

ISSN 2457 - 5275 (Online, English)  
ISSN 1842 - 4074 (Print, Online, Romanian)

June 2020  
Volume 26  
Number 2  
4<sup>th</sup> Series

# *RoJAE*

## Romanian Journal of Automotive Engineering

---

**SIAR**

*The Journal of the Society of Automotive Engineers of Romania*  
[www.siar.ro](http://www.siar.ro)  
[www.ro-jae.ro](http://www.ro-jae.ro)

# RoJAE Romanian Journal of Automotive Engineering

## SIAR

Societatea Inginerilor de Automobile din România  
Society of Automotive Engineers of Romania  
[www.siar.ro](http://www.siar.ro)

SIAR – The Society of Automotive Engineers of Romania is the professional organization of automotive engineers, an independent legal entity, non-profit, active member of FISITA (Fédération Internationale des Sociétés d'Ingénieurs des Techniques de l'Automobile - International Federation of Automotive Engineering Societies) and EAEC (European Cooperation Automotive Engineers).

Founded in January 1990 as a professional association, non-governmental, SIAR's main objectives are: development and increase the exchange of professional information, promoting Romanian scientific research results, new technologies specific to automotive industry, international cooperation.

Shortly after its constitution, SIAR was affiliated to FISITA - International Federation of Automotive Engineers and EAEC - European Conference of Automotive Engineers, thus ensuring full involvement in specific activities undertaken globally.

In order to help promoting the science and technology in the automotive industry, SIAR is issuing 4 times a year rIA - Journal of Automotive Engineers (on paper in Romanian and electronically in Romanian and English).

The organization of national and international scientific meetings with a large participation of experts from universities and research institutes and economic environment is an important part of SIAR's. In this direction, SIAR holds an annual scientific event with a wide international participation. The SIAR annual congress is hosted successively by large universities that have ongoing programs of study in automotive engineering.

Developing relationships with the economic environment is a constant concern. The presence in Romania of OEMs and their suppliers enables continuous communication between industry and academia.

A constant priority in SIAR's activity is to ensure optimal framework for collaboration between universities and research, industry and business specialists.

### The Society of Automotive Engineers of Romania

#### President

**Adrian-Constantin CLENCI**  
University of Pitesti, Romania

#### Honorary President

**Eugen Mihai NEGRUS**  
University „Politehnica” of Bucharest, Romania

#### Vice-Presidents

**Cristian-Nicolae ANDREESCU**  
University „Politehnica” of Bucharest, Romania

**Nicolae BURNETE**  
Technical University of Cluj-Napoca, Romania

**Victor CEBAN**  
Technical University of Moldova, Chisinau, Moldova

**Anghel CHIRU**  
„Transilvania” University of Brasov, Romania

**Liviu-Nicolae MIHON**  
Politehnica University of Timisoara, Romania

**Victor OTAT**  
University of Craiova, Romania

**Ion TABACU**  
University of Pitesti, Romania

#### General Secretary

**Minu MITREA**  
Military Technical Academy of Bucharest, Romania

### Honorary Committee of SIAR

#### Alexander SIMIONESCU

Renault Technologie Roumanie  
[www.renault-technologie-roumanie.com](http://www.renault-technologie-roumanie.com)

#### Attila PAPP

Magic Engineering srl  
<http://www.magic-engineering.ro>

#### RADIAN TUFĂ

Romanian Automotive Register  
[www.rarom.ro](http://www.rarom.ro)

#### Radu DINESCU

IRU  
The National Union of Road Hauliers from Romania

[www.untrr.ro](http://www.untrr.ro)

#### Gerolf STROHMEIER

AVL Romania  
[www.avl.com](http://www.avl.com)



SIAR – Society of Automotive Engineers of Romania is member of:



FISITA - International Federation of Automotive Engineers Societies  
[www.fisita.com](http://www.fisita.com)

EAEC - European Automotive Engineers Cooperation



## CONTENTS

Volume 26, Issue No. 2

June 2020

Modeling and Control of Active Suspension whit MATLAB Sorin MARCU, Dinel POPA, Nicolae Doru STANESCU and Nicolae PANDREA .....	35
Study Regarding the Side Impact Consequences Upon the Vehicle Occupant using Accident Reconstruction Software Alexandru Ionut RADU, Daniel Dragos TRUSCA, George TOGANEL and Bogdan BENEĂ .....	41
Introducing Modularity Strategy in New Products Development (Case Study: Iranian Automobile Industry) Amir Hossain DOCTORAN, Manouchehr MANTEGHI, Changiz VALMOHAMMADI and Mahnaz RABIEI .....	49
Multibody Model Adaptation for Simulating Helmet Airbags in Vehicle-Cyclist Accidents Ovidiu Andrei CONDREA, Anghel CHIRU and Daniel Dragoș TRUȘCĂ .....	57
Study on the Recycling Methods of Used Engine Oil Sorin Aurel RAȚIU, Nicolae Liviu MIHON and Miruna Diana ARMIONI .....	63
Experimental Study on the Functioning of the Traction Batteries for Hybrid Vehicles Ioan Radu ȘUGAR and Olivian CHIVER .....	69

---

The RoJAE's articles are included in the „*Ingineria automobilului*” magazine (ISSN 1842 – 4074), published by SIAR in Romanian.

The articles published in „*Ingineria automobilului*” magazine are indexed by Web of Science in the „*Emerging Source Citation Index (ESCI)*” Section.

Web of Science



RoJAE 26(2) 31 – 76 (2020)

ISSN 2457 – 5275 (Online, English)

ISSN 1842 – 4074 (Print, Online, Romanian)

The journals of SIAR are available at the website [www.ro-jae.ro](http://www.ro-jae.ro).

# RoJAE

## Romanian

## Journal of Automotive Engineering

### Editor in Chief

**Cornel STAN**

West Saxon University of Zwickau, Germany

E-mail: [cornel.stan@fh-zwickau.de](mailto:cornel.stan@fh-zwickau.de)

### Technical and Production Editor

**Minu MITREA**

Military Technical Academy, Bucharest, Romania

E-mail: [minumitrea@yahoo.com](mailto:minumitrea@yahoo.com)

### Contributors

*Miruna Diana ARMION*

*Bogdan BENEĂ*

*Anghel CHIRU*

*Olivian CHIVER*

*Ovidiu Andrei CONDREA*

*Amir Hossain DOCTORAN*

*Günter HOHL*

*Manouchehr MANTEGHI*

*Sorin MARCU*

*Nicolae Liviu MIHON*

*Nicolae PANDREA*

*Dinel POPA*

*Mahnaz RABIEI*

*Ionuț Alexandru RADU*

*Sorin Aurel RAȚIU*

*Nicolae Doru STĂNESCU*

*Radu ȘUGAR*

*George TOGĂNEL*

*Daniel Dragoș TRUȘCĂ*

*Changiz VALMOHAMMADI*

*The authors declare that the material being presented in the papers is original work, and does not contain or include material taken from other copyrighted sources.*

*Wherever such material has been included, it has been clearly indented or/and identified by quotation marks and due and proper acknowledgements given by citing the source at appropriate places.*

*The views expressed in the articles are those of the authors and are not necessarily endorsed by the publisher.*

*While every case has been taken during production, the publisher does not accept any liability for errors that may have occurred.*

### Advisory Editorial Board

**Dennis ASSANIS**

University of Michigan, USA

**Rodica A. BARANESCU**

Chicago College of Engineering, USA

**Michael BUTSCH**

University of Applied Sciences, Konstanz, Germany

**Nicolae BURNETE**

Technical University of Cluj-Napoca, Romania

**Giovanni CIPOLLA**

Politecnico di Torino, Italy

**Felice E. CORCIONE**

Engines Institute of Naples, Italy

**Georges DESCOMBES**

Conservatoire National des Arts et Metiers de Paris, France

**Cedomir DUBOKA**

University of Belgrade, Serbia

**Pedro ESTEBAN**

Institute for Applied Automotive Research Tarragona, Spain

**Radu GAIGINSCHI**

„Gheorghe Asachi” Technical University of Iasi, Romania

**Eduard GOLOVATAI-SCHMIDT**

Schaeffler AG & Co. KG Herzogenaurach, Germany

**Ioan-Mircea OPREAN**

University „Politehnica” of Bucharest, Romania

**Nicolae V. ORLANDEA**

University of Michigan, USA

**Victor OTAT**

University of Craiova, Romania

**Andreas SEELINGER**

Institute of Mining and Metallurgical Engineering, Aachen, Germany

**Ulrich SPICHER**

Karlsruhe University, Karlsruhe, Germany

**Cornel STAN**

West Saxon University of Zwickau, Germany

**Dinu TARAZA**

Wayne State University, USA

# SIAR

**The Journal of the Society of Automotive Engineers of Romania**

[www.ro-jae.ro](http://www.ro-jae.ro)

[www.siar.ro](http://www.siar.ro)

**Copyright © SIAR**

**Production office:**

The Society of Automotive Engineers of Romania (Societatea Inginerilor de Automobile din România)

Facultatea de Transporturi, Splaiul Independentei Nr. 313

060042 Bucharest ROMANIA Tel.: +4.021.316.96.08 Fax: +4.021.316.96.08 E-mail: [siar@siar.ro](mailto:siar@siar.ro)

**Staff: Professor Minu MITREA, General Secretary of SIAR**

**Subscriptions:** Published quarterly. Individual subscription should be ordered to the Production office.

Annual subscription rate can be found at SIAR website <http://www.siar.ro>.

## MODELING AND CONTROL OF ACTIVE SUSPENSION WITH MATLAB

Sorin MARCU\*, Dinel POPA, Nicolae Doru STANESCU, Nicolae PANDREA

University of Pitesti, Manufacturing and Industrial Management Department,  
 Strada Târgul din Vale 1, 110040 PITESTI, Romania

(Received 15 October 2019; Revised 23 November 2019; Accepted 21 December 2019)

**Abstract:** This paper simulates and analyzes the performance of a vehicle that is equipped with an active suspension system on a quarter-car model with two degrees of freedom. This model will be analyzed using the transfer function, and Matlab will be used as simulation software. To solve mathematical equations a computational program will be performed where different excitation signals can be input.

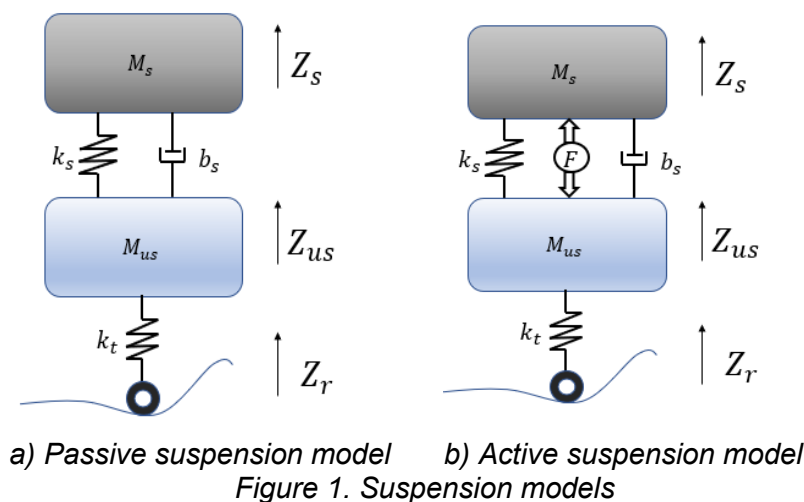
**Key-Words:** suspension passive, suspension active, matlab

### 1. INTRODUCTION

The dynamic features of the vehicle, such as ride comfort and steering stability can normally be improved by the suspension system[1]. Passive suspension systems used in automotive applications are simple in design and economical, but can generate an uncontrollable damping force created in the system[2]. The dynamic behavior of passive suspensions for vehicles is firstly determined by the choice of the damping coefficient of the shock absorber and the stiffness of the spring. Different aspects are taken into account when choosing these parameters. One thing is that, the driver must always have control over the vehicle to ensure safety[3]. The trade-off between comfort and safety of the vehicle is very difficult to achieve. For driving safety, it is extremely important to ensure the constant contact of the vehicle's wheels with the road surface. This determines the high depreciation coefficient. These contradictory requirements can be overcome by using active suspensions. To ensure optimum vibration isolation for passengers, the suspension's damping properties must be changeable in the operating state. Currently, many car companies offer adaptive shock absorbers or active suspensions. The active suspension offers more comfort and handling characteristics of the vehicle but with a high power consumption by the engine and a complicated control strategy. This system uses pneumatic, magneto-rheological, hydraulic or electromagnetic actuators to generate the control force.

### 2. THE MATHEMATICAL MODEL

To simplify the analysis we will use a quarter car model. Model is commonly used in the design of passive and active suspensions. Figure 1 shows the two models: passive and active.



\* Corresponding authors e-mail: [marcuisorin@yahoo.com](mailto:marcuisorin@yahoo.com), [dinel.popa@upit.ro](mailto:dinel.popa@upit.ro), [s\\_doru@yahoo.com](mailto:s_doru@yahoo.com)

For the passive and the active suspension presented in Figure 1 we can write the equations of motion for the two masses  $M_s$  which represents the sprung mass and  $M_{us}$  which represents the un-sprung mass [4].

For passive suspension:

$$\begin{cases} M_s \ddot{Z}_s + b_s (\dot{Z}_s - \dot{Z}_{us}) + k_s (Z_s - Z_{us}) = 0 \\ M_{us} \ddot{Z}_{us} + b_s (\dot{Z}_{us} - \dot{Z}_s) + k_s (Z_{us} - Z_s) + k_t (Z_{us} - Z_r) = 0 \end{cases} \quad (1)$$

For active suspension:

$$\begin{cases} M_s \ddot{Z}_s + b_s (\dot{Z}_s - \dot{Z}_{us}) + k_s (Z_s - Z_{us}) = F \\ M_{us} \ddot{Z}_{us} + b_s (\dot{Z}_{us} - \dot{Z}_s) + k_s (Z_{us} - Z_s) + k_t (Z_{us} - Z_r) = -F \end{cases} \quad (2)$$

where  $Z_s$ ,  $\dot{Z}_s$ ,  $\ddot{Z}_s$  represents the displacement, speed and acceleration of the sprung mass, respectively  $Z_{us}$ ,  $\dot{Z}_{us}$ ,  $\ddot{Z}_{us}$  are the displacement, speed and acceleration of the un-sprung mass, respectively  $b_s$  is the damping coefficient of the damper;  $k_s$ ,  $k_t$  the rigidity of the spring and the tire,  $F$  represents the force generated by the controller [5].

We write the Laplace transform for the active suspension equations:

$$Z_s(s)[M_s s^2 + b_s s + k_s] - Z_{us}(s)[b_s s + k_s] = F(s) \quad (3)$$

$$Z_s(s)[-b_s - k_s] + Z_{us}(s)[M_{us} s^2 + b_s s + k_s + k_t] = k_t Z_r(s) - F(s) \quad (4)$$

In order to find the transfer functions we need the following terms:

$$\frac{Z_s(s)}{F(s)}; \frac{Z_{us}(s)}{F(s)}; \frac{Z_s - Z_{us}}{F(s)}; \frac{Z_s(s)}{Z_r(s)}; \frac{Z_{us}(s)}{Z_r(s)} \text{ and } \frac{Z_s - Z_{us}}{Z_r(s)}$$

We write Laplace transformation in matrix form

$$\begin{bmatrix} M_s s^2 + b_s s + k_s & -(b_s s + k_s) \\ -(b_s s + k_s) & M_{us} s^2 + b_s s + k_s + k_t \end{bmatrix} \begin{bmatrix} Z_s(s) \\ Z_{us}(s) \end{bmatrix} = \begin{bmatrix} F(s) \\ Z_r k_t - F(s) \end{bmatrix} \quad (5)$$

$$A = \begin{bmatrix} M_s s^2 + b_s s + k_s & -(b_s s + k_s) \\ -(b_s s + k_s) & M_{us} s^2 + b_s s + k_s + k_t \end{bmatrix}; \quad x = \begin{bmatrix} Z_s(s) \\ Z_{us}(s) \end{bmatrix}; \quad B = \begin{bmatrix} F(s) \\ Z_r k_t - F(s) \end{bmatrix} \quad (6)$$

$$Ax = B \Rightarrow x = A^{-1}B = \frac{1}{\det A} A^* B \quad (7)$$

$$\begin{bmatrix} Z_s(s) \\ Z_{us}(s) \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} M_{us} s^2 + b_s s + k_s + k_t & b_s s + k_s \\ b_s s + k_s & M_s s^2 + b_s s + k_s \end{bmatrix} \begin{bmatrix} F(s) \\ Z_r k_t - F(s) \end{bmatrix} \quad (8)$$

For the calculation of the first three terms we consider  $Z_r = 0$ , for the last three we will consider  $F = 0$ .

We calculate the three terms with  $Z_r = 0$

$$\begin{bmatrix} Z_s(s) \\ Z_{us}(s) \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} M_{us} s^2 + b_s s + k_s + k_t & b_s s + k_s \\ b_s s + k_s & M_s s^2 + b_s s + k_s \end{bmatrix} \begin{bmatrix} F(s) \\ -F(s) \end{bmatrix} \quad (9)$$

$$Z_s(s) = \frac{F(s)(M_{us}s^2 + b_s + k_s + k_t) - F(s)(b_s s + k_s)}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (10)$$

$$\frac{Z_s(s)}{F(s)} = \frac{M_{us}s^2 + k_t}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (11)$$

$$Z_{us}(s) = \frac{-F(s)(M_s s^2 + b_s s + k_s) + F(s)(b_s s + k_s)}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (12)$$

$$\frac{Z_{us}(s)}{F(s)} = \frac{-M_s s^2}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (13)$$

$$\frac{Z_s(s) - Z_{us}(s)}{F(s)} = \frac{M_{us}s^2 + k_t + M_s s^2}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (14)$$

We calculate the last three terms with  $F = 0$

$$\begin{bmatrix} Z_s(s) \\ Z_{us}(s) \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} M_{us}s^2 + b_s s + k_s + k_t & b_s s + k_s \\ b_s s + k_s & M_s s^2 + b_s s + k_s \end{bmatrix} \begin{bmatrix} 0 \\ Z_r k_t \end{bmatrix} \quad (15)$$

$$Z_s(s) = \frac{k_t Z_r (b_s s + k_s)}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (16)$$

$$\frac{Z_s(s)}{Z_r(s)} = \frac{k_t (b_s s + k_s)}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (17)$$

$$Z_{us}(s) = \frac{k_t Z_r (M_s s^2 + b_s s + k_s)}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (18)$$

$$\frac{Z_{us}(s)}{Z_r(s)} = \frac{k_t (M_s s^2 + b_s s + k_s)}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (19)$$

$$\frac{Z_s(s) - Z_{us}(s)}{Z_r(s)} = \frac{-k_t M_s s^2}{(M_s s^2 + b_s + k_s)(M_{us}s^2 + b_s + k_s + k_t) - (b_s s + k_s)^2} \quad (20)$$

Based on these equations, the two models will be simulated in Matlab / Simulink.

### 3. CONTROLLER DESIGN

The automatic regulator has the role to retrieve the error signal, (obtained from the comparison of the input size  $y_r$  and the measured size  $y$ , in the comparison element) and to elaborate at the output a control signal  $u$  for the execution element. Depending on the law of dependence between input and output, the regulators can be linear, or nonlinear.

Continuous linear regulators are of type P, PI, PID [7].

The classification of regulators can be done according to the type and characteristics of the regulated process (P):

*Proportional regulator (P):*

This type of regulator is characterized by a differential equation:

$$u(t) = K_R a(t) \quad (21)$$

where,  $K_R$  is a parameter referred to as the amplification factor (the proportionality factor) of the regulator.

#### Proportional regulator - integral (PI):

This regulator combines the proportional effect, with an integral effect integrates the deviation  $a(t)$  over time and is described by the following relation

$$u(t) = K_R \left[ a(t) + \frac{1}{T_I} \int_0^t a(t) dt \right]. \quad (22)$$

These factors  $K_R$ ,  $K_I$ , are the tuning parameters of the PI type regulator and they can be modified to a large extent, depending on the performances required by the automatic control system.

A PI controller is a combination of a P controller, supplemented with an I controller.

#### Proportional regulator - derivative (PD):

The PD regulator combines the proportional effect with a derivative effect, so it derives the deviation  $a(t)$ , in time.

The operating equation of a PD regulator is:

$$u(t) = K_R \left( a(t) + T_D \frac{da(t)}{dt} \right), \quad (23)$$

where  $T_D$  – the constant of the derivative action, which is also a parameter of tuning the regulator, which together with the amplification factor  $K_R$  determines the law regulating the PD regulator.

#### Proportional regulator - integral - derivative (PID):

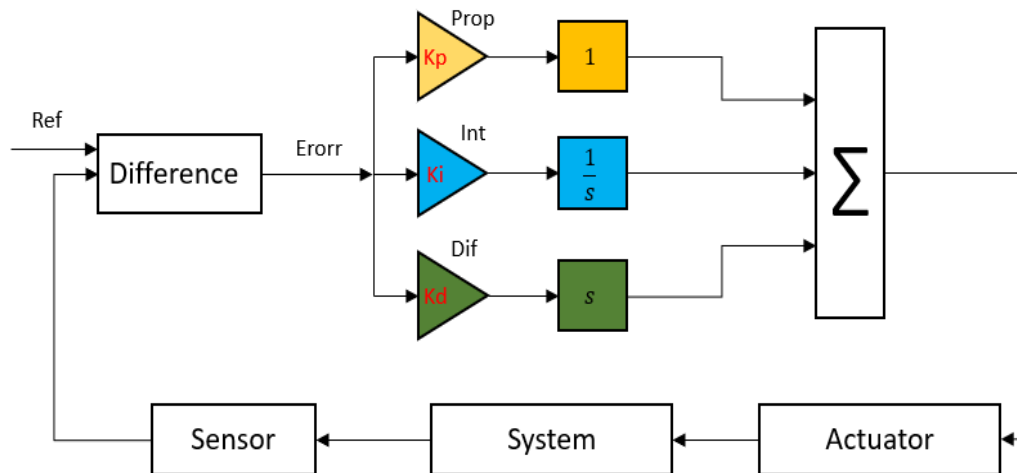


Figure 2. System controlled by a PID controller

$$u(t) = K_R \left[ a(t) + \frac{1}{T_I} \int_0^t a(t) dt + T_D \frac{da(t)}{dt} \right]. \quad (24)$$

## 4. SYSTEM SIMULATION

The simulation is performed using the equations and the Matlab / Simulink software, where the mathematical equations presented above have been introduced.

The purpose of the simulation is to obtain as little amplitude as possible for the displacement, speed and acceleration of the sprung mass.

The parameters that have been chosen for the simulation are the following.

Table 1.  
 Parameter Values of suspension system

$M_s$	260 [kg]
$M_{us}$	55 [kg]
$k_s$	16200 [N/m]
$k_t$	19500 [N/m]
$b_s$	900, 1050, 1200 [Ns/m]

Simulation for Step input is 0.08 m.

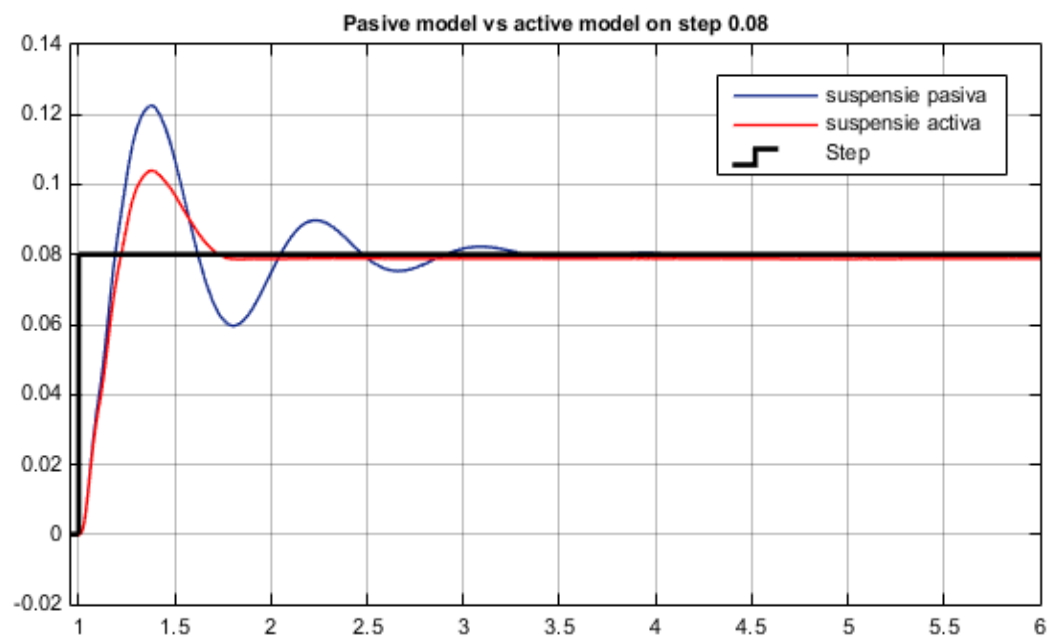


Figure 3. Car body displacement for step input 0.08 m

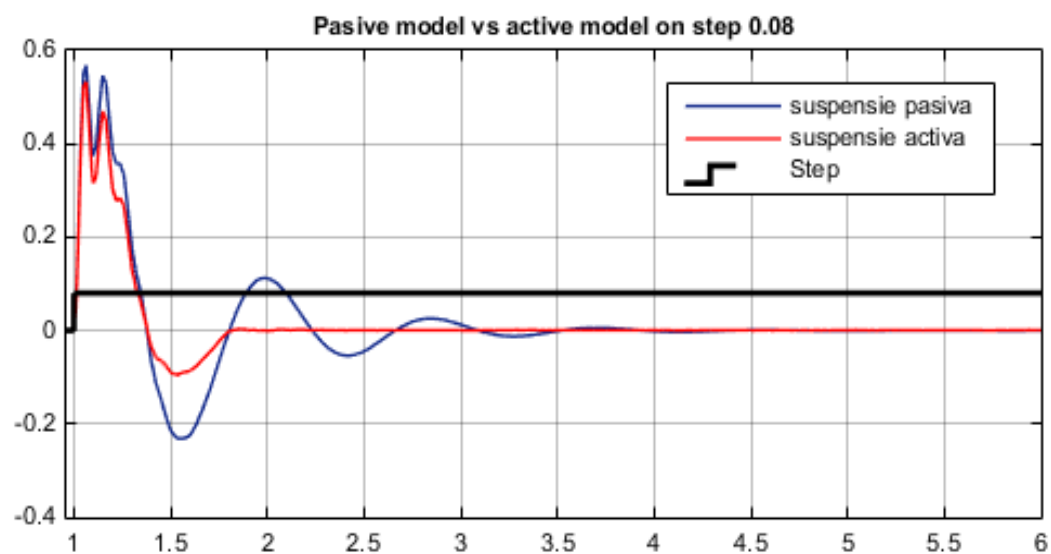


Figure 4. Car body velocity for step input 0.08 m

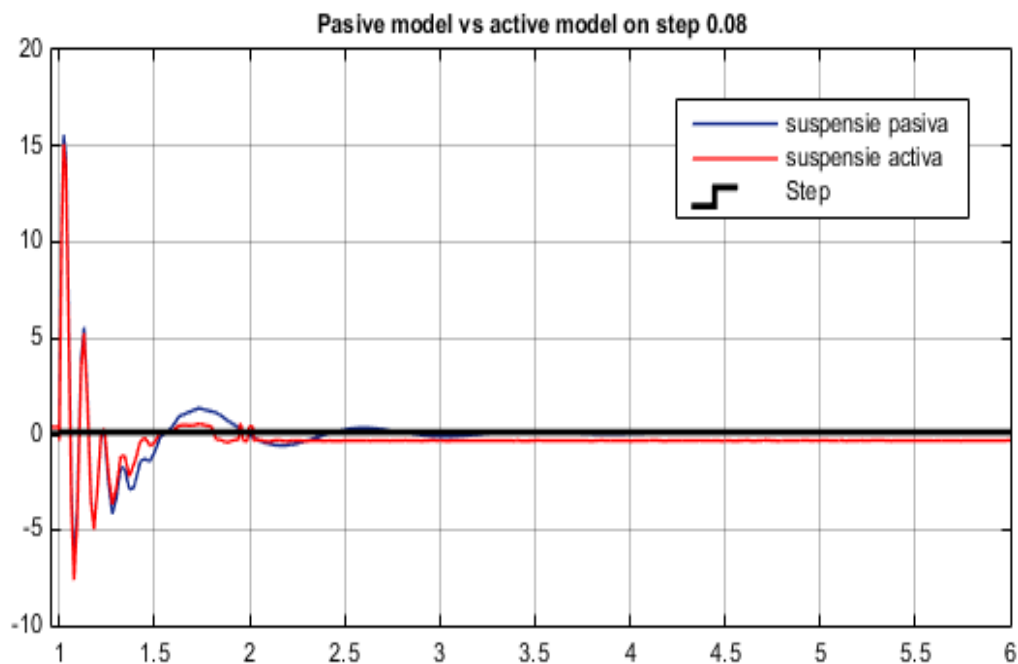


Figure 5. Car body acceleration for step input 0.08 m

Table 2.  
 Reduction in overshoot values for step road input

No	Parameters	Passive	Active	Reduction
1	Car body displacement	0.122	0.103	15.574%
2	Car body velocity	0.568	0.532	6.338%
3	Car body acceleration	15.569	15.085	3.109%

## 5. CONCLUSIONS

The methodology was developed to design an active suspension for a car, by designing a controller, which improves the performance of the system in terms of design objectives compared to the passive suspension system. As shown in the table presented, the amplitude of the sprung mass of the active suspension was reduced compared to that of the passive suspension. The mathematical modeling was performed using a two-degree model of the quarter car model for the passive and active suspension system. The dynamic model for linear suspension systems was formulated and derived a single type of controller that is used to test the performance of PID systems.

## REFERENCES

- [1] Kum-Gil S., Min-Sang S., Seung-Bok C., *Performance evaluation of electronic control suspension featuring vehicle ER dampers*. Meccanica, 2013, 48, p.121–134
- [2] Kamalakkannan K., Elayaperumal A., Managlamam S., *Input advanced control of semi active half car heave model*. Journal of Mechanical Science and Technology, 2013, 27(5), p.1225 – 1231
- [3] Aboud W., Haris S., Yaacob Y., *Advances in the control of mechatronic suspension systems*. Journal of Zhejiang University, SCIENCE C, 2014, 15(10), p.848 – 860
- [4] Eshkabilov S., *Modeling and simulation of non-linear and hysteresis behavior of magneto-rheological damper in the example of quarter-car model*.
- [5] Sayel M., *Constructing Control System for Active Suspension System*. Contemporary Engineering Sciences, 2012, vol. 5, no. 4, p.189 – 200
- [6] Pandrea N., Popa D., Parlac S., *Modele pentru studiul vibratiilor automobilelor*, TIPARG, Pitesti, 2001
- [7] Guido K., *Adaptive Control of Mechatronic Vehicle Suspension Systems*, 2011
- [8] Rajesh R., *Vehicle Dynamics and Control*, 2012

## STUDY REGARDING THE SIDE IMPACT CONSEQUENCES UPON THE VEHICLE OCCUPANT USING ACCIDENT RECONSTRUCTION SOFTWARE

Alexandru Ionut RADU\*, Daniel Dragos TRUSCA, George TOGANEL, Bogdan BENEĂ

Transilvania University of Brasov, Automotive and Transport Engineering Department,  
Str. Politehnicii, Nr. 1, 500024 BRASOV, Romania

(Received 08 November 2019; Revised 15 December 2019; Accepted 17 January 2020)

**Abstract:** *The paper presents the probability of injury for an occupant in the case of vehicle accidents, side collisions, using virtual accident reconstruction software and a mathematical multi-body model of an occupant. The key aspect of this study was to recreate the interior of the vehicle by the means of CAD software for occupant kinematic simulation. By achieving this, the impact between the occupant and the interior of the vehicle can be analysed. For a better evaluation of accident injury outcome for the driver, we used the multibody model without the seatbelt to study the maximum injury potential. The results show an increase in injury of the occupant head and torso area with the increase of vehicle striking velocity. The simulations showed an impact of the head with the side window and also, at high velocity, the impact of the torso with the side of the vehicle.*

**Key-Words:** *Simulation, kinematics, accident, thoracic injury, head injury, multibody, interior DXF*

### 1. INTRODUCTION

Because of the increasing number of motor vehicles on the roads, the number of accidents have risen as well, mainly in the urban areas where congestions frequently occur. To counteract this, automotive manufacturers implement active and passive safety systems to reduce the likelihood of traffic accidents and to prevent injuries not only to the occupants of the vehicles, but also to the pedestrians, that are usually involved in urban traffic accidents [1][ 2].

The research in road traffic motor vehicle accidents shows the study of the kinematic occupant behavior of the vehicle occupants during the collision but also the risk evaluation of the injury level [3].

Real accident cases show that the occupant injuries could give vital information about the impact velocity and also the initial position of a pedestrian at the moment of impact [4].

Side-impact collisions have a higher risk of injury for the occupants of motor vehicles than frontal or rear collisions due to the fact that passenger vehicles have a lower potential to absorb energy in collisions. In these cases, occupants have a higher risk of serious injury to the head and chest [5]. A study from 2011 conducted on samples of human skulls concluded that the fracture of the cranium can appear at a peak force of 6270 N with a secondary fracture at 6400 N [6].

Blunt chest trauma is way more common than penetrating trauma and have a percentage of 20% to 25% of trauma deaths. The cause of this comes from motor vehicle accidents with a higher mortality that is associated with high-speed vehicle collisions with the lack of seat belt use. The main components of the chest wall are as follow: the rib cage, costal cartilage and intercostal musculature. The blood supplied and innervation to the chest wall travel by neurovascular bundles, comprising of intercostal artery, vein, and nerve that course at the inferior border of each rib [7].

Chest force limits have been deducted to be around 1340 – 1780 N with static load on a thoracic surface of 180 cm<sup>2</sup>. Tests concluded that for a velocity of 27 km/h, a contact force of around 6000 N is produced that determines a chest deflection of 4.3 cm that can result in rib fractures [8][9].

### 2. OBJECTIVES

Objectives of the paper are focused on occupant injury probability based on simulation results from the road vehicle accident reconstruction software.

---

\* Corresponding author e-mail: [alexandru.radu@unitbv.ro](mailto:alexandru.radu@unitbv.ro)

By this medium, one objective was to simulate a side vehicle collision at different velocities and with an offset of the collision point in order to give the vehicle a post – impact spin effect. This is a more accurate and more deadly than a 90 degree collision due to the fact that the spinning effect will have a greater impact upon the occupants of the vehicle. In order to study of secondary collisions between the occupant and the vehicle interior, we set out as a second objective to model the vehicle interior. The final objective was to evaluate the potential injury level of the occupant for every velocity tested and investigate the contact points between different parts of the body with the vehicle interior.

### 3. METHODOLOGY

In order to obtain a valid result, simulations were conducted using the accident reconstruction software called PC-Crash, used worldwide by experts to reconstruct traffic accidents.

A simulation was created to replicate a side offset impact.

The position of the impact is offset by 1 meter from the center of gravity of both vehicles (CG) in order to give a spinning motion of the struck vehicle (Figure 1). This way, the centrifugal force will give the multibody model an angled direction of motion during the impact phase striking not only the left door and window area, but the dashboard area as well. Modeling the interior of the vehicle was achieved by the means of CAD software and blueprints of a vehicle type sedan as seen in the Figure 2.

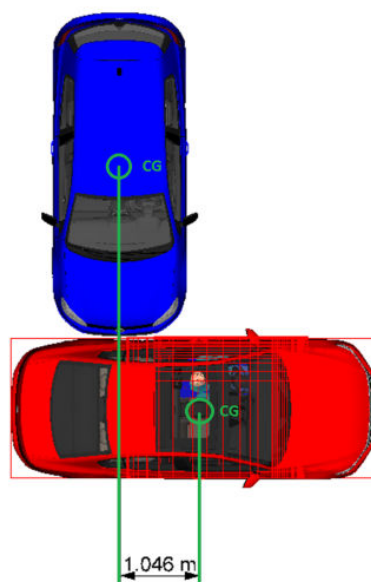


Figure 1. Simulation position of the vehicles with an offset from the CG of 1 m

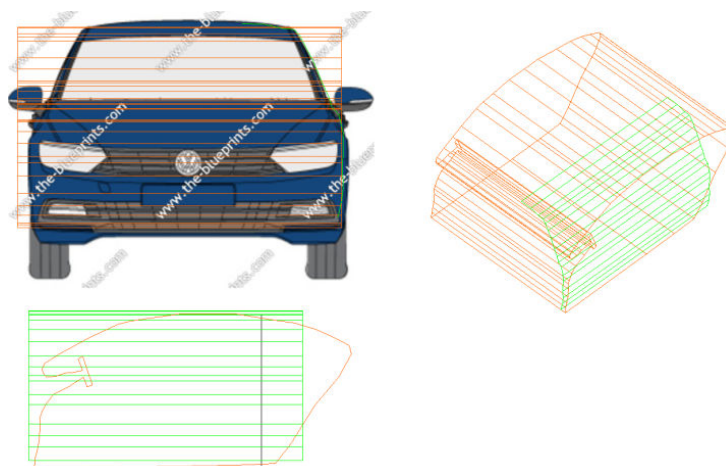
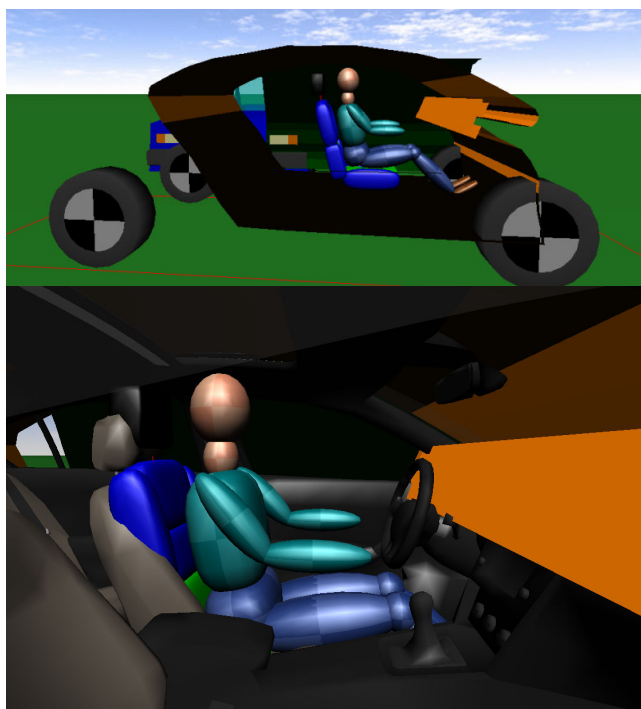


Figure 2. Vehicle interior DXF

The interior of the vehicle was drawn so that it is representative of the actual vehicle interior body, the cockpit of the vehicle and the left front door of the vehicle. This simple model will be used in the collision simulation as a 3D contact plane environment for the occupant during the collision with focus on contact points of the occupant body parts with the interior. After creating the interior, it was saved as a DXF file format and inserted in the PC-Crash as a vehicle drawing by positioning it inside the vehicle by setting an X, Y and Z coordinate system so that it matches the real vehicle.

Simulation of the multibody kinematic model was done by incorporating the occupant inside the vehicle and adding the possibility of contact detection between the model and the dxf interior. By doing this, during the simulation, contact forces will be calculated on impact of the multibody model with the dxf interior. For the case studied, the occupant was unbelted in order to study the maximum injury potential during the collision as well as analyzing the trajectory of each body part during the spinning motion of the vehicle. Position of the occupant inside the vehicle is presented in the Figure 3, as well as the dxf interior.



*Figure 3. Positioning the interior dxf along with the multibody occupant model*

Positioning the occupant was a crucial step in achieving valid results for the simulation. The occupant was set as the vehicle driver on the left side as in can be seen in the Figure 3. The important aspect of this was that during the simulation, parts of the occupant body move in accordance with a real human and hit the side window as well as the dashboard. After the positioning of the driver, simulations of the impact can be achieved at different velocities. We chose the following velocities, starting from 20 km/h, 40 km/h and up to 120 km/h. By this mean, we can successfully evaluate a wide range of traffic accidents, starting from slow collision and up to high velocity collisions.

#### 4. RESULTS

Results of the study focus on data provided by the simulation software for the multibody occupant and less on the data from the vehicles. We were interested on aspects regarding parameters that are linked to the multibody in order to evaluate the outcome of the accident and its consequences upon the occupant body. Also, as a secondary interest to the simulation was the kinematics of the occupant during the collision with emphasis on direction of movement for the body parts in the impact phase and the points of impact between them and the interior of the vehicle. A visual representation of this is presented in the Figure 4 where we can observe the contact points between the multibody model and the dxf interior of the vehicle.

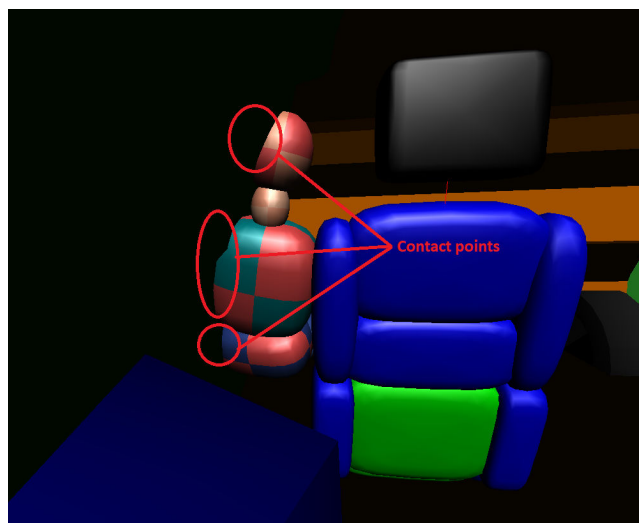


Figure 4. Points of contact between the occupant and the interior of the vehicle

This contact point analysis will be studied for each velocity the accident was simulated. Important areas that have a direct influence with the injury level of a occupant is the head as well as the torso. The contact point will provide a good representation of the occupant kinematic during the impact. The vehicle velocity variation is presented in the Figure 5 and it represents the variation of both vehicles, the striking vehicle and the hit vehicle. Both vehicles are clearly represented by the values of the velocity where for the striking vehicle, the velocity drops from the maximum value to the lower post-impact velocity and for the hit vehicle, the value rises from zero up to a maximum post-impact velocity. The maximum values of the velocity where the set tested values (from 20 km/h and up to 120 km/h) for the striking vehicle. It can be seen that the velocities equalize at the point of 0.05 second of impact. In order to better understand the outcome of the accident on the occupant, parameters for the multibody were extracted from the simulation software and presented in the next figures. The parameters of interest were focused on two areas where most injuries occur, the occupant head and torso area. The Figure 6 presents the variation of the head acceleration value for each collision velocity tested. Since in this type of accident, the occupant movement has a linear type of motion, translation on the Y-axis, the values of acceleration is presented for this axis only since on the X and Z axis were low and considered negligible.

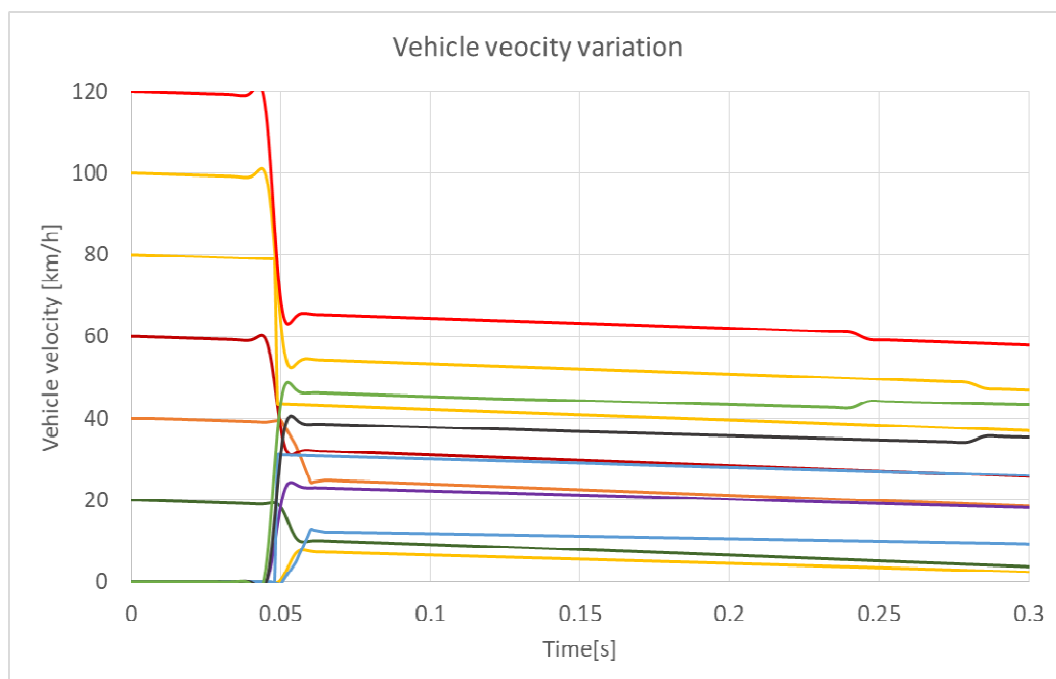


Figure 5. Velocity variation in time

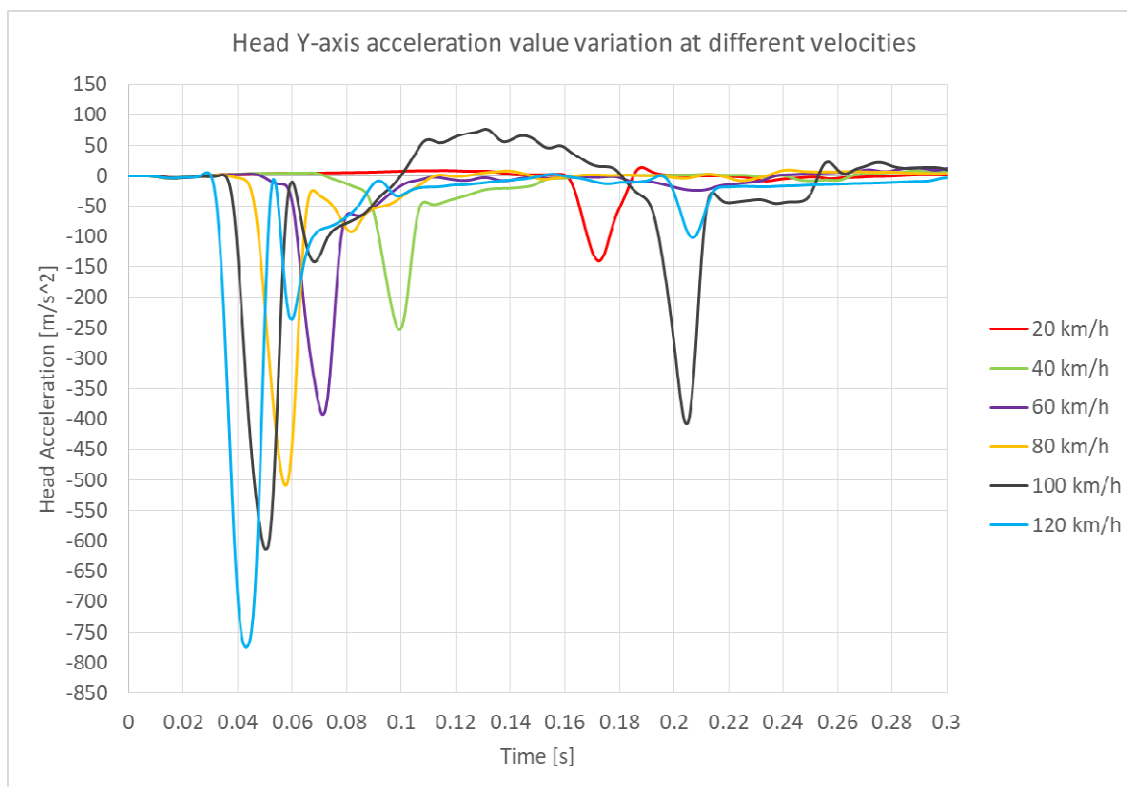


Figure 6. Head acceleration values on the Y-axis at different impact velocities

The graph show that the increase in acceleration is linear with each increase in vehicle collision velocity registering a maximum peak of 760 m/s<sup>2</sup> at the maximum tested velocity of 120 km/h. The maximum peak values were marked and presented in the table below.

Table 1.  
Maximum peak acceleration values

Tested velocity [km/h]	Maximum peak acceleration value [m/s <sup>2</sup> ]	Length of time of the peak acceleration [ms]
20	150	20
40	256	10
60	420	10
80	495	11
100	610	9
120	760	8

While the value of acceleration was high at peak level, the length of time when this values was registered was short (under 20 ms) that concludes from this point of view that the acceleration values, even though there are high, the time is short giving a low injury level resulting just from the acceleration value standpoint. Another parameter of interest is the acceleration level of the occupant torso presented in the Figure 7.

Similar to the previous parameter, only the Y-axis acceleration was taken into account. The results show that the values are higher that on the head level, reaching a peak of 1230 m/s<sup>2</sup> for the maximum tested velocity of 120 km/h. Even though in this case the values recorded were high, the length of time was short just like in the case of the head (under 10 ms). Also, for the lower velocities, under 60 km/h, the peak values were low (around 200 m/s<sup>2</sup>) for the torso area.

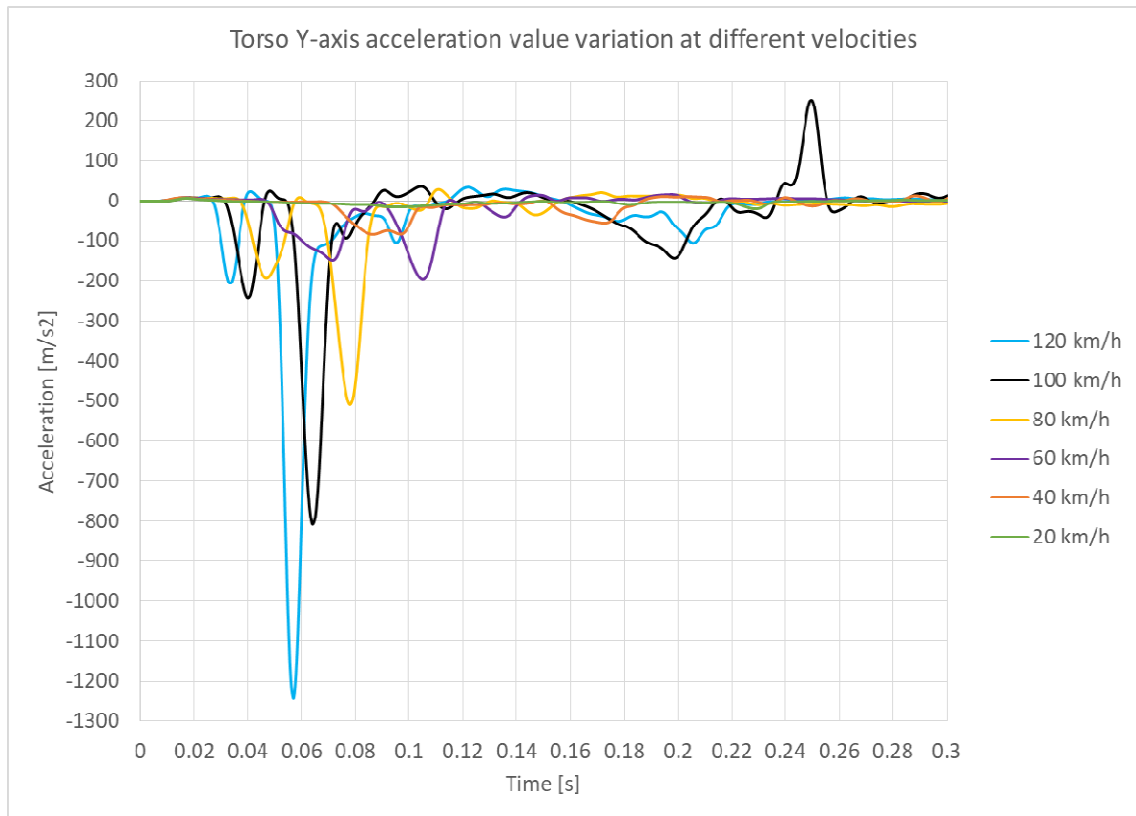


Figure 7. Torso acceleration values on the Y-axis at different impact velocities

A more important parameter of this study was the contact force values between the head and the interior of the vehicle. This is representative of any traumas that can occur by the impact between the head and the side window. This means that values of the force can indicate any potential skull fracture that can lead to internal head hemorrhage. The head contact force is presented in the Figure 8.

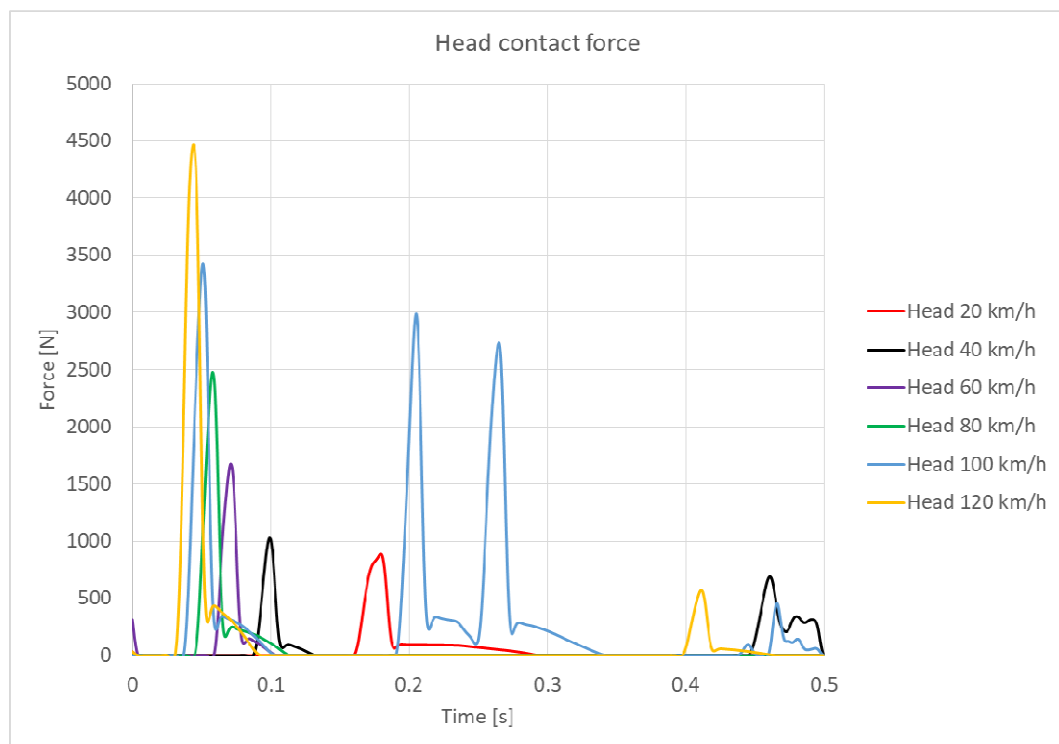


Figure 8. Head response to the contact with the interior of the vehicle

The results show that in this case the force value have a linear increase with each velocity tested. The maximum force value of 4490 N registered, was at the maximum tested velocity of 120 km/h. Studies showed that skull fractures appear at a much higher contact force of about 6270 N, in the case presented, the value is 28% lower than the fracture value, it can be said that low injuries can occur without head trauma. The last parameter to presented was the torso contact force with the vehicle interior that can give valuable information about any possible injuries that can occur in the torso area such as rib fracture, chest deflection and internal hemorrhage. The results are shown in the Figure 9.

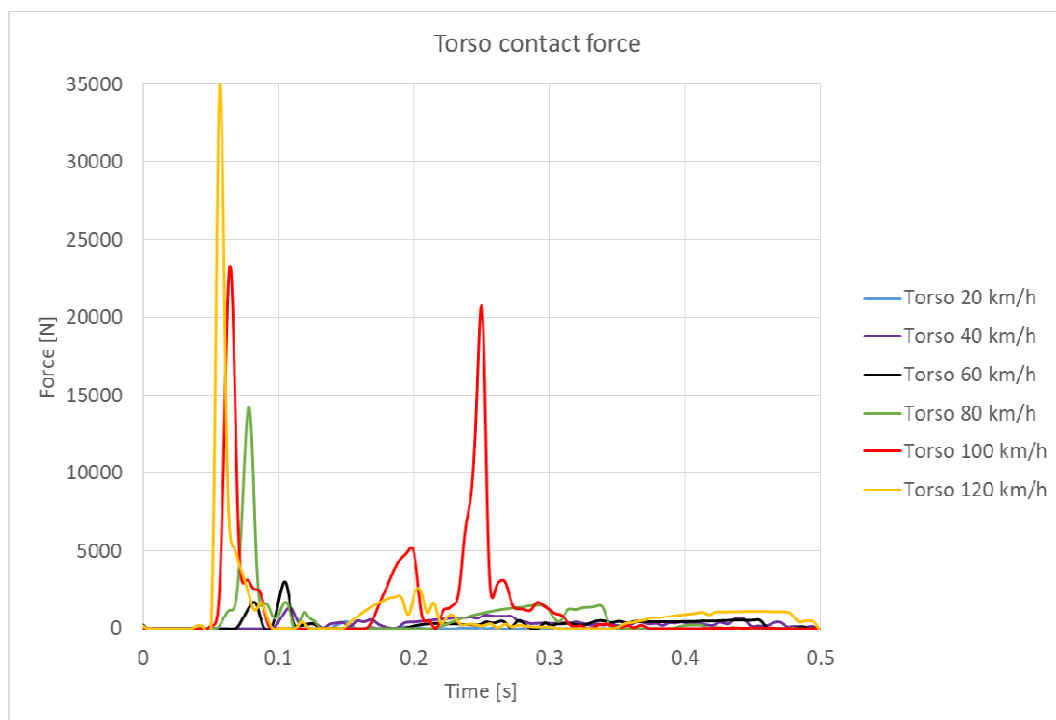


Figure 9. Torso response to the contact with the interior of the vehicle

From the results of the simulation we can observed that for the lower velocities (under 60 km/h), the values were low due to the fact that the head hit the side of the interior first and the force was transferred only to the head. At higher velocities, the torso hit the side of the interior first, and the head second.

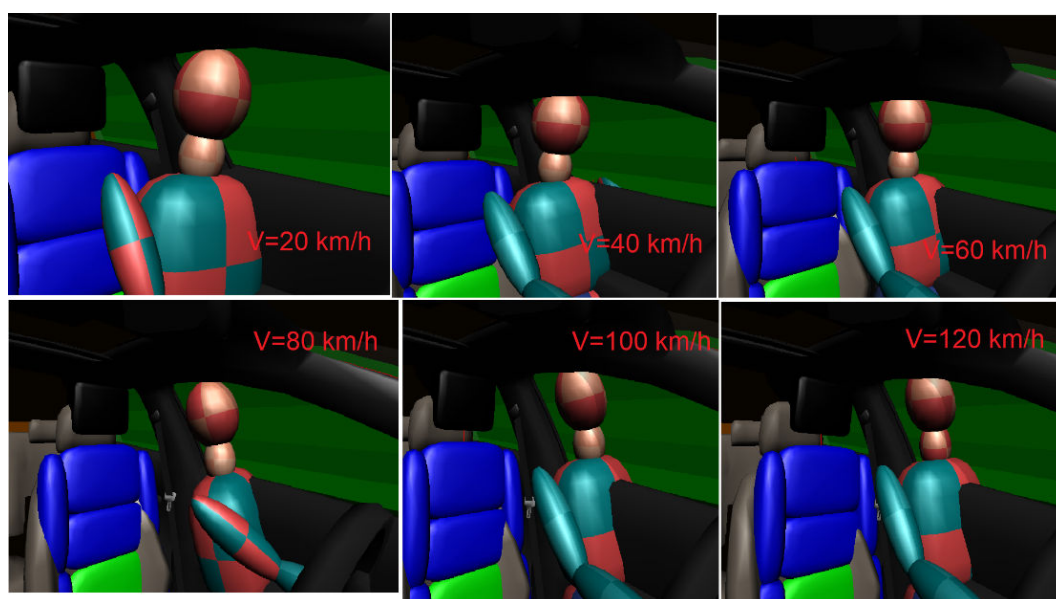


Figure 10. Occupant kinematic for each velocity tested

This means that the full force of the collision was transferred to the torso area that can suggest increased thoracic injuries such as multiple rib fracture and also internal hemorrhage generated from rib fractures and punctures of the internal organs.

Studies show that on a low speed collision of 27 km/h, the torso value was 6000 N generating minor rib fraction. In this case study, at low velocities, the force values were under 5000N, but at high velocities, force values were very high, with a maximum of 35 kN at the highest velocity of 120 km/h.

Occupant kinematics during the impact and post-impact phase were also visually analyzed and presented in the next figure. By the results shown above, we did expect to observe that at high velocities, the torso hits the side vehicle interior first.

The visual representation gives a good perspective on the kinematics of the occupant during the impact phase of the collision. At lower velocities (20 km/h, 40 km/h and 60 km/h) we can observe that the head hits the widows area first, followed by the upper limb and torso. At higher velocities (80 km/h, 100 km/h and 120 km/h) the upper limb and torso hit the side of the vehicle followed by the head. The fact that the torso hits the side of the vehicle first can mean that head fractures (that are most common in traffic accidents) can be reduced, but increases the chance of internal thoracic hemorrhage.

## 5. CONCLUSIONS

This study concludes that in the case of side vehicle collisions, the outcome can be sever for the driver occupant at high speed, when he is not wearing a seatbelt. The results show that at low impact velocities, under 60 km/h, possible injuries can occur on the head area given by the force contact values between the head and the side window of the front door of the vehicle.

In these cases, the torso registered low values due to the fact that the head hit the side first and not the torso. Possible injuries suggest minor head trauma and external hemorrhage.

At high impact velocities, over 60 km/h and up to 120 km/h, high force values were registered on the torso area given by the fact that the torso hits the side door of the vehicle first, followed by the head hitting the side window. In this case, the values suggest lethal injuries for the occupant in the chest area such as: multiple rib fractures, internal organ puncture and internal chest hemorrhage.

## REFERENCES

- [1] Oțăt O. V., *Modeling The Frontal Collision In Vehicles And Determining The Degree Of Injury On The Driver*, ACTA Universitatis Cibiniensis, 67(1), 2015, p.115-120
- [2] Tolea B., Trusca D., Antonya C., Beles H., *The influence of the frontal profile design of a vehicle upon the pedestrian safety at low velocity*, Annals of DAAAM & Proceedings, 26(1), 2015
- [3] Oțăt O. V., Dumitru N., Oțăt V., *Vehicles' Passive Safety Systems Influence on Driver's Thorax Injuries*, Applied Mechanics and Materials, Trans Tech Publications, vol. 823, 2016, p.187-192
- [4] Tolea B., Antonya C., Beles H., *Assessment of the injury severity of the pedestrian lower limbs at the collision with a vehicle*, Proceedings of the Annual Session of Scientific Papers "IMT-Oradea", 2015, p.189-192
- [5] Bedard M., Guyatt G. H., Stones M. J., Hirdes J. P., *The independent contribution of driver, crash, and vehicle characteristics to driver fatalities*, Accident Analysis & Prevention, 34(6), 2002, p.717-727
- [6] Kroman A., Kress T., Porta D., *Fracture propagation in the human cranium: a re-testing of popular theories*, Clinical Anatomy, 24(3), 2011, p.309-318
- [7] Edgecombe L., Angus L. D., *Thoracic Trauma*. StatPearls Publishing, 2018
- [8] Cordos N., Burnete N., Todorut A. *Coliziunea automobilelor*, Editura Todesco, Cluj-Napoca, 2003

## INTRODUCING MODULARITY STRATEGY IN NEW PRODUCTS DEVELOPMENT (CASE STUDY: IRANIAN AUTOMOBILE INDUSTRY)

Amir Hossain DOCTORAN<sup>1)\*</sup>, Manouchehr MANTEGHI<sup>2)</sup>,  
Changiz VALMOHAMMADI<sup>1)</sup>, Mahnaz RABIEI<sup>1)</sup>

<sup>1)</sup>South Tehran Branch, Islamic Azad University, District 3, Yakhchal St., TEHRAN, Iran

<sup>2)</sup>Malek Ashtar University of Technology, Lavizan, Babaei Hwy, TEHRAN, Iran

(Received 10 April 2020; Revised 04 May 2020; Accepted 28 May 2020)

**Abstract:** After the Industrial Revolution, principles were introduced that would enable better production management and product life cycle actions. For sample, the principle of standardization was primary cited in the specific literature in this field by Henry Ford. Standardization has created it conceivable to configure diverse products by means of a great set of common mechanisms. Additional strategy known as modularity was primary declared in the literatures in the 1980s. Modularity is suggested for product component groups for specific practical purposes of production. Currently, modularity and standardization are significant tools in new product development for the reason that they create possible to design a family of products by using component-like modules. The use of this offers significant savings in family planning and ease of construction. This article introduces the modular strategy in new product development by referring to its usage in the Iranian automotive manufacturing. The modular description and related ideas such as product architecture, modularization, and standardization are outlined and the implications and will be examined the benefits of the modular strategy from both technical and organizational perspectives in the Iranian automotive industry.

**Keywords:** New Product Development (NPD), Product Planning, Modularization, Modular, New Product Design and Development

### 1. INTRODUCTION

The modularity concept has developed a key concept product in the invention process. This methodology can have a fundamental effect on the process of new product progress and the whole innovative method, as well as relations with sellers and clients [1]. A clear description of modularity is as follows: A moderately great set of components of a produce that are actually interconnected by way of a peripheral device and create diverse models of the end product [2]. By means of a modularity concept, the business can expand a range of distinct goods [3]. By comparing the multi-product strategy based on family products that share a common modular, it has been proven to be an effective method for many productions. Specifically, the following benefits are highlighted in the NPD method: Improved speed, reduced cost, increased reliability and greater diversity in the product development process, as well as reduced management difficulty, and improved flexibility in corporate strategy [2]. The primary identified benefit is speeding up in NPD. Wheelwright and Clark defined the position of long-term NPD based on strong modularity documentation, which enables rapid product updates and upgrades [3].

In this approach, companies are able to successful in closing the technical gap against rivals or creating longstanding management. Through the 1990s, Block & Decker added a modularity concept to developing their original produce lines. Their success stood adding four new goods per month [2].

Additional large success stays reducing NPD costs.

In the automobile manufacturing, for example, the supposed "global automobiles" are introducing global business models by customizing the regional market, all of which share a particular product modular.

The situation is broadly recognized that this strategy necessarily means saving on product development and production costs [4]. As a result, durability developed unique of the key functions that determine the great achievement of this particular produce domestic in the marketplace.

---

\* Corresponding authors e-mail: [st\\_a\\_doctoran@azad.ac.ir](mailto:st_a_doctoran@azad.ac.ir), [manteghi@guest.ut.ac.ir](mailto:manteghi@guest.ut.ac.ir), [valmohammadi@yahoo.com](mailto:valmohammadi@yahoo.com),  
[dr\\_mahnaz\\_rabiei@azad.ac.ir](mailto:dr_mahnaz_rabiei@azad.ac.ir)

A further consequence of the implementation of the modular strategy is to increase the quality of the module's lifespan, and therefore, reliability will be one of the key functions that determine the countless achievement of this particular produce domestic in the marketplace [4]. A similar example from Sony illustrates how product increase diversity in the market while produce reducing line diversity simultaneously. In the individual stereo section, at 1989-1990, Sony offered twenty-four diverse lines in the United States and eighteen diverse lines in Japan, which performed better than any other competitor. The same models were derived from the individual produce domestic and shared the same know-how [4]. Modularity rise corporate flexibility by increasing and decreasing. In fact, the modular approach enables aggressive market strategies because of the reduced costs and time complicated in the progress of derivative new products. The instance of Compaq illustrates an interesting in which the corporation goes beyond penetrating an elementary modularity complete diverse marketplace sections. Specifically, the corporation has expanded its "base position" modular into customer sections and performance levels [2]. Modularity can be very difficult because the product must meet both the needs of the market and demonstrate differentiation, although at the similar period having to be industrialized and manufactured at small price. Modularity also influences the development process and has an important effect on the organizational structure of companies.

The modularity concept has already developed a competitive importance in the automotive business, and numerous companies implement and apply this concept with varying interpretations and degrees.

## 2. CONCEPTS

### 2.1. Architecture of product

The first approach enclosed in this article is the concept of architecture of product. Architecture of product was first presented by Utterback and Abernathy in 1975 [5], and then a large number of other researchers widely adopted it and developed it [3][6][7][17]. Product architecture, with Ulrich's view [8][10][11][16], was defined as "the design by which the product function is assigned to physical components" or "the design of functional elements; the mapping of functional elements to physical components; the characteristics of interfaces between physical components".

### 2.2. Modules

The module has been defined as a major collection of mechanisms that are actually intelligible with a subsystem. That most have standard of boundary designs. Modules can be shared across diverse products; nonetheless they can similarly be specific to each specific typical. Modularity suggestions numerous benefits [9]. They are including:

- The possibility of producing different types of products that need one a incomplete bounded on manufacturing processes;
- Narrow reproduction of parts;
- Increase efficiency for the reason that numerous pre-assembly processes are eradicated;
- More efficiency and quality of mechanization.

Modularity can likewise be a complementary stage for modular adjustment because from the customer's perspective, this stage can be distinguished to a high degree of productivity. In addition, modularity is also important for supplier relationships, helps to reduce costs and make the supplier responsible for the whole development. It is also significant throughout the assembly stage of the module [12].

However, the modularity strategy has some disadvantages. First of all, the problem is defining the modules and organizing the options so that it solves the problem of integrating components.

A small number of modules are "standalone". Most need exact design of interfaces.

As a result, architecture of automobiles is nevertheless much locked. The automobiles can have some extent of modular architecture (open) or complete architecture (closed). Presenting modular architecture into the automotive industry mean components necessity be designed for open modular architecture, which typically mean higher prices and weightier cars, which have undesirable factor [13].

The modular can as well as be viewed as of an organizational viewpoint. Fundamentally, the modular provides a cross functional team development tool in NPD. This team can be technical policymaking, or in a broader sense, also responsive to business concepts. Technical metrics are usually prioritized when end-products are split into enterprise modular; as regards marketplace sections and source capacity are also significant. There will likewise be numerous resemblances among diverse modular s.

As a result, the organizational and methodological features of the modular will overlap well.

The connection among modular organization and produce innovation is too crucial. Technological innovations typically come from progressive engineering centers, but modular team's duty incorporate persons innovations into expansion plans. On the other view, the modular team is naturally answerable for together the product approach and the general recital of the automobile [13].

### 3. RESEARCH DESIGN

This article is part of a study plan on the impact of architectures and modularity on the NPD process and purposes to describe a straightforward agenda for modular decision-making and evaluation finished an experimental research of how companies confront with issues.

The main research questions go beyond the following three main aspects: modularity as the physical structure of the product; modularity strategy; and modularity organization.

#### 3.1. Modularity as the physical structure of the product

Q1: Given the complexity of the modular product, how is it technically defined?

Q2: How does the modular relate to other produce scheduling models such as product architecture?

#### 3.2. Modularity strategy

Since modularity strategy involves some product standardization, how far tin can the business drive with a standardization methodology without product combination?

How does the modularity strategy efficacy the internationalization of research and development processes of automotive industry?

#### 3.3. Modularity Organization

What method of association is there among modularity development and product innovation? This Study will attempt to response these problems over and done with experiential indication. It is organized by way of follows: First, a description of the modularity is provided and the essential arrays that organization follows are identified. Next, it provides functional analysis for the modularity development then describes the main features and problems of the modularity strategy. Also, possible correlation analyzes between modularity development and product architecture is deliberated.

Finally, a summary explanation of the modularity organization and its linked features is provided.

### 4. MODULARITY IN THE AUTOMOTIVE INDUSTRY

In the circumstance of vehicles, the modularity base definition is technically included under the body and finely tuned (with axles, excel). Sub-body includes front, under-floor, engine compartment, and car skeleton (under-body reinforcement). When we start from this substantial pattern of understanding the modularity, three descriptions can stand said about Korea companies: accurate, extensive, and flexible.

#### 4.1. Modularity Definition in Corporation X

Modularity X is clear as per: Chassis & Body, with power Transmission System

#### 4.2. Modularity Definition in Corporation Y

Company Y Modularity is defined as per: Chassis & Body, power Transmission System, Fuel System.

The aforementioned should be eminent that the definitions of Company X and Company Y have a relatively conservative approach. That is, using the usual manufacturing of the automobile base without main variation in the Company structure.

#### 4.3. Modularity Definition in Corporation Z

At Modularity Z, the company defines the following: Chassis & Body, power Transmission System, Engine, Combustion Chamber, Fuel System, Steering system, and exhaust system with an "aggressive" methodology or an additional extended modularity strategy with substantial effect on NPD performance and Company organization Z.

What matters is that:

- 1) Are modularity even usable with the same custom templates, even with slight modifications?
- 2) Whether the modularity allows the production line to apply without most important correction.

By these limitations, the modularity can utilize a composition of components for instance undercarriage Chassis X, Body Y, and so on. Malleability must as well deal by interactions. The same modularity can be jointed with diverse Transmission System. Therefore, NPD should take into account the risk of weight gain on the chassis when combining big Transmission System.

## 5. EFFICIENCY ON THE MODULARITY

Modularity strategy was developed in the form of a request for simplification of NPD plan in the first of 1980s; it was the year that nearly all corporations confronted the must to accomplishment modularity strategy. Iranian Automotive industries are at this time at various phases of developing their modularity strategy. The core whys and wherefores for the development of the modularity are:

- Reduce costs;
- Product Development Productivity; and
- Reduce the processing time (the time between deciding to produce a particular commodity and starting production).

Each corporation has described cost decreases after adopting a modularity strategy, especially in the industrial situation. Specifically, subdivision among models will outcome in a 40% decrease in core investment, especially in welding tools. Due to product development productivity, modularity allows samples to be industrialized and investment reduced for monitoring and measurements of products. Major decreases in NPD processing time can be present attributed in particular to an additional developed methodology to defining modularity. Processing times for product development can be reduced by up to 5% [14].

Improvements in the delivery time marketplace are thinkable for the reason that the development of a rigid, modularity is, as of a scientific experience standpoint, separated from the development of the vehicle. Therefore, performance-based competition brings NPD into a different point, involving significant inside organizational ups and downs along with changes in relationships with the external global.

## 6. ARCHITECTURE OF PRODUCTION AND MODULARITY

As of a practical perspective, by significant implications for the NPD process and complete function, the relationship flanked by modularity strategy and product modulation and production architecture necessity is practical [15].

### 6.1. Modularity Development

Connection among Modularity development and modularity architecture is low, apparently for two key explanations: cost and malleability.

#### 6.1.1. Cost

Modularity development (with power Transmission System, and chassis) justifies 5% of the total cost of automotive development. Therefore, the side cost investments via modularity development are not many important and are not approximately equal through the cost of modularity development.

#### 6.1.2. Malleability

Modularity can present malleability whether complete cost-effectiveness is elicited and malleability need be preserved by model variations. Then again, modularity can be a helpful in simplifying manufacturing. Modularity methodologies is exactly diverse.

Some companies use small modules, while others anticipate a powerful endeavor in this path in the after time. The trend towards modularity is related to a more developed methodology to modularity development, one that reinforces the approach of modularity (Company Z).

Corporation Z has got project to implement modularity for car Steering system, and exhaust. But, modularity is not linked to supplier innovation. The goal is to enhance the quality and ability of sub assembling within the corporation. In other corporations, determinations are being made to simplify the vehicle and are strongly linked to modular strategy.

For the Steering system, to maintain product integrity, the procedure of shared pieces and, at the same time, diversity is perfectly balanced.

## 6.2. Modular Development and Architecture of Product

However, Cars have relatively shut architecture.

The approach of full-blown architecture has not yet been developed.

Features that hinder the development of extra full-blown architecture include product differentiation and effectiveness. Alternatively, dramatic variations are needed in the development procedure, especially in the product development stage.

## 7. MODULARITY STRATEGY

The modularity strategy relic an amount of issues, particularly the following:

- Relationship between modularity
- Relationship with suppliers
- Relationships with subsidiaries.

### 7.1. Modular number and their relationship

Main decision problems include: Modular Ratio, Increasing or decreasing modular, integrating existing modular and developing new modular. The initial query is how numerous models can obtained as of a modular? For most companies, for passenger cars, this ratio is usually 3. For commercial car and multipurpose car, the modular ratio is usually near to 1. The general tendency is to decrease the quantity of modular. Corporations with additional developed modular concepts typically reduce this number greatly. Due to the increase / decrease of the models, the tendency is especially upward for caravans. Corporate globalization also often encourages an increase in the amount of models. Due to fast variations in customer sensitivities, sales of various kinds of products are also more likely to develop lightweight vehicles than passenger car modular.

### 7.2. Modular Development and Supplier Variations

Modularity development does not significantly Variation supplier relationships. Nevertheless, two significant features that are the subsequences of modularity development have to be identified.

The initial is about reducing costs through modularity development, and the second is about reducing the processing time (the time between deciding to produce a particular product and starting production).

#### 7.2.1. Cost Reduction

Developing a modularity means looking at integrating products as well. They produce similar parts / components in higher volumes and, in turn, bring the benefits of economies of scale and thus cost savings. Finally, modularity development can affect suppliers in terms of 'supplier integration' or, in simple terms, a decrease in the amount of providers.

#### 7.2.2 Reduce processing period

Organizational variations presented by modularity development can have a significant effect on relations with dealers. In fact, if the product development model changes from one of "Build a Product and modify it later" to a "Predict and Build" model [10][11][15], then suppliers will have to this. Provide and assess the components themselves, which need be more and more standardized. The concept of combined component development can be modified and the fusion relationship can change and the relationship is less taken into account, a relationship where marketplace systems play a greater impress.

### 7.3 Link with sub companies

From the view of research, development and processes globalization, three key tendencies appear. These three tendencies respect choices on the amount and kind of modular to deploy in diverse areas; focus / decentralize modularity development versus typical development; localization and / or globalization of modularization. Regarding the amount and kind of modular to be developed in diverse parts of the global, there is a tendency for a reduction in the amount of modular around the world, and companies usually opt for the existing modularity integration policy. The whole broader policy is to integrate the internal and external developed modular. This combination is typically problematic for the reason that, uniform at the modular level, the vernacular wants setting by the development team is moderately robust.

This is the case of Corporation X.

The aim was to develop a Korean modular in shared with Iranian models, and then finally became autonomous. On the subject of the focus / decentralization of modularity development versus typical development, the key strategy pursued by Iranian corporations is to focus on modularity development and decentralization of the Chassis & body or typical development.

Besides there is a very general policy with regard to the modular localization and / or globalization: Regionalization of Modularity Development, that is, the development of modular s specific to the every region tow modular, since each area has a core marketplace section. This needs integrating the current modular and involvement the modular in among of Iran and other areas.

Some limitations may influence the introduction of modularity strategy. The first limitation relates to the lifecycle. In the meantime models resulting from the same modular are in the right place to diverse lifecycle, developing them as of a single, standalone modular can be problematic. Likewise, modularity development is lone possible when it is stable over additional than one typical set, thus the modularity lifecycle is a choice that needs to be carefully succeeded. In addition, corporations need to address the variances among deployed modular in dissimilar areas and replicate prototypes, which require a re-integration policy between internal and external deployed modular s. From this perspective, the inconsistency of model changes across regions does not support modularity strategy.

A country's laws will also undermine the development of the standard structure, which could be abandoned accordingly of the outline of novel laws and protocols. In the meantime modular are standard components of a produce, modular can be considered the outcome of together developed schemes. Combined development includes additional Iranian corporations and external corporations.

Up to now, the development of a common modular has been restricted and affected by the key strategy of needing a solitary modular in each area.

At Iran Khodro Company (IKCO), a modular is being shared with Peugeot.

## 8. MODULARITY ORGANIZATION

The term modularity organization affects the NPD process and the organization arrangement pursued. Depending on the development procedure, the key characteristic of the sub-body / upper body development is the separation. In fact, equal to 5% of the chassis can be developed self-sufficiently.

This enables dissociation of modularity development from typical development. By separating modularity development and typical development, model development can be reduced to 15 to 20 months.

Prior to the outline of the modularity strategy, in attendance was involuntary proof of identity of the modular and typical at the start of the development procedure.

Modularity strategy justifies more malleability and when there is a need to make a decision about developing a original model, there is additional autonomy to choose a modular. Alternatively, the modular strongly affect the user-proposed vehicle status. Therefore, modularity development should be near to general thought development. The next significant subject is the relationship between the current modular and the development of the different modular. Until now, the fundamental design has been to get modular from new produces and then to get models from that modular. This needs acceptance and makes it problematic to integrate the overall idea of the modular.

In effect, corporations with a broad description of modular require having a general idea of the modular in the overall process of corporate development. Referring to the structure of the organization in modularity development, the key subjects are the link among modularity development / typical development and issues among modularity development and product innovation.

Iranian corporations seem to have implemented very diverse methodologies that cannot be simply analyzed in relations of conventional organizational models. Despite corporations, whether those with a wide description of modular or those that did not, modularity development is same near to typical development. The Modularity team's "companionship" varies greatly from company to company.

We must bear in mind the detail that the actuality of integrated, integrated organizational arrangements, the credibility of which container be recognized, is a deterrent to the experience of new arrangements, for instance those on the modularity team. In all reason, innovations are generally obtained from radical engineering centers and developed singly from modularity development.

Therefore, in the broad definition of a modular, the modularity this one will be developed using progressive engineering funding, resulting in a greater integration of core components, which in the definition of the modularity itself is more valuable than the technological perspective.

## 9. CONCLUSIONS

Adopting a modularity strategy is motionless a continuing development. Each corporation views modularity strategy as a main subject in their yet to come national and international policy. In spite of this, there are significant variances among companies in defining what the modularity actually is, and subsequently there are variances among development procedures and organizational arrangements. The strong competitive potential of the modularity strategy has been identified in relations of enhanced performance. Overall, the main benefits of modularity development are able to understand in budget savings. Nevertheless, it is conceivable to see how a additional evolving concept, opening from the wider description of a modular, will define the profits of reductions in processing time for the last product development.

Modularity has a significant effect on the development procedure by means of the split-up among NPD and typical development creates a new approach of understanding NPD, which progressively more splits the technical element of the modularity from mode and aestheticism. As of this perspective, it turned out that the description of a modular must be narrowly related to the overall idea of the product.

The modification of the product arrangement, which was created as a outcome of the outline of the modularity strategy, seems to be rather partial, and the architecture of product and modularity must be better assessed on diverse strictures. At all change in architecture of product should be understood in conjunction with the development of models that provide standardization of the crossing point of the essential elements of the produce, though modulation of all the above-mentioned benefits makes clear in relations of simplifying manufacturing processes.

Finally, modularity strategy has a significant impact on global NPD and corporate processes management strategy. Decreases in the number of modular around the world and the progress of a modular specific to a region are valuable benchmarks attributed to product standardization. Developing collaborative vendors based on a developing collaborative modularity is also a good indicator of increased knowledge and skill exchange between companies.

The presentation of modularity strategy has importantly enhanced the possible for modification.

This article has search to illustrate the impact of adopting a modularity strategy that can have an impact on the NPD process. The outline of modularity strategy also has an impact on corporate performance.

As a result, the typical relationship between organizational options and the competitive advantages that are achievable needs to be further explored. In addition, it is necessary to look for factors that reduce the use of the modular overall thinking.

Finally, an evaluation ought to similarly be through among the Iranian methodology and the methodology of other countries in the automotive field, which are more organizational-based, nevertheless are perhaps less active and violent in relations of function, especially over time.

## REFERENCES

- [1] Clark K. B., Fujimoto T., *Product Development Performance*. Harvard Business School Press, Boston, 1991
- [2] Meyer M. H., Lehnerd A. P., *The power of product platforms: building value and cost leadership*. New York, 10020, 39, 1997
- [3] Wheelwright S. C., Clark K. B., *Revolutionizing product development: quantum leaps in speed, efficiency, and quality*. Simon and Schuster, 1992
- [4] Baldwin C. Y., Clark K. B., *Managing in an age of modularity. Managing in the modular age: Architectures, networks, and organizations*, 149, 2003, pp. 84-93
- [5] Utterback J. M., Abernathy W. J., *A dynamic model of process and product innovation*. 3(6), 1975, pp. 639-656
- [6] Uzumeri M., Sanderson S., *A framework for model and product family competition*. Research Policy, 24(4), 1995, pp. 583-607
- [7] Sanchez R., *Strategic flexibility in product competition*. Strategic management journal, 16(S1), 1995, pp. 135-159
- [8] Ulrich K. T., Eppinger S. D., *Methodologies for product design and development*. 1994
- [9] Wilhelm B., *Platform and modular concepts at Volkswagen - their effects on the assembly process*. Transforming automobile assembly, Springer, Berlin, Heidelberg, 1997, pp. 146-156

- [10] Ulrich K., *The role of product architecture in the manufacturing firm*. Research policy, 24(3), 1995, pp. 419-440
- [11] Ulrich K., Tung K., *Fundamentals of product modularity*. Proceedings of ASME Winter Annual Meeting Symposium on Issues in Design/Manufacturing Integration, Atlanta, 1991.
- [12] Kinutani H., *Modular assembly in mixed-model production at Mazda*. Transforming automobile assembly, Springer, Berlin, Heidelberg, 1997, pp. 94-108
- [13] Muffatto M., *Enhancing the product development process thorough a platform approach*. Proceedings of 14th International Conference on Production Research, Osaka, 1997
- [14] Ikeda M., *Product development by Japanese auto industry*. Proceedings of the International Conference on New Product Development and Production Networks. Learning from experience in Different Industries and Countries, Berlin, 1997, pp. 20-22
- [15] Ulrich K., *The role of product architecture in the manufacturing firm*. Research policy, 24(3), 1995, pp. 419-440
- [16] Nobeoka K., *Multi-project management: strategy and organization in automobile product development*, Doctoral dissertation, Massachusetts Institute of Technology, 1993
- [17] Robertson D., Ulrich K., *Planning for product platforms*. Sloan management review, 39(4), 1998

## MULTIBODY MODEL ADAPTATION FOR SIMULATING HELMET AIRBAGS IN VEHICLE-CYCLIST ACCIDENTS

Ovidiu Andrei CONDREA<sup>\*</sup>, Anghel CHIRU, Daniel Dragoş TRUŞCĂ

Transilvania University of Brasov, Automotive and Transport Engineering Department,  
Str. Politehnicii, Nr. 1, 500024 BRASOV, Romania

(Received 19 February 2020; Revised 29 March 2020; Accepted 06 May 2020)

**Abstract:** *In this study a multibody model of a helmet airbag was developed in PC Crash and used to simulate a vehicle-cyclist crash-test. The helmet airbag was generated in its deployed form as a multibody assembly comprised of four articulated bodies, which was further used to simulate the experimental test. The airbag model was attached to the cyclist multibody model through a fixed joint representing the zipper system through which the airbag is retained onto the neck. Regarding the peak head accelerations obtained, a 4% error was recorded between the crash-test and the simulation, which shows that the multibody model of the helmet airbag can be used for reconstructing head impacts with reasonable accuracy.*

**Key-Words:** *Cyclist impact. Helmet airbag. Helmet airbag simulation. Multibody simulation*

### 1. INTRODUCTION

Airbag systems have become the pinnacle of passive safety and not just for vehicle occupants. Recent designs such as the external airbags for vehicles, helmet airbags or vest airbags, have significantly increased the safety potential of vulnerable road users. Besides offering passive safety in road accidents, airbags are also currently used in protecting vulnerable body areas of old people in case a fall or other similar non-human natural movements occur [6].

Helmet airbags have been developed in order to improve cyclist safety during falls or collisions with vehicles. The development of these types of systems was done since there were indications that the traditional bicycle helmets are not sufficiently effective [3].

The form of the airbag is similar to a scarf and it is worn similarly around the neck.

The system is comprised of two airbag components, which upon inflation cover the neck and almost the entirety of the head except the face in order to allow vision.

Other system components are the trigger, the external waterproof collar and the rear casing which houses an electronic card, the inflator, a speaker and a USB user interface [7].

The trigger device must be manually activated before the ride and consists of a microsensor and electronics which have a role in preventing false positives and controlling the inflation conditions of the airbags [1]. The inflator comprises a hybrid gas generator, a deflator and a battery.

The detection system of the airbag consists of an algorithm based on artificial intelligence technology, which is continuously improved by providing it with both accident and non-accident data [4].

According to the producers, the airbag deployment time is less than 100 ms.

When triggered, the system initially deploys the neck airbag and subsequently the head one.

A Swedish company named Folksam conducted a series of drop tests (both vertical and oblique) using all types of cyclist helmets available, including helmet airbags. The results showed that helmet airbags performed nearly three times better regarding the peak head accelerations obtained in comparison with traditional helmets (48g vs. 175 g for a 5.42 m/s impact speed) [8].

Also, the use of helmet airbags generated a 60% reduction in rotational accelerations in comparison with other helmets, including MIPS helmets which are specifically designed to mitigate head injuries which result from rotational acceleration [8].

<sup>\*</sup> Corresponding author e-mail: ovidiu.condrea@unitbv.ro

A more recent study conducted a comparative analysis between traditional helmets and helmet airbags through vertical and oblique drop tests, which resulted in significantly reduced HIC values when helmet airbags were used in comparison with conventional helmets, to a maximum of 7-8 times if the airbag pressure is optimized [5].

Rotational accelerations were also diminished by a minimum of 66% in most cases compared to traditional helmets. These studies show that helmet airbags present a highly improved safety potential compared to conventional cyclist helmets. In addition to their superior safety performances, the improved aesthetics may propel helmet airbags to become the most used safety system for cyclist in the future.

Although the use of helmet airbags by cyclists is inherently positive and encouraged, the presence and influence of such systems during vehicle-cyclist collisions may pose a problem for accident reconstruction specialists and forensics, since there is no casuistry regarding such types of collisions. Another impediment is given by the fact that at the moment, all multibody software which are generically used in accident reconstruction lack modules and functions which could allow the implementation of external deployable airbags attached to the human multibody models (such as helmet airbags) or to the vehicles (such as external airbags).

In this paper a crash-test involving a cyclist equipped with a helmet airbag was simulated and validated in the PC Crash multibody software, by generating the airbag using the multibody module of the program. The method through which the airbag was generated in the program is shown in this paper, along with the adopted characteristics of the four bodies which compose the airbag.

## 2. EXPERIMENTAL TESTING

The experimental testing was carried out at the ICDT Institute in Brasov.

A vehicle-cyclist crash-test was performed for a longitudinal front-rear impact configuration.

An Opel Corsa vehicle, a regular bicycle and an anthropometric dummy equipped with an activated helmet airbag were used for the experiment.

A laser detection system coupled with an electromagnetic support mechanism (shown in Figure 1) were used for maintaining the dummy stationary until the moments prior to the impact.

The vehicle impact velocity was 10.33 m/s and the deceleration was  $6.7 \text{ m/s}^2$ .

A Fastec HiSpec 5 high speed camera was used to record the crash-test.



Figure 1. The crash-test scene and the system used for dummy alignment and positioning

## 3. CRASH-TEST SIMULATION AND VALIDATION. PROCEDURE FOR GENERATING AND SIMULATING HELMET AIRBAGS WITHIN MULTIBODY SOFTWARE

The carried-out crash-test was simulated in the PC Crash multibody software.

In order to achieve the validation of cyclist kinematics, a helmet airbag representation within the software was constructed.

Theoretically, modelling the deployment of an airbag system in PC Crash is not possible.

However, this limitation can be bypassed if the airbag representation is done in its deployed state. The helmet airbag was generated as a multibody object attached to the cyclist's neck, comprising four component bodies connected through fixed joints, as presented in Figure 2.

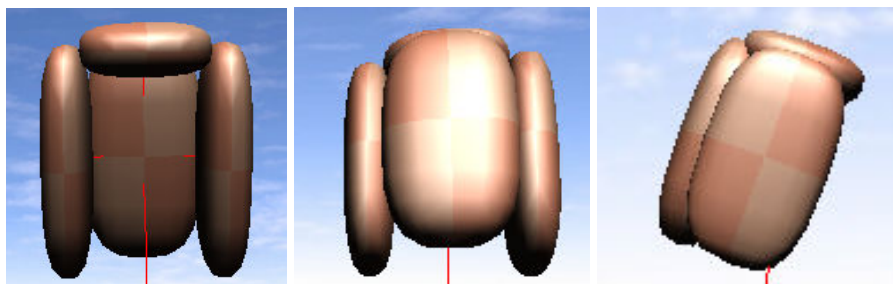


Figure 2. The multibody model of the helmet airbag developed in PC Crash

The stated work hypothesis is relevant since the multibody model of the helmet airbag can be optimized such that it yields the protective effect observed during the head impact in the crash-test.

The total weight of the airbag is 0.68 kg and the dimensions of the airbag in its deployed form were introduced to shape the airbag model.

However, another work hypothesis consists in assuming the head impact takes place when the airbag is optimally deployed, since it is possible for late airbag deployment to occur [2].

At high impact velocities, there is also a risk that the airbag flattens out, with further research being required in order to clarify this aspect [5].

The helmet airbag was attached to the cyclist dummy through a fixed joint which connects the neck of the dummy with the rear part of the airbag, as presented in Figure 3.

The posture of the cyclist was adjusted in conformance with the crash-test, while the vehicle velocity and deceleration were introduced as entry parameters for the simulation.

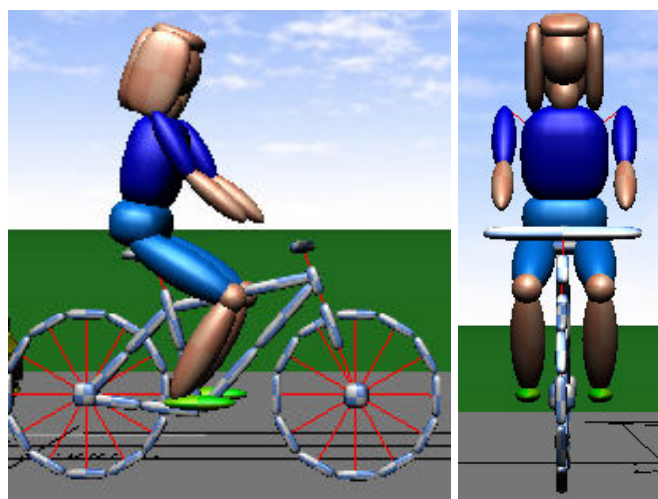


Figure 3. The helmet airbag developed in PC Crash, attached to the cyclist

The validation of the simulation was done by achieving similar cyclist kinematics with the crash-test, after a significant amount of iterations. Furthermore, the defining parameters of the airbag were also manually iterated until similar head acceleration peaks were obtained.

Head resultant acceleration diagram for the crash-test and simulation is shown in Figure 4.

The peak head acceleration obtained during the crash-test was  $852.51 \text{ m/s}^2$ , while the peak head acceleration obtained during the simulation was  $815.86 \text{ m/s}^2$ , resulting in a relative error of 4%.

Further optimizations of the airbag model are possible, in this case resulting in more reduced errors (up to 2%), but with kinematic alterations of the vehicle-cyclist head impact in comparison to the staged test.

The kinematic sequences of the crash-test and simulation show a good congruence, as shown in Figure 5. The cyclist kinematic behaviour is similar for both instances and there is also good correlation between the moments at which each kinematic phase takes place.

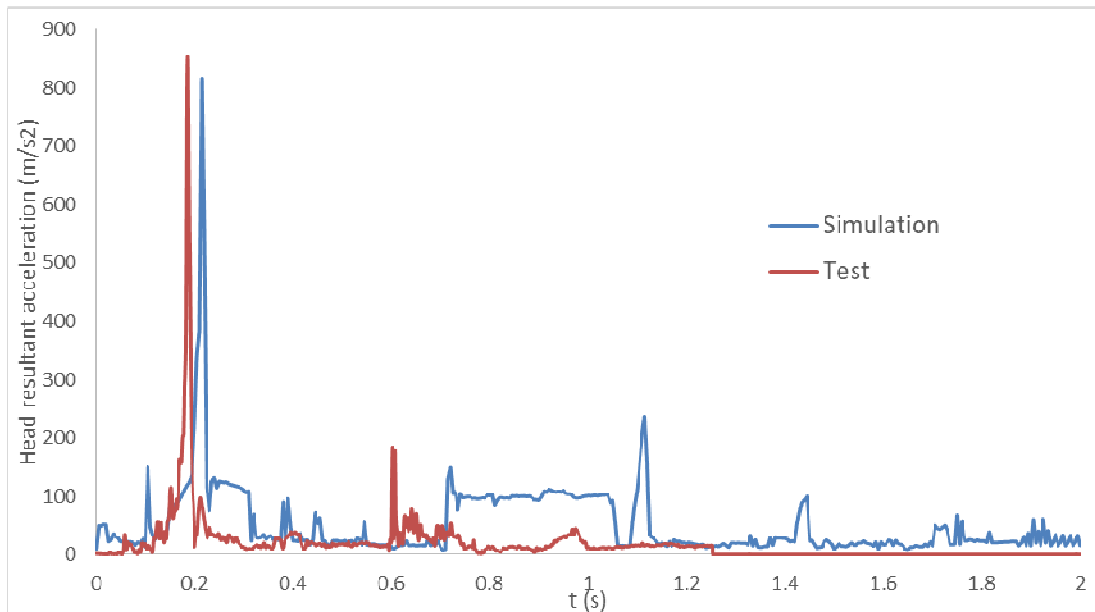


Figure 4. Head resultant acceleration diagram for the crash-test and simulation


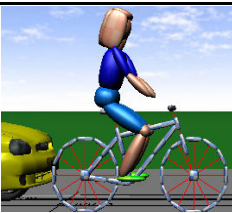

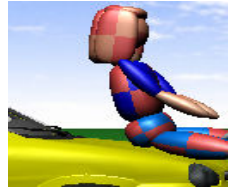




<b><i>Phases of impact</i></b>	<b>Test 1</b>	<b>Test 2</b>
<i>Vehicle-bicycle impact</i>		
<i>Vehicle - dummy pelvis impact</i>		
<i>Vehicle - dummy head impact</i>		
<i>Launch-off moment</i>		

Figure 5. The kinematic phases of the carried-out crash-test and simulation

The defining parameters of the helmet airbag's component bodies are presented in Table 1, as they resulted from the validated simulation.

**Table 1.**  
*The defining parameters of the helmet airbag developed in PC Crash*

Body	Mass (kg)	Dimensions (m)	Stiffness (N/m)	Hysterezis	Friction coefficient	
					Ground	Vehicle
1	0.17	0.06 x 0.10 x 0.18	49050	0.2	0.7	0.3
2	0.17	0.11 x 0.04 x 0.18	20000	0.1	0.7	0.3
3	0.17	0.11 x 0.04 x 0.18	20000	0.1	0.7	0.3
4	0.17	0.11 x 0.10 x 0.04	49050	0.1	0.7	0.3

#### 4. CONCLUSION

- A helmet airbag model was developed in PC Crash in deployed form by generating a four body assembly connected through fixed joints, which was further attached to the neck of the cyclist multibody model.
- The use of the airbag model in reconstructing a vehicle-cyclist front-rear crash-test generated a good congruence between the kinematic behavior of the cyclist during the crash-test and simulation.
- The peak head accelerations obtained showed a good correlation (4% error), therefore making the model optimal for simulating cyclist impacts which involve helmet airbags. Further optimizations of the model are possible, in this case leading to a 2% error but with a lower degree of similarity of cyclist kinematics.
- The work hypothesis of the model also serves as a limitation, specifically the airbag was generated in its deployed form, assuming airbag deployment occurs optimally and the head impact occurs when the airbag is inflated.

#### REFERENCES

- [1] Alstin, Terese and Haupt, Anna, System and method for protecting a bodypart. Hovding Sverige AB. U.S. Patent 8,402,568, 2013
- [2] Condrea, Ovidiu Andrei; Chiru, Anghel; Togănel, George Radu; Truşcă, Daniel Dragoş, The Influence of Vehicle Low Impact Velocity over the Helmet Airbag Deployment and Cyclist Injuries. SIAR International Congress of Automotive and Transport Engineering: Science and Management of Automotive and Transportation Engineering, pp. 273-pp. 280, 2019.
- [3] Curnow, William, The efficacy of bicycle helmets against brain injury. Accident Analysis & Prevention, vol. 35(2), pp. 287-pp. 292, 2003.
- [4] Hovding Airbag for Cyclists. Hovding. 2020. Available: <http://www.hovding.com/>
- [5] Kurt, Mehmet; Laksari, Kaveh; Kuo, Calvin; Grant, A. Gerald and Camarillo, B. David, Modeling and Optimization of Airbag Helmets for Preventing Head Injuries in Bicycling. Annals of biomedical engineering, vol. 45(4), pp.1148–pp.1160, 2017.
- [6] McDowell, Patrick; Dennis Dale, Protective Inflatable Garment System for People with Unstable Balance. Journal of Emerging Trends in Computing and Information Sciences vol. 6(1), pp. 15-pp. 19, 2015.
- [7] Olsson, Dick and Sellergren, Ulf, Airbag suitable for head protection. Hovding Sverige AB. U.S. Patent Application 13/823,986, 2013

[8] Stigson, Helena; Rizzi, Matteo; Ydenius, Anders; Engströem, Emma and Kullgren Anders, Consumer Testing of Bicycle Helmets, IRCOBI (International Research Council On the Biomechanics of Impact) Conference,, pp.173-pp.181, 2017.

## STUDY ON THE RECYCLING METHODS OF USED ENGINE OIL

Sorin Aurel RAȚIU <sup>1)\*</sup>, Nicolae Liviu MIHON <sup>2)</sup>, Miruna Diana ARMIONI <sup>3)</sup>

<sup>1),3)</sup>Politehnica University of Timișoara, Faculty of Engineering Hunedoara,  
Department of Engineering and Management, Str. Revoluției, Nr. 5, 331128 HUNEDOARA, Romania

<sup>2)</sup>Politehnica University of Timișoara, Mechanical Faculty, Department of Mechanical Machinery,  
Equipment and Transport, Bdul Mihai Viteazu, Nr. 1, 300222 TIMIȘOARA, Romania

(Received 29 October 2019; Revised 17 December 2019; Accepted 07 January 2020)

**Abstract:** *Used oils are part of the hazardous waste category, which requires special management strategies, due to the pollutant content and the high degree of environmental impurity. They are also a by-product of significant economic value, their recycling facilitating the replacement of products extracted from fossil fuels with ecological variants of lubricants. Therefore, many recycling technologies have been created for this type of waste. The purpose of this paper is to present the different recycling methods currently used globally, to provide a study on the techniques applied, the substances used and the benefits of recycling waste engine oils.*

**Key-Words:** *used oil, hazardous waste, pollution, recycling, sustainability, internal combustion engine*

### 1. INTRODUCTION

In the contemporary period, we find that the notion of "pollution" has become familiar to anyone. Almost any human activity, whether domestic or industrial, involves the impurity of the environment with harmful substances, called pollutants [16].

These affect not only the sphere of human activity, but also the biotic and abiotic factors essential to life. Given that the increase in demand for products and services causes an increase in the level of environmental pollution, the evolution of the socio-climatic situation at global level determines the need to find fast and efficient solutions for environmental problems.

Two of these problems are inadequate waste management and the intensive exploitation of fossil fuels. At their center are the waste oils, which by the high content of pollutants are classified in the category of hazardous waste, requiring constant monitoring and special management.

The modern society is based on the use of the car, which cannot operate without lubricants.

With the increase of population and the number of vehicles, the quantity of waste oils has increased.

The term "waste oil" characterizes any lubricating oil, mineral or synthetic, that has become unusable for the purpose for which it was originally intended [1].

Degradation of lubricating oil occurs when different additives or foreign substances (metallic powders, sulphur, water, carbon, ash, etc.) pollute the oil, modifying its chemical composition and affecting its properties [7].

As it is insoluble, persistent and has a high content of heavy metals and other pollutants, it is necessary to collect and recycle waste oil, in order to avoid contamination of the environment [5].

Also, its use contributes to the conservation of natural resources and to the reduction of pollution from the exploitation of fossil fuels.

In this sense, in the last decades a series of recycling techniques have been developed, which aim to solve the ecological, technical and economic problems associated with waste oils.

---

\* Corresponding authors e-mail: [sorin.ratiu@fih.upt.ro](mailto:sorin.ratiu@fih.upt.ro), [livi.mihon@upt.ro](mailto:livi.mihon@upt.ro), [miruna.armioni.97@gmail.com](mailto:miruna.armioni.97@gmail.com)

## 2. RECYCLING TECHNOLOGIES

The possibilities of recycling used engine oil depend on the nature of the base oil (mineral or synthetic) as well as the nature and quantity of the contaminating substances.

Figure 1 shows the general chemical composition of the used engine oils.

Percentage variations are possible, depending on the type of oil and the pollutants that may appear. Due to the varied range of engine oils, several recycling methods have been developed.

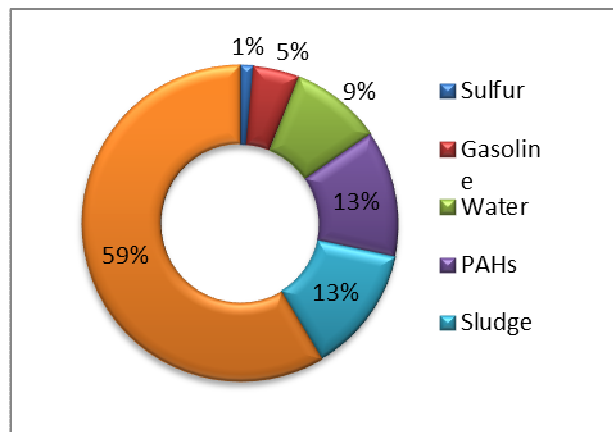


Figure 1. Chemical composition of used engine oil [18]

### 2.1. Treatment with acid/clay

The process is based on treating the waste oil with different acids (sulfuric, acetic, formic) to remove pollutants and then using binders (clay or bentonite) to neutralize the resulting product [17].

Activated carbon can also be used for neutralization [2].

Figure 2 shows the diagram of the acid/clay treatment process.

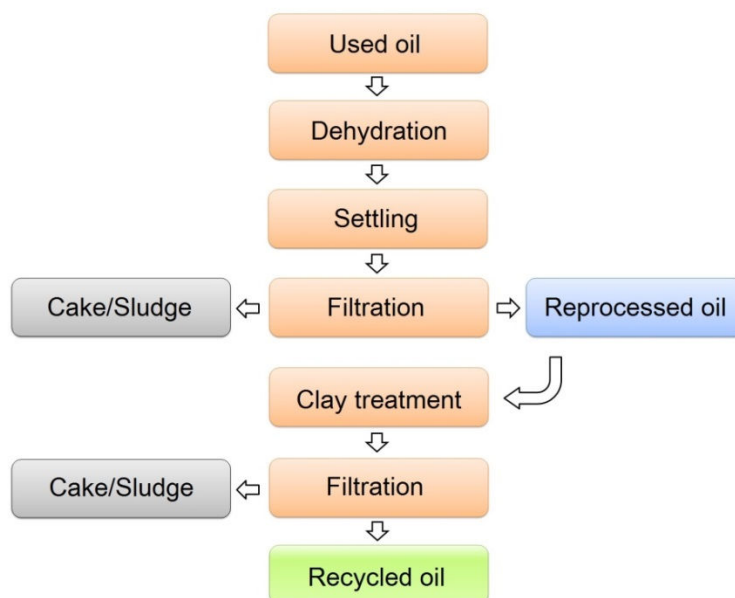


Figure 2. Block diagram of the acid/clay recycling method [7]

The stages of the acid / clay treatment process are:

1. Acid treatment: the waste oil is heated to 40-45°C, then the acid is introduced, while a continuous mixing is carried out for 10 minutes;

2. Sedimentation: after acid treatment, the oil container is left for 24 hours to form a sediment layer at the bottom of the container. After this period, the oil is filtered through a piece of textile material and transferred to another container, and the sludge residue is stored for disposal;
3. Bleaching: the oil is heated to 110°C, then the clay is introduced and the resulting solution is mixed for 15 minutes;
4. Neutralization: at the end of the bleaching stage, sodium hydroxide is introduced and mixed for 10 minutes, in order to improve the pH of the oil, bringing it to neutrality;
5. Filtration: At the end of this stage, the oil is left to settle for 24 hours, then it is filtered through a piece of textile material, and the residue is stored for disposal [9].

## 2.2. Vacuum distillation and dehydration process

Vacuum distillation and hydrogenation is another method of recycling used engine oil.

The first stage of the process is atmospheric dehydration, the purpose of which is to remove light hydrocarbons and water. Subsequently, vacuum distillation is applied at a temperature of 250°C.

The last step is the hydrogenation of the distilled product, to remove the toxic compounds of nitrogen and sulphur, as well as other oxides present in the chemical composition of the waste oil.

Also during this stage the odors from the oxidation of some chemical elements are eliminated and the color of the final product is improved [7].

Figure 3 gives an overview of the technologies based on vacuum distillation and hydrogenation.

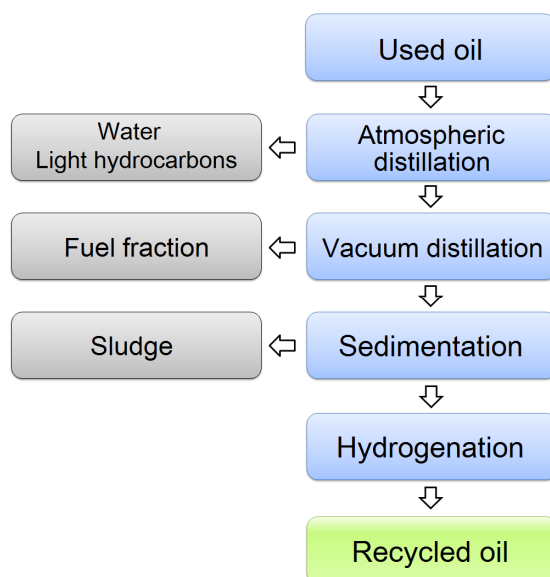


Figure 3. Block diagram of the vacuum distillation and hydrogenation process [17]

## 2.3. Vacuum distillation and clay treatment process

Similar to the process presented at point 2.2, vacuum distillation technology is in this case accompanied by clay treatment.

The basic stages of the process are the following:

1. Distillation: separation of water and light compounds;
2. Vacuum distillation (TDA column - Thermal deasphalting) and fractionation: in this stage the organo-metallic compounds and the asphalt minerals are separated and three quantities of waste oil are fractionated;
3. TCT (heat treatment with clay): the stage in which the characteristics of the three fractions of used oil separated in the previous phase are improved;
4. Pressure filtration [17]

Figure 4 shows a schematic representation of the process of vacuum distillation and clay treatment.

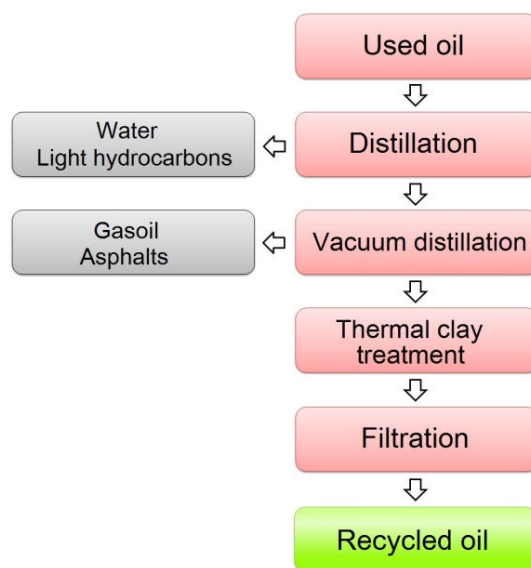


Figure 4. Block diagram of the vacuum distillation and clay treatment process [17]

## 2.4. Solvent extraction technology

Essentially, the method consists in dissolving the aromatic components that affect the properties of the oils, while preserving the desired components, such as saturated hydrocarbons [15].

Before treatment, the waste oil is filtered to remove solids.

Then, the oil is treated with solvent, mixing a preset amount of oil and solvent for one hour, then letting the solution settle for 24 hours.

The oil is separated from sludge, then transferred to a evaporator to facilitate the separation of the solvents from the recycled oil.

Subsequently, the oil is mixed with active alumina to remove the dark color and specific odors [14].

Solvents that can be used to treat waste oils include 1-butanol, methanol, ethanol, propane, toluene, methyl ethyl ketone, acetone, etc. [6].

Figure 5 shows the simplified scheme of the solvent extraction process.

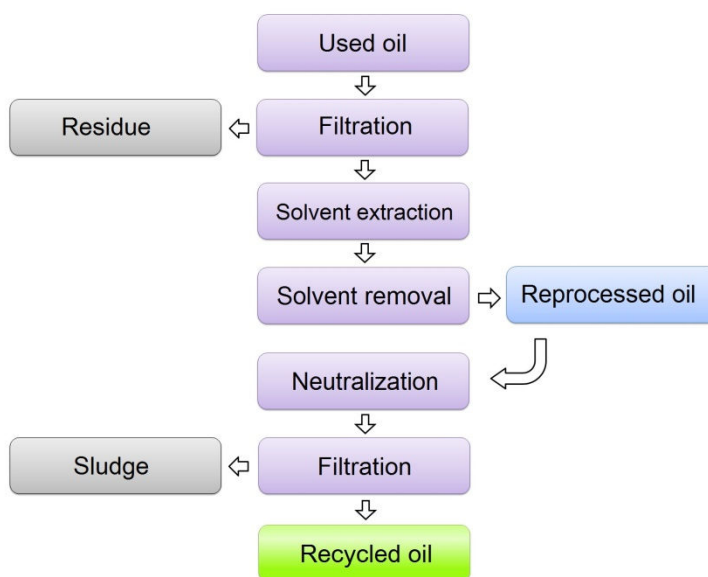


Figure 5. Block diagram of the solvent extraction method [13]

## 2.5. Membrane technology

Another method used for recycling used engine oils is membrane filtration technology. The membranes are made of polymeric fibers, such as: polyethersulfone (PES), polyvinylidene fluoride (PVDF) and polyacrylonitrile (PAN). This process is carried out at 0.1 MPa pressure and 40°C [12] and is a continuous operation that removes metal particles, soot and dust from used engine oil and also leads to the recovery of lubrication properties of the treated oil. Despite the benefits presented by this process, the membranes are expensive and can be damaged and soiled by large particles [10].

## 2.6. Pyrolysis using microwave heating

Pyrolysis using microwave heating is a relatively recent process, in which spent hydrocarbons are mixed with a strong microwave absorbing material, such as carbon particles; as a result of microwave heating, they are then thermally cracked in the absence of oxygen in shorter chains of hydrocarbons. The resulting gaseous products are subsequently re-condensed into liquid oils of different compositions, depending on the characteristics of the substances introduced and the reaction conditions [11]. This process is constantly being optimized and there is not enough data yet to determine its efficiency in recycling used engine oil, but many researches are ongoing in this direction.

## 2.7. Bentonite treatment

Bentonite powder plays an important role in the regeneration and clearing of waste. Following the experiments carried out in this field, it has been shown that bentonite has a high adsorption capacity of heavy metals due to its specific surface, small particle size, high porosity and high cation exchange capacity. For the treatment of used engine oil with bentonite, different amounts of bentonite powder added in a given volume of used oil are used. The oil samples are homogenized according to certain conditions, determined experimentally (for example, 2 weeks, 8 hours a day at room temperature and 300 rpm) [4]. The use of bentonite as a material for regenerating used engine oils is proving to be an effective solution in reducing the metal content and improving the combustion process [8].

## 3. CONCLUSIONS

The need for proper management of used engine oils has led to the development of different methods of treating this waste for recycling. In the context of the global trend towards sustainability, the most environmentally friendly technologies are preferred, with minimal impact on the ecosystem. Treatment with acetic acid, vacuum distillation, solvent extraction and membrane filtration technology are among the most widespread such processes, the waste generated after the treatment of used engine oil being subsequently eliminated by energy recovery or incineration. In the future, it is planned to make these more efficient and to increase the amount of recycled oil worldwide, in order to optimize the production-consumption-waste ratio.

## REFERENCES

- [1] Abdalla N., Fehrenbach H., *Ecological and energetic assessment of re-refining waste oils to base oils*, Heidelberg, June 2017
- [2] Ahamad M. T., Chadra Sekhar B. P., Mohan P. N., Joshi K. S., Sree T. D. R., *Recycling and Analysis of Spent Engine Oil*, International Journal of Scientific & Engineering Research, Volume 6, Issue 11, 2015, pag. 711-715
- [3] Akilimali F. C., *Feasibility study of recycling used lubricating oil*, The University of Dodoma, 2017
- [4] Akpomie K. G., Dawodu F. A., *Potential of a low-cost bentonite for heavy metal abstraction from binary component system*, Beni-Suef University Journal of Basic and Applied Sciences, Volume 4, Issue 1, 2015, pag. 1-13
- [5] Andrews L., *Compendium of Recycling and Destruction Technologies for Waste Oils*, United Nations Environment Programme, 2008

- [6] Boadu K. O., Joel O. F., Essumang D. K., Evbuomwan B. O., *A Review of Methods for Removal of Contaminants in Used Lubricating Oil*, Chemical Science International Journal, 26(4), 2019, pag. 1-11
- [7] Diphare M. J., Muzenda E., Pilusa J., Mollagee M., *A Comparison of Waste Lubricating Oil Treatment Techniques*, 2nd International Conference on Environment, Agriculture and Food Sciences (ICEAFS'2013), August 25-26, Kuala Lumpur, Malaysia, 2013, pag. 106-109
- [8] Dragne M., Pop E., Covaliu C. I., Matei E., Pişa I., *Experiments in use of bentonite for energy recovery of used oils*, E3S Web of Conferences 112, 2019, pag. 1-6
- [9] Hegazi S. E. F., Mohamd Y. A., Hassan M. I., *Recycling of Waste Engine Oils Using Different Acids as Washing Agents*, International Journal of Oil, Gas and Coal Engineering. Vol. 5, No. 5, 2017, pag. 69-74
- [10] Henry M., *Re-refining and recycling of used lubricating oil and natural resource conservation in Ghana*, ARPN Journal of Engineering and Applied Sciences, vol. 10, 2015, pag. 797-801
- [11] Lam S. S., Russell A. D., Chase H. A., *Pyrolysis Using Microwave Heating: A Sustainable Process for Recycling Used Car Engine Oil*, Ind. Eng. Chem. Res., 2010, pag. 10845-10851
- [12] Martins J., *The extraction of used lubricating oil using ternary organic solvents*, 1997
- [13] Ogbeide S. O., *An Investigation To The Recycling Of Spent Engine Oil*, Journal of Engineering Science and Technology Review 3 (1), 2010, pag. 32-35
- [14] Osman D. I., Attia S. I., Taman A. R., *Recycling of used engine oil by different solvent*, Egyptian Journal of Petroleum 27, 2018, pag. 221-225
- [15] Rincon J., Canizares P., *Waste oil recycling using mixtures of polar solvents*, Ind.. Eng. Chem. Res., 2005, pag. 7854-7859
- [16] Siddiqui T. F., *Environmental pollution in petroleum refineries*, Bahria University Karachi, 2015
- [17] \*\*\* - *Possibilities for the recycling and reuse of used oils*, Regional Activity Centre for Cleaner Production (RAC/CP) Mediterranean Action Plan, 2000
- [18] \*\*\* - *PurePath Green Technology*, <https://www.purepathtech.com/literatures/recycling-of-used-motor-oil/>

## EXPERIMENTAL STUDY ON THE FUNCTIONING OF THE TRACTION BATTERIES FOR HYBRID VEHICLES

Ioan Radu ȘUGAR<sup>1)</sup>, Olivian CHIVER<sup>2)\*</sup>

1) Technical University of Cluj-Napoca, Faculty of Engineering, Department of Engineering and Technology Management, Str. Victor Babes 62A, 430083 BAI A MARE, Romania

2) Universitatea Tehnică din Cluj-Napoca, Faculty of Engineering, Department of Electrical, Electronic and Computer Engineering, Str. Victor Babes 62A, 430083 BAI A MARE, Romania

(Received 10 March 2020; Revised 18 April 2020; Accepted 05 May 2020)

**Abstract:** On an increasingly polluted planet, with declining oil resources and, implicitly, higher fuel prices, electric and hybrid cars can provide a viable solution. This paper presents a series of results obtained in testing the traction batteries used by these vehicles, using an original experimental support.

**Key-Words:** Batteries, Charge, Discharge.

### 1. INTRODUCTION

If in the last century the vehicles with internal combustion engine were imposed due to the production system introduced by Henry Ford. In today's tendency to run out of fossil fuel and the increased pollution, electric vehicles are regarded as a sustainable replacement [1][2][4][6][7].

In their construction, the following are the safety, reliability, durability, nominal power and cost of the different loading methods. Of course, an Evs loading systems plays an important role [13].

An ordinary charging station comprises the power outlet, the charging cable, the charging bracket, the mounting jack, and the vehicle connector and protection system. When designing a charging station someone must take into account the following aspects: the voltage, the frequency and the connection to the network. The result, nevertheless, may differ from country to country [4][13].

The proper charge time and battery life depend on the charger's characteristics. A good charger must be efficient and reliable, with high power density, low cost and low mass and volume.

The charging time, cost, equipment and network effect depend on the power level of the charger.

An important issue in the operation of electric vehicles is the recycling of batteries. If we consider some materials obtained by recycling, the benefits are not substantial. For example, the value of the glass obtained by recycling depends on the transport distance [10].

Recycling the car batteries, on the other hand is beneficial for the environment. By recycling it eliminates the pollution that comes from the ores and their processing. If pollution is taken into account due to recycling, it is smaller than the one resulting from the primary production.

Exception is lithium recovery. On the other hand, the recycling of materials avoids the costs of waste treatment. Another problem is that used batteries fall into the category of hazardous waste.

This involves increasing costs in transportation, treatment and also disposal costs [10].

The type of battery used depends on the "grade of electrification" of the vehicle. In case of micro-hybrid vehicles (which have only a stop-start function and regenerative braking) the battery has a voltage level by 12-48 V, the power up to 10 kW, and usually it is lead-acid battery.

For mild-hybrid vehicles (as micro-hybrid plus an electric motors which assists the engine during acceleration) the battery has the same type as in the precedent case, but the voltage level is 48-200 V and the power up to 20 kW.

---

\* Corresponding author e-mail: [radusugar@yahoo.com](mailto:radusugar@yahoo.com), [olivian.chiver@cunbm.utcluj.ro](mailto:olivian.chiver@cunbm.utcluj.ro)

Full hybrid vehicle (FHEV allows in plus to drive only with electric motor for short distance, the battery is recharged only during driving) and Plug-in hybrid vehicle (the pure electric driving range is higher than with full-hybrid vehicles and the battery is recharged during standing times when the car is plugged into the grid) use battery with voltage level by 200-400V, the power 20-70 kW, but the stored energy is about 3-5 kWh in case of FHEV and about 10 kWh for Plug-in HEV [5].

Nickel-metal hydride or Nickel-Cd batteries are used for FHEV. For Plug-in HEV, the sodium-nickel chloride or Li-ion batteries are used as for electric vehicle (EV have only electric motor/motors, without engine). In case of EV the power is up to 120 kW. Li-ion batteries can have high stored energy or high power (up to 10 kW/kg).

The manner how the energy stored in the battery is consumed by the traction motor depends on the used motor type. Between the main characteristics that the electric motors must fulfil are high starting torque, high power density and of course high efficiency. From the wide range of existing electric motors, there are five major types that are suitable for EV or HEV.

One of the most used in the past, and also used until now in some countries (like India), is the DC motor with series excitation. His mechanical characteristic is ideal for traction, and it has an easy speed control. The disadvantage is the maintenance of brushes and commutators (cost and time).

Most used in the last years is the induction motor. Its natural mechanical characteristic is not suitable for traction, but this characteristic can be altered by different control strategies like  $V/f = \text{const.}$ , resulting in a very good traction motor.

The motor is cheap and reliable, but motor control is more difficult than in the case of synchronous PM motors. Other disadvantages comparatively with synchronous PM motor are power density, efficiency and volume/weight [9].

The manufacturers use the induction motor in small and cheap vehicles but also it is used in high-performance cars like the Tesla Roadster, the Model S or the Audi R8. Usually this motor is for EV not for HEV. PM synchronous motor is the most used now. It is available for high power ratings, has a very good power density, high efficiency, and compact design. It is found in both HEV and EV.

The brushless DC motor has a very suitable mechanical characteristic for traction (like DC series motor) but does not require brushes and commutators, the commutation is done electronically.

The BLDC has a very high efficiency, around 95-98%, and is suitable for a high power density, although at this point the most common is on cycles and light vehicles. It is one of the most preferred motors for the light electric vehicle application at this time.

Although probably in the near future different types of electric motors will continue to be used in EV or HEV, the switched reluctance motor (SRM) will be one of the most used. Simple construction (both classic and with PM), relatively easy control and high performance, recommend it as one of the motors of the future. At the moment he is already equipping some EVs as Tesla Model 3.

## 2. MATERIALS AND METHODS

In order to observe the variation of the voltage in terms of the batteries current, a system of two batteries (lead-acid, 12V, 60 Ah, 540A) series connected, was tested in the laboratory.

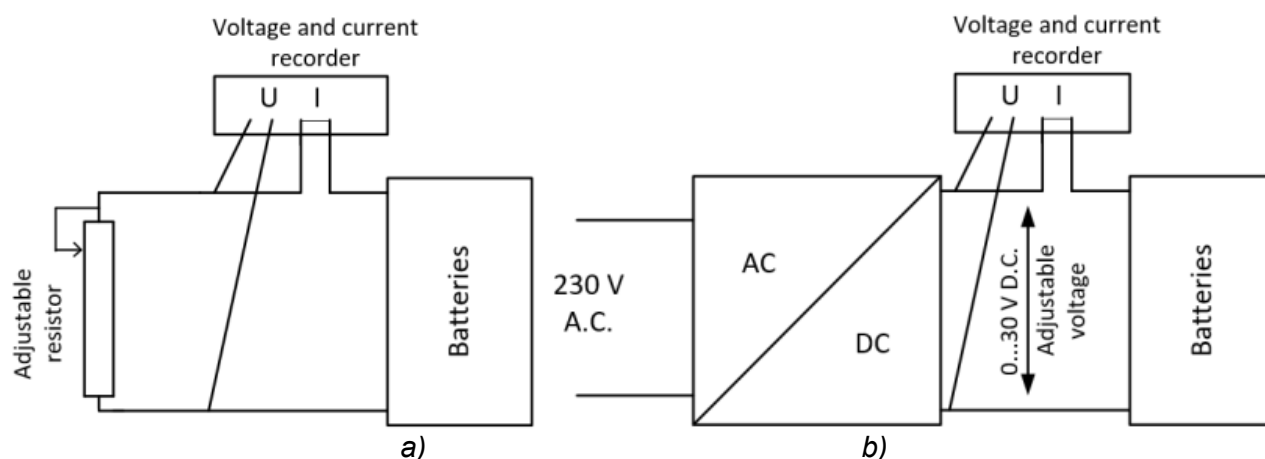


Figure 1. Electrical diagram for testing the batteries

Figure 1a shows the electrical diagram used in order to discharge the batteries and Figure 1b presents the electrical diagram used for charging the batteries.

First tests have been done to discharge the batteries and then to the charging.

## 2. MATERIALS AND METHODS

In the following figures, the characteristics  $U(t)$ ,  $I(t)$  during the discharging time are shown. Because the batteries were slightly discharged, the initial voltage was only around 22V.

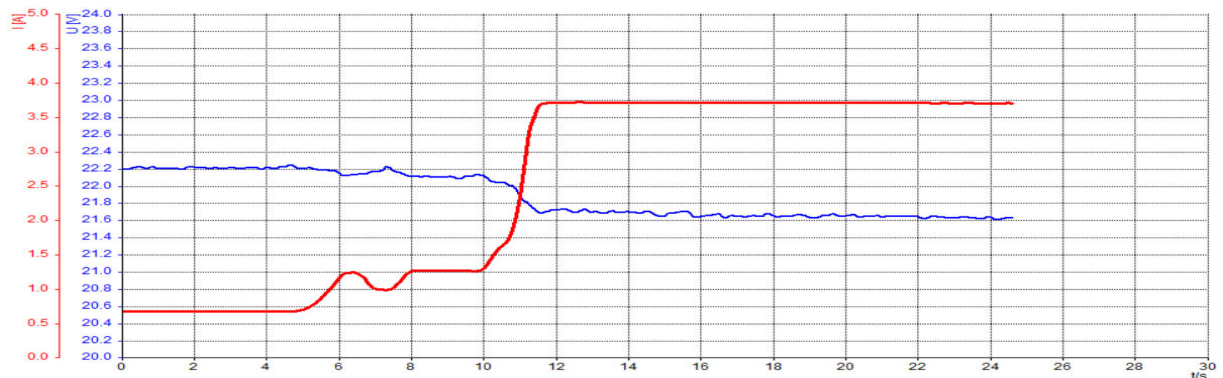


Figure 2.  $U(t)$  for slow variations or constant  $I(t)$  (values between 0.7 and 3.7 A)

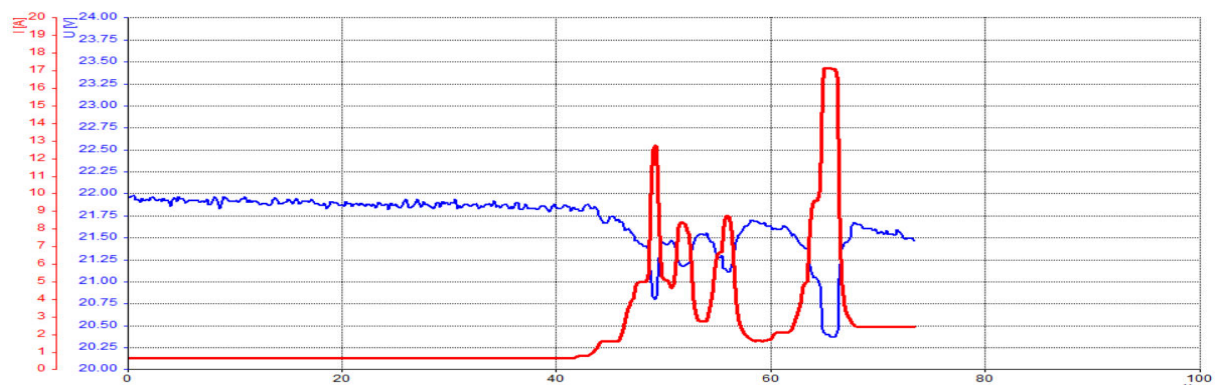


Figure 3.  $U(t)$  for rapid and big variations of  $I(t)$ , the current value up to 17 A

After several tests, the batteries voltage dropped and other recordings regarding discharge process were made, in the following being show this.

The charging process was also registered, but this time, the initial batteries voltage was about 27 V. The following figures show the performed records.

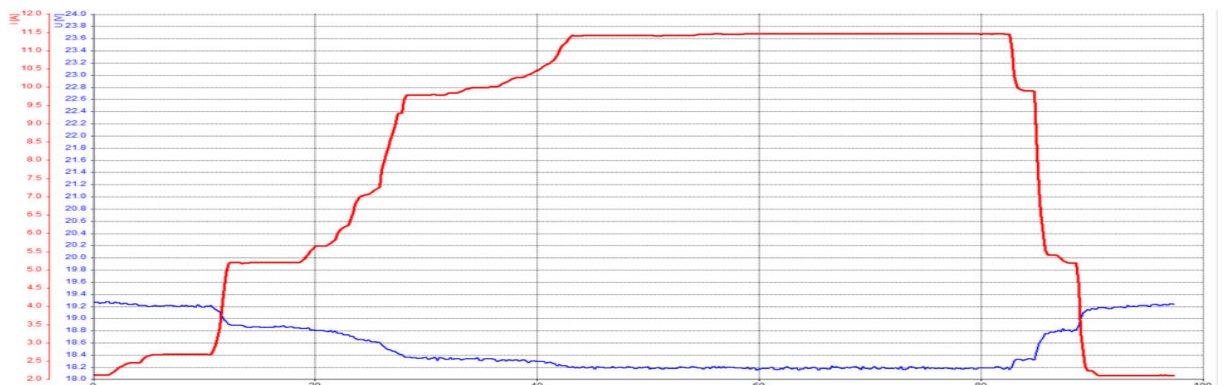


Figure 4.  $U(t)$  for  $I(t)$  between 2 and 12A, the batteries being quite discharged

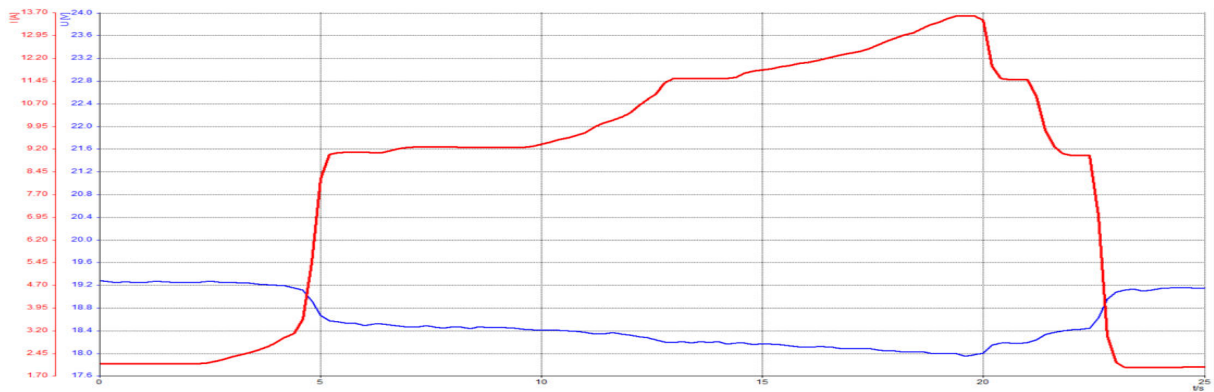


Figure 5.  $U(t)$  for  $I(t)$  between 2 and 14A, the batteries being quite discharged

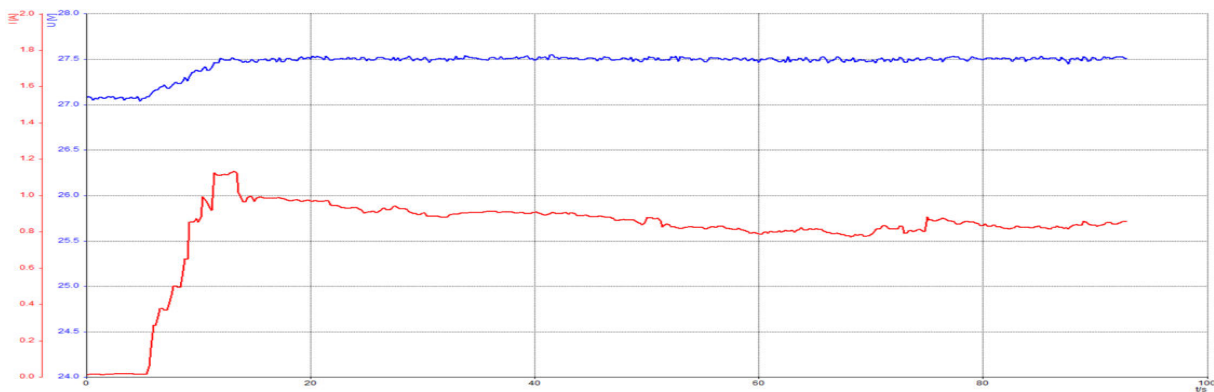


Figure 6.  $U(t)$  and  $I(t)$ , starting and charging at constant voltage 27.5 V

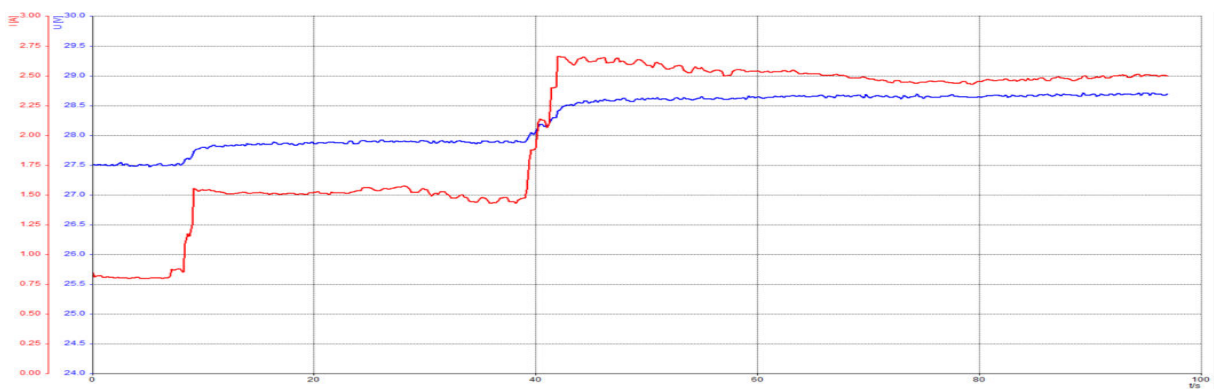


Figure 7. Charging and increasing the voltage

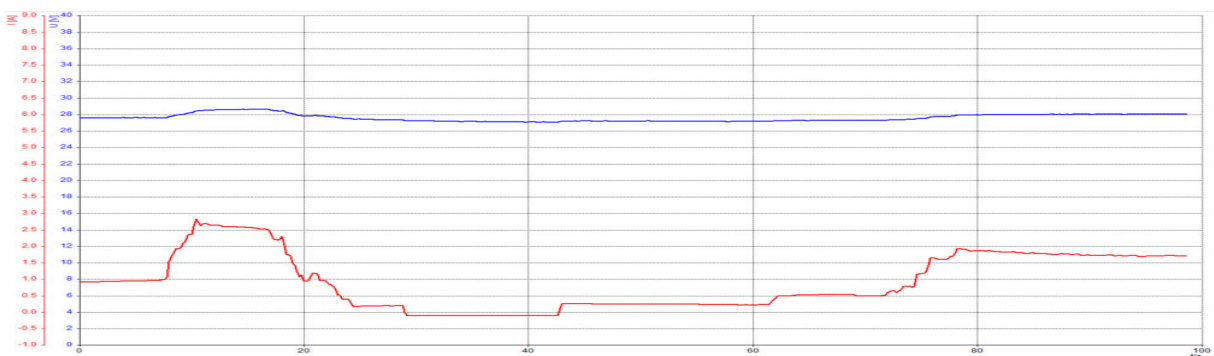


Figure 8. Charging and influence of the voltage variation

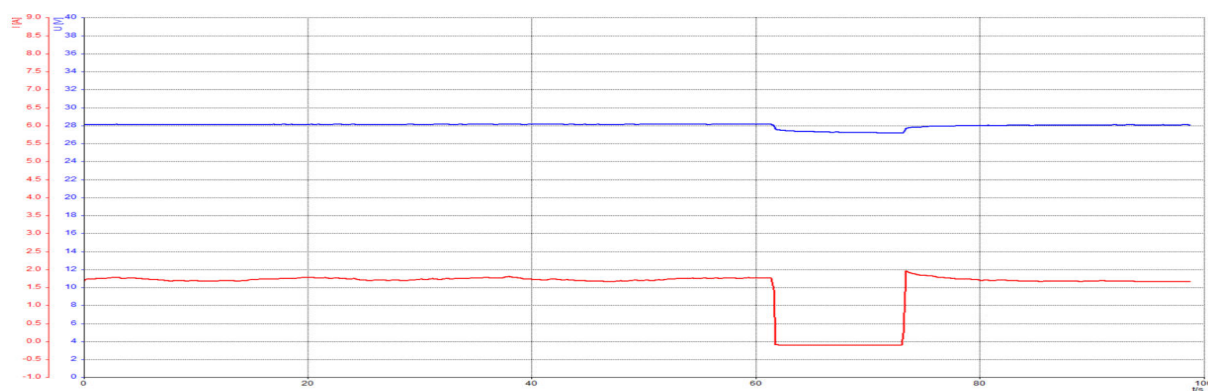


Figure 9. Charging at constant voltage and a voltage fluctuation

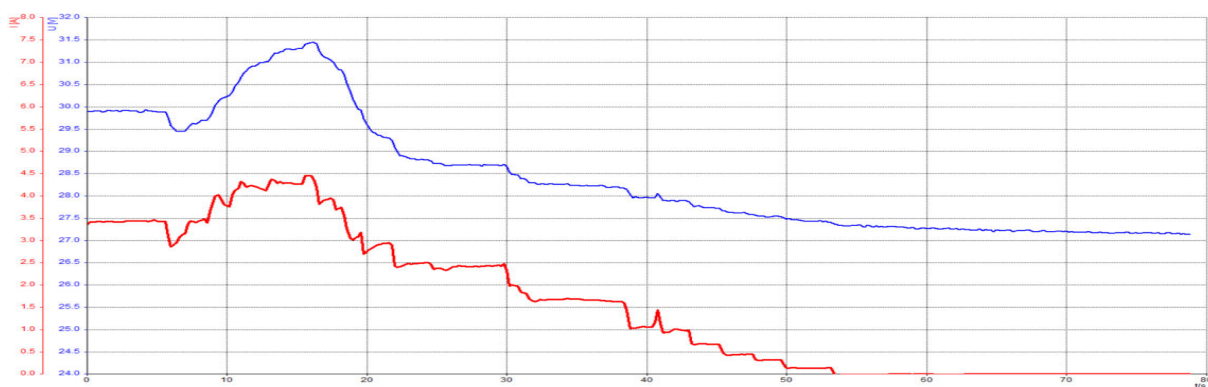


Figure 10.  $U(t)$  and  $I(t)$  during charging time, with rapid variation

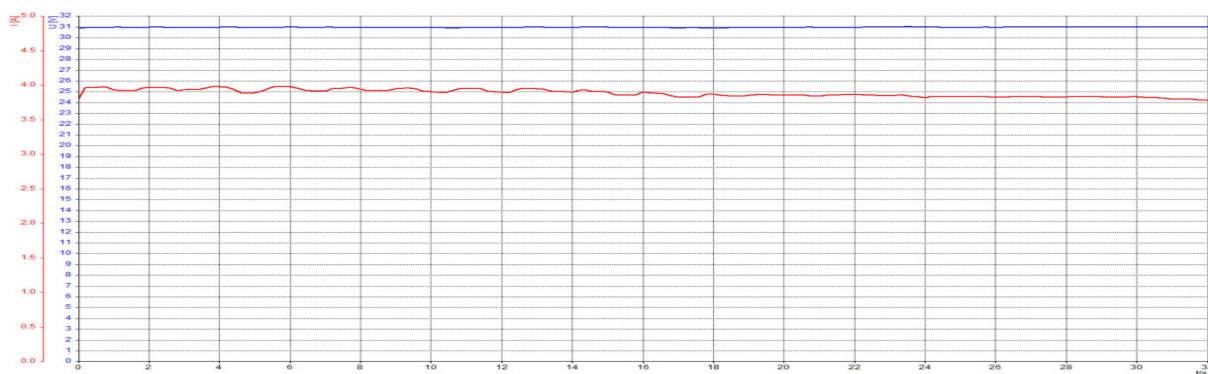


Figure 11. Charging at constant voltage, well-charged batteries

## 5. CONCLUSION

The current and voltage variation during discharging and charging a system of batteries (24 V, 60 Ah, 540A) was studied.

In the static discharging process, with a current (3.7A) of 0.7% from maximum starting current (540 A), the voltage decreases in time about 2.5% (from 22 to 21.6 V, reported to 24V).

In a dynamic process, at a maximum variation of 3.14% of the current, the voltage variation is about 6%. It is mentioned that the batteries have forth years old.

After the batteries were quite discharged, at a discharging current of 2.1%, the voltage drop was 3.3% and at a maximum current of 2.5% (13.7A, short time) the voltage drop was 5%.

In the charging regime (batteries being quite charged) at a variation of the current of 0.19%, the voltage variation is about 1.67% (Figure 5).

Rapid variation (decreasing) of the charging current of 0.83% determines a variation of the voltage (well-charged batteries) of 17.5% (Figure 9).

Charging at constant voltage impose a slow decreasing of the charging current (Figure 10).

The average cost of charging an electric vehicle for a 100 km journey is typically lower than the average cost of gasoline or diesel for a distance movement.

At the same time, as electric motors have fewer moving parts than combustion engines, their maintenance costs may be lower than those of a conventional engine.

## REFERENCES

1. Barabás I., Todoruț I.A., *Biodiesel Quality, Standards and Properties. Biodiesel Quality, Emissions and By-Products*, Gisela Montero and Margarita Stoytcheva, InTech, Rijeka, DOI: 10.5772/25370, 3-28, 2011
2. Bățaș N., Burnete N., Barabas I., Căzilă A., Filip N., Naghiu A., Dan F., Szasz R., Karamusantas D., *Motoare cu ardere internă. Combustibili. Lubrifianți. Materiale speciale pentru autovehicule*, Economicitate. Poluare, Editura U.T. Press, Cluj-Napoca, 2000
3. Bățaș N., Burnete N., Căzilă A., Rus I., Sopa S., Teborean I., *Motoare cu ardere internă*, Editura Didactică și Pedagogică, București, 1995
4. Boulanger G., Chu A., Maxx S., Waltz D., *Vehicle electrification. Status and issues*, Proceedings of the IEEE, vol. 99, no. 6, 2011
5. Budde-Meiwes H., Drillkens J., Lunz B., Muennix J., Rothgang S., Kowal J., Sauer D. U., *A review of current automotive battery technology and future prospects*, Proc IMechE, Part D, J, Automobile Engineering, DOI: 10.1177/0954407013485567, 2013
6. Burnete N., Naghiu A., Rus I., Chintăoan M., Mariașiu F., Varga B., Ilarie I., Roman C., Abraham B., Pitl G., Deac T., Vlad N., Naghiu L., Ispas N., Rakoși E., Mihon L., Neag L., Nicola S., *Motoare Diesel și biocombustibili pentru transportul urban*, Editura Mediamira, Cluj-Napoca, 2008
7. Burnete N., Bățaș N., Karamusantas D., *Construcția și calculul motoarelor cu ardere internă*. Editura Todesco, Cluj-Napoca, 2001
8. Chiru A., Anca H.R., Cofaru C., Kuchar R., Soica A., Ispas N., *Materiale compozite*. Vol. I. Editura Universității Transilvania, Brașov, 1999
9. Frieske B., Kloetzke M., Mauser F., *Trends in Vehicle Concept and Key Technology Development for Hybrid and Battery Electric Vehicles*. World Electric Vehicle Journal, Vol. 6, ISSN 2032-6653, 2013, p. 09-20
10. Gaines L., *The future of automotive lithium-ion battery recycling*, Charting a sustainable course Sustainable Materials and Technologies, vol 1–2, 2011
11. Negurescu N., Pană C., Popa M. G., *Motoare cu aprindere prin scânteie. Procese*. Editura Matrixrom, București, 2009
12. Scutaru M. L., Chiru A., Vlase S., Cofaru C., Teodorescu-Draghicescu H., *Materiale plastice și compozite în ingineria autovehiculelor*, Editura Matrixrom, București, 2013
13. Veneri O., Ferraro L., Capasso C., Iannuzzi D., *Charging infrastructures for EV*. Overview of technologies and issues, IEEE ESARS, 2012

# RoJAE Romanian Journal of Automotive Engineering

## AIMS AND SCOPE

The Romanian Journal of Automotive Engineering has as its main objective the publication and dissemination of original research in all fields of „Automotive Technology, Science and Engineering”. It fosters thus the exchange of ideas among researchers in different parts of the world and also among researchers who emphasize different aspects regarding the basis and applications of the field.

Standing as it does at the cross-roads of Physics, Chemistry, Mechanics, Engineering Design and Materials Sciences, automotive engineering is experiencing considerable growth as a result of recent technological advances. The Romanian Journal of Automotive Engineering, by providing an international medium of communication, is encouraging this growth and is encompassing all aspects of the field from thermal engineering, flow analysis, structural analysis, modal analysis, control, vehicular electronics, mechatronics, electro-mechanical engineering, optimum design methods, ITS, and recycling. Interest extends from the basic science to technology applications with analytical, experimental and numerical studies.

The emphasis is placed on contribution that appears to be of permanent interest to research workers and engineers in the field. If furthering knowledge in the area of principal concern of the Journal, papers of primary interest to the innovative disciplines of „Automotive Technology, Science and Engineering” may be published.

No length limitations for contributions are set, but only concisely written papers are published. Brief articles are considered on the basis of technical merit. Discussions of previously published papers are welcome.

### Notes for contributors

Authors should submit an electronic file of their contribution to the **Production office**: [www.siar.ro](http://www.siar.ro). All the papers will be reviewed and assessed by a series of independent referees.

### Copyright

A copyright transfer form will be send to the author. All authors must sign the "Transfer of Copyright" agreement before the article can be published.

*Upon acceptance of an article by the journal, the author(s) will be asked to transfer copyright of the article to the publisher. The transfer will ensure the widest possible dissemination of information. This Journal and the individual contributions contained in it are protected by the copyright of the SIAR, and the following terms and conditions apply to their use:*

### Photocopying

*Single Photocopies of single articles may be made for personal use as allowed by international copyright laws. Permission of the publisher and payment of a fee is required for all other photocopying including multiple or systematic copying, copying for institutions that wish to make photocopies for non-profit educational classroom use.*

### Derivative Works

*Subscribers may reproduce table of contents or prepare lists of article including abstracts for internal circulation within their institutions. Permission of the publisher is required for resale or distribution outside the institution.*

*Permission of publisher is required for all other derivative works, including compilations and translations.*

### Electronic Storage

*Permission of the publisher is required to store electronically and material contained in this journal, including any article or part of article. Contact the publisher at the address indicated.*

*Except as outlined above, no part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without prior written permission of the publisher.*

### Notice

*No responsibility is assumed by the publisher for any injury and or damage to persons or property as a matter of products liability; negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein. Although all advertising material is expected to conform to ethical (medical) standards, inclusion in this publication does not constitute a guarantee or endorsement of the quality or value of such product or of the claims made of it by its manufacturer.*



The Journal of the Society of Automotive Engineers of Romania

[www.ro-jae.ro](http://www.ro-jae.ro) [www.siar.ro](http://www.siar.ro)

ISSN 2457 – 5275 (Online, English)

ISSN 1842 – 4074 (Print, Online, Romanian)

## The Scientific Journal of SIAR A Short History

The engineering of vehicles represents the engine of the global development of the economy.

SIAR tracks the progress of the automotive engineering in Romania by: the development of automotive engineering, the development of technologies, and road transport services; supporting the work of the haulers, supporting the technical inspection and of the garage; encouraging young people to have a career in the automotive engineering and road haulage; stimulation and coordination of activities that promote an environment that is suitable for continuous education and improving of knowledge of the engineers; active exchange of ideas and experience, in particular for students, master students, PhD students, and young engineers, and dissemination of knowledge in the field of automotive engineering; cooperation with other technical and scientific organizations, employers' and socio-professional associations through organization of joint actions, of mutual interest.

By the accession to FISITA (International Federation of Automotive Engineering Societies) since its establishment, SIAR has been involved in achieving an overall professional community that is homogeneous in competence and performance, interactive, dynamic, and competitive at the same time, oriented towards a balanced and friendly relationship between people and the environment; this action will be constituted as a challenge worthy of effort and recognition.

The insurance of a favorable framework for the initiation and the development of cooperation of the specialists in this field of activity allows for an efficient and easy exchange of information, specific knowledge and experience; it supports the cooperation between universities and between research centers and industry; it speeds up the process of implementing the new technologies, it simplifies the identification of training and specialization needs of the personnel involved in the engineering of motor vehicles, transport, and road safety.

In order to succeed, ever since its founding, SIAR has considered that the stress should be put on the production and distribution, at national and international level, of a publication of scientific quality.

Under these circumstances, the development of the scientific magazine of SIAR had the following evolution:

### 1. RIA – Revista inginerilor de automobile (in English: *Journal of Automotive Engineers*)

ISSN 1222 – 5142

Period of publication: 1990 – 2000

Frequency: Quarterly

Total number of issues: 30

Format: print, Romanian

Electronic publication on: [www.ro-jae.ro](http://www.ro-jae.ro)

Type: Open Access

**The above constitutes series nr. 1 of SIAR scientific magazine.**

### 2. Ingineria automobilului (in English: *Automotive Engineering*)

ISSN 1842 – 4074

Period of publication: as of 2006

Frequency: Quarterly

Total number of issues: 55

(including the June 2020 issue)

Format: print and online, Romanian

Electronic publication on: [www.ingineria-automobilului.ro](http://www.ingineria-automobilului.ro)

Type: Open Access

**The above constitutes series nr. 2 of SIAR scientific magazine (Romanian version).**

### 3. Ingineria automobilului (in English: *Automotive Engineering*)

ISSN 2284 – 5690

Period of publication: 2011 – 2014

Frequency: Quarterly

Total number of issues: 16

(including the December 2014 issue)

Format: online, English

Electronic publication on: [www.ingineria-automobilului.ro](http://www.ingineria-automobilului.ro)

Type: Open Access

**The above constitutes series nr. 3 of SIAR scientific magazine (English version).**

### 4. Romanian Journal of Automotive Engineering

ISSN 2457 – 5275

Period of publication: from 2015

Frequency: Quarterly

Total number of issues: 22 (June 2020)

Format: online, English

Electronic publication on: [www.ro-jae.ro](http://www.ro-jae.ro)

Type: Open Access

**The above constitutes series nr. 4 of SIAR scientific magazine (English version).**

### Summary

Total of series:

4

Total years of publication:

26 (11: 1990 – 2000; 15: 2006 – 2020)

Publication frequency:

Quarterly

Total issues published:

85 (Romanian), out of which, the last 38 were also published in English

