004), Effects of seat angle on comfort and lower back pain at work Swiss federal institute of technology. Zurich: ETH, p. 182.

[13] Lapa, V.V., Neverov, G.I., Poliakov, V.V., Solov'ev, N.N., (2000) "Effect of inclination angles of supporting surfaces of aircraft seat on pilot's working capacity in longduration flight", Aviakosm Ekolog Med;34(3):17-21.

[14] Schmidt, S., Amereller, M., Franz, M., Kaiser, R., Schwirtz, A. (2014) "A literature review on optimum and preferred joint angles in automotive sitting posture" Applied Ergonomics, Volume 45, Issue 2, Part B, March 2014, Pages 247-260

[15] URL 1: Human solutions, (2010) "RAMSIS model applications", accessed 07.04.2017, http://www.human-solutions.com/mobility/ front_content.php?idcat=252.

[16] URL 2: http://dined.io.tudelft.nl/en, accessed 01.03.2017.

[17] RAMSIS 3.8 in CATIA V5 User Guide - HUMAN SOLUTIONS GmbH, 29-November-2012

[18] Heiner, B.H., Bengler, K., Grünen, R., Vollrath, M., (2015) „Automobilergonomie", Springer Vieweg.

[19] URL 3: ECE/TRANS/180/Add.3: Agreement concerning the establishing of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles, 21 December 2006, International Organization for Standardization, Geneva, Switzerland, accessed 07.04.2017.