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S.M.A.T. 2019

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Dumitru Ilie
Racilă Laurențiu Daniel

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Editori:
Ilie DUMITRU
Laurențiu RACILĂ

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PREFACE

*The International Congress **S.M.A.T. 2019 (Science and Management of Automotive and Transportation Engineering)** is held under the higher patronage of Ministry of Education of Romania.*

It's the XXXth edition of this International Congress.

By the collaboration inside S.I.A.R. (Society of Automotive Engineers of Romania), this Congress represent the effort of the academic peoples and researchers from the main romanian universities centers, Bucharest, Brasov, Craiova, Cluj-Napoca, Pitesti and Timisoara.

The congress topics are focused on novel, most challenging issues on automotive and transportation, providing both field-related engineers and researchers within the industry and/or the academic environment the possibility to track down topical issues disseminated via the congress papers. Public presentation of papers enables the attendants to initiate and active participate in cross-fertilizing dialogs that can lead to new interdisciplinary projects and cooperation partnerships.

The main purpose of the S.M.A.T. 2019 Congress it's to offer to all researchers and specialists in automotive field a large discussion environment, a place to present the newest achievements in scientific research and innovation activities, within the topics:

- *Advanced Powertrain and Propulsion*
- *Road Vehicles and Environment*
- *Modern Transport Systems and Road Traffic*
- *Advanced Engineering Methods*
- *Materials and Technologies*

The congress aims is to bring together academics, researchers, engineers and other specialists from the large field of automotive engineering and road transport, to foster some of their latest achievements and generate opportunities for further collaboration. Both plenary sessions and scientific sections will focus on the high quality of the submitted papers. Presentations will be mediated by leading moderators. We are glad to receive academics, researchers, engineers and other spe-

cialists within automotive engineering and road transport, students and anyone interested to attend our congress.

The congress topics underpin the latest trends and scientific development directions within the field of automotive and transport fields. The target audience will benefit from the most innovative solutions put forward by the submitted papers, within the field of automotive and transport, and further collaboration and professional networking opportunities that reside in this congress.

The congress has a long historical progress, S.M.A.T. 2019 being the XXXth edition. Over the time, the congress topics has been actualized permanently, one of the organizers targets being the international visibility and the continued increase of the scientific content of the papers.

Many remarkable romanian and international researchers from automotive and transports engineering will be present to the Congress. During the Congress acts a scientific student contest will be organized, and also a roundtable with social and economic representatives, about security, safety road and urban logistic.

The social, economic, technical and scientific impact of Faculty of Mechanics activities, a pillow of University of Craiova, is finding in a large area of scientific and technical achievements of students, graduates and researchers of this Faculty, all around the world.

Editors

Aspects Relating to Operation of Transmission Provided with Torque Converter

Ion Lespezeanu, Daniela Voicu, Andrei Indreș, Marin Nicolau, and Ion Copae

Military Technical Academy "Ferdinand I", Bucharest, Romania

Abstract. The paper presents some aspects regarding the mathematical modeling of the hydromechanical transmissions operation and a study of the dynamics of the vehicle. The characteristics of the torque converter and transmission with automatic gearbox type XC200-5C from Allison are established. Also there are presented performance curves for the internal combustion engine linked with this transmission. Static characteristic modeled with analytical expressions are part of the initial database for the dynamic study of the vehicle within the work.

Keywords: torque converter, gearbox, mathematical model, vehicle dynamics

1 Introduction

Modern torque converters have two main roles: increasing torque transmitted from the engine and efficiency when operating in a hydro clutch mode (without changing the engine torque).

Figure 1 shows a torque converter comprising the following elements: pump (1), stator (2), turbine (3), lock clutch assembly with oscillation absorber (4), housing (5), grooved hub (6) and single-way clutch (7) [6].

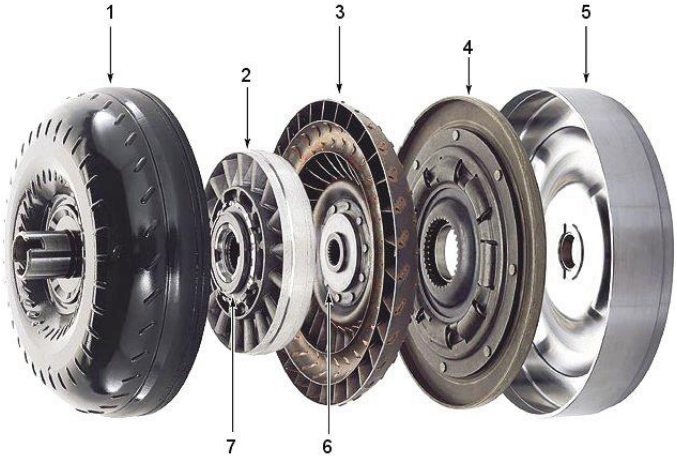

Fig. 1. – Torque Converter

2 Torque converter's characteristics

Torque converter transforms torque from the pump, acting as hydraulic reductor, due to stator's location between pump and turbine. The torque converter has some important characteristics presented below.

The transformation ratio kh (or dynamic transmission ratio) is defined as the ratio between turbine shaft's torque Mt and pump shaft's torque Mp:

$$k_h = \frac{M_t}{M_p} \tag{1}$$

The kinematic transmission ratio ih represents the ratio between pump shaft's speed np (or angular speed wp) and turbine shaft's speed nt (or angular speed wt):

$$i_h = \frac{n_p}{n_t} = \frac{\omega_p}{\omega_t} \tag{2}$$

The energy efficiency of torque converter □h is given by the ratio between turbine shaft's power Pt and pump shaft's power Pp:

$$\eta_h = \frac{P_t}{P_p} = \frac{M_t \omega_t}{M_p \omega_p} \tag{3}$$

From relations (1) and (2) results:

$$\eta_h = k_h \frac{1}{i_h} = k_h i'_h \tag{4}$$

Where represents the reverse kinematic transmission ratio.

In fig.2 and fig. 3 the static characteristic of the torque converter of the transmission X200-5C is presented. Generally they are called as exterior characteristics of torque converter [5].

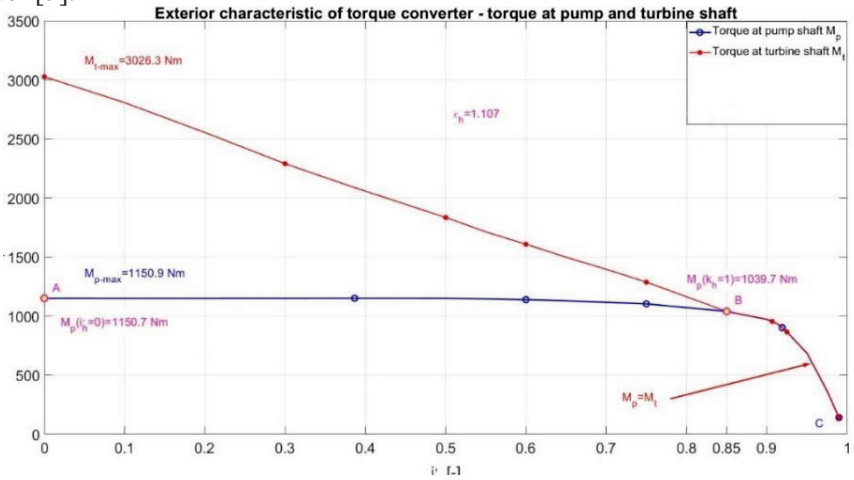

Fig. 2. – Exterior characteristic of torque converter – torque at pump and turbine shaft

Based on the experimental data obtained for the X200-5C transmission, the the efficiency of the torque converter is shown in Fig. 3a.

Figure 3b shows the variation of the transformation ratio. It can be seen that the maximum value of the transformation ratio is 2.63, which is achieved when the vehicle starts up.

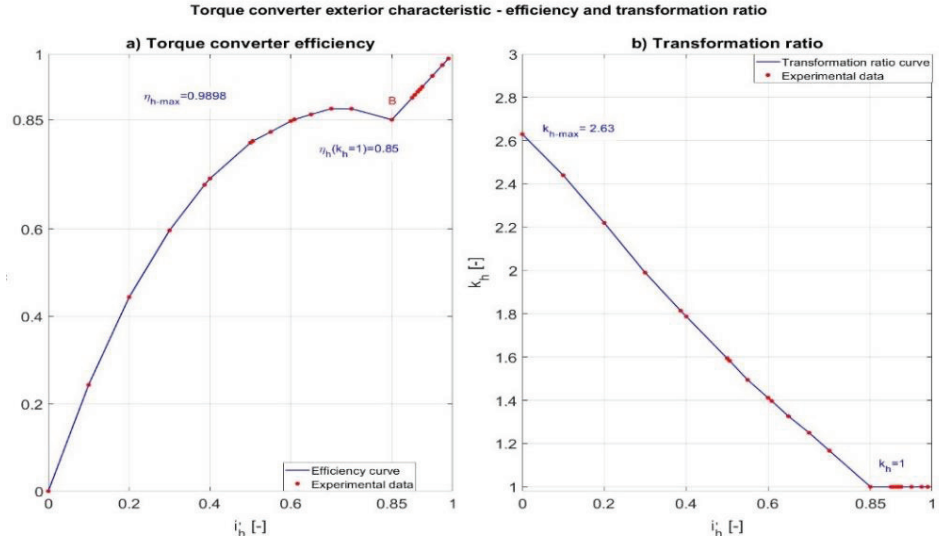

Fig. 3. – Torque converter exterior characteristic – efficiency and transformation ratio

3 Internal combustion engine performance curves

Figure 4 shows the static characteristic of the engine with which the X200-5C hydromechanical transmission is coupled.

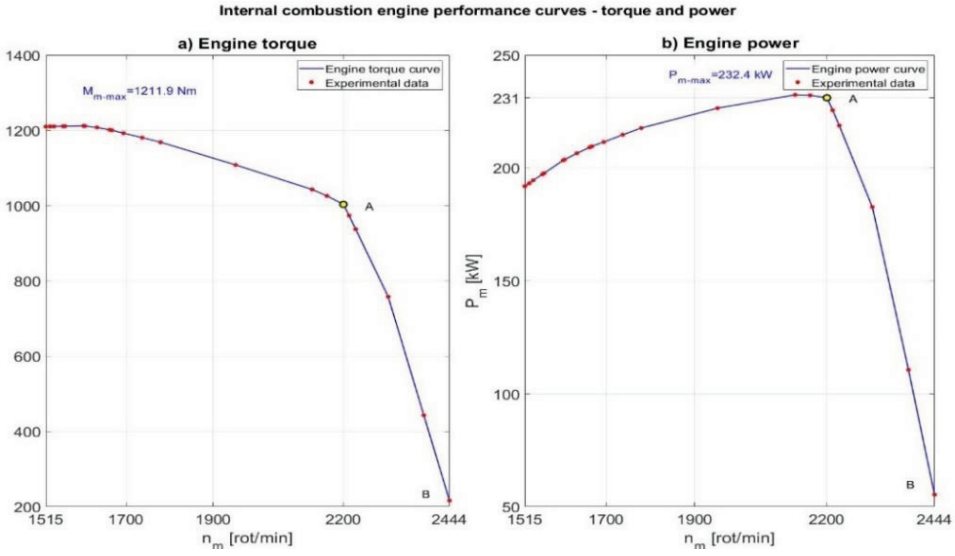

Fig. 4. – Internal combustion engine performance curves – torque and power

4 Transmission's static characteristic.

The static characteristic of the transmission consists of graphs of torque, power and energy efficiency of transmission output shaft, in different gears. So in fig.5 and fig.6 torque Mtr and power Ptr of output shaft from transmission in different gears are presented, in the case when the torque converter is not locked ($i'_h \neq 1$).

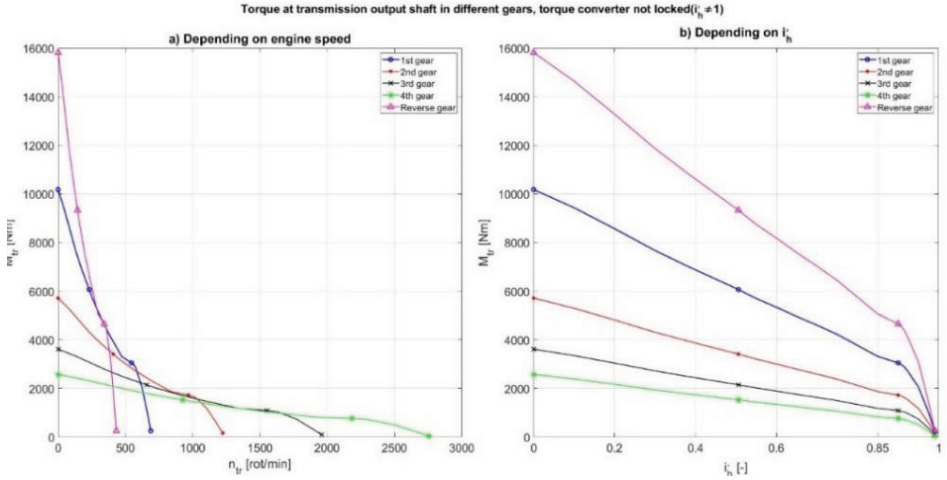

Fig. 5. – Torque at transmission output shaft in different gears, torque converter not locked

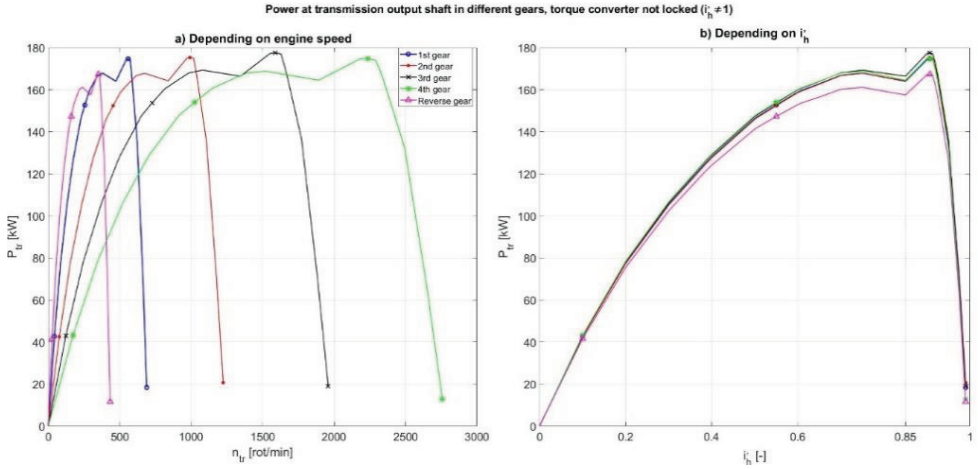

Fig. 6. – Power at transmission output shaft in different gears, torque converter not locked

Similarly, in Fig. 7 are presented the torque and power of the output shaft of the transmission in different gears where torque converter is locked ($i'_h \neq 1$).

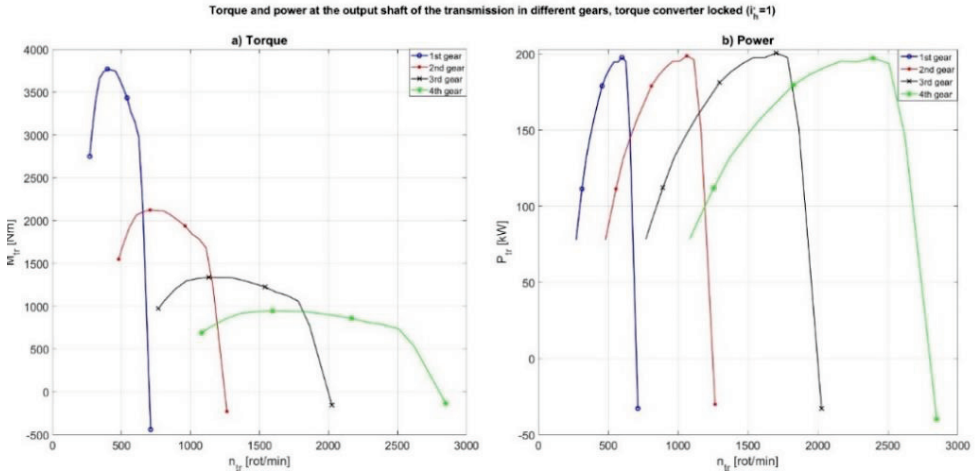

Fig. 7. – Torque and power at output shaft of the transmission in different gears, torque converter locked

Fig. 8 shows the variation of transmission efficiency □tr in different gears in the case when the torque converter is not locked, and in fig. 9 the power that converts to heat Pctr in this case.

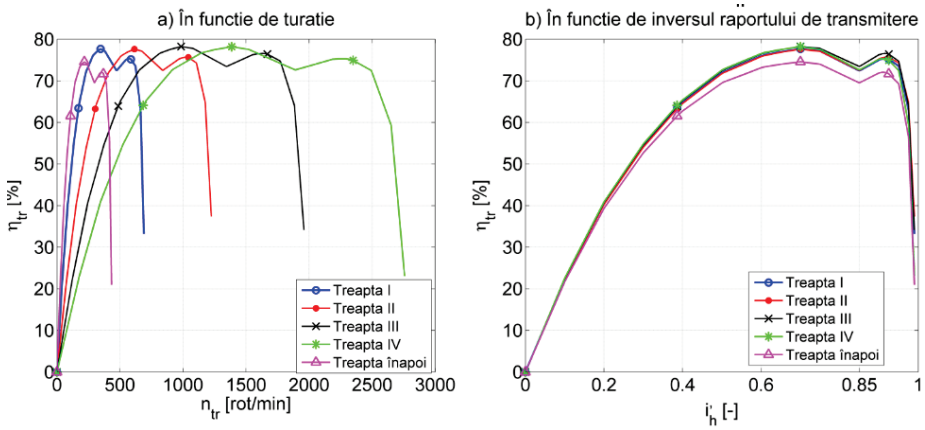

Fig. 8. – Torque converter efficiency in different gears, not locked

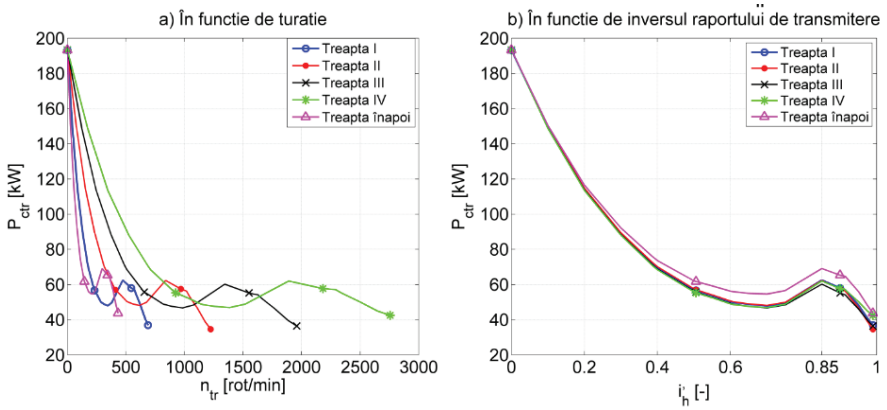

Fig. 9. – Power turned into heat in different gears, torque converter not locked

5 Vehicle dynamics

For the study of the internal combustion engine dynamics, we are resorting to the first order differential equations [2; 4]. For this purpose the static characteristics of the engine and transmission, as well as the various construction parameters of the vehicle are used.

Next we will use the mathematical model used by Matlab to solve the equation system (5) [7]. The system of differential equations is:

$$\left.\begin{matrix} J_{mp}\dot{\omega}_m = M_m - M_p \\ J_v\dot{\omega}_r = i_{tf}(M_{tr} - M_r \end{matrix}\right\} \tag{5}$$

In addition to the previously used variables: Jmp - moment of inertia of the engine and pump reduced to the axis of the input shaft in the torque converter; Jv - the moment of inertia of the vehicle reduced to the crankshaft axis; itf - transmission ratio of the final transmission; Mr - the moment of resistance to movement.

To solve the system (5), we will use the Matlab Simulink modeling scheme where the dynamics study can be done by taking into account the driver's action by simulating acceleration and braking.

In the system of differential equations (5) the static characteristics presented above and the analytical expressions based on them are used. For example, we present the analytical relationship determined for the torque used to drive the pump:

$$M_p = -0.000049\omega_m^4 + 0037\omega_m^3 - 10.514\omega_m^2 + 1322.066\omega_m - 60852.356 \tag{6}$$

The graphs in figures 10, 11 and 12 are thus obtained with the functional variables mentioned in each case.

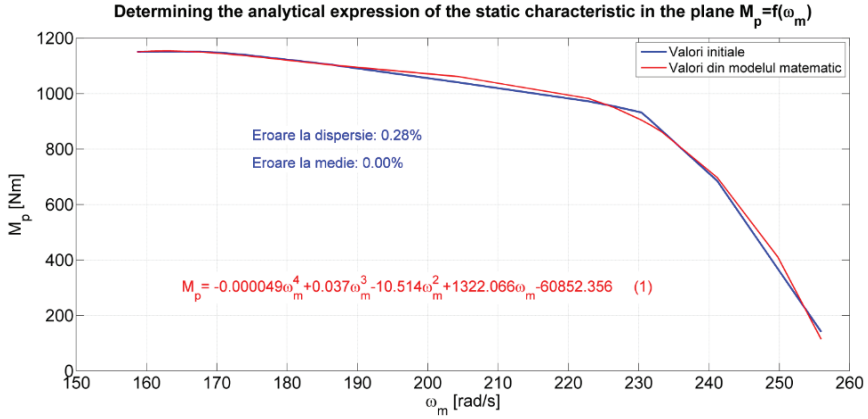

Fig. 10. – Analytical expression of the static characteristic in the plane $M_p = f(\omega_m)$

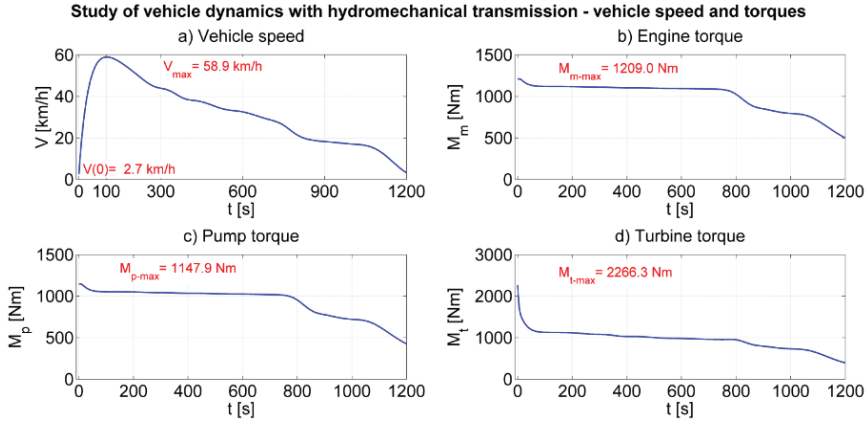

Fig. 11. – Study of vehicle dynamics with hydromechanical transmission – vehicle speed and torques

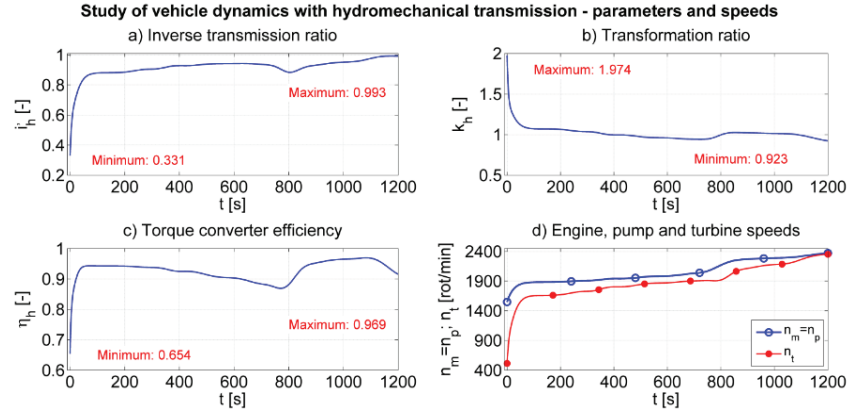

Fig. 12. – Study of vehicle dynamics with hydromechanical transmission – parameters and speeds

6 Conlcusions

In the paper the static characteristics of the internal combustion engine and the automatic transmission were modeled based on experimental data.

Using vehicle dynamics equations and analytical relations of the static characteristics of the engine and transmission, the speed of the vehicle was determined.

The maximum speed determined based on the mathematical modeling proposed in the paper has a value of 58.9 km / h, a value very close to the value obtained by real vehicle testing.

The theoretical study based on experimental data can be a way of assessing the dynamic performance of the vehicle.

References

1. Banerjee J. , Adibi H., Azad N.L., McPhee J., Parametric Importance Analysis and Design Optimization of Torque Converter Model Using Sensitivity Information. Universiy of Waterloo, 2017
2. Copae I., Lespezeanu I., Cazacu C., Dinamica autovehiculelor, Editura ERICOM, București, 2006
3. Costache D., Transmisii hidraulice pentru autovehicule, Editura Academiei Tehnice Militare, Bucuresti, 2002
4. Vilău R., Issues concerning plotting the static characteristics of the servomechanisms of the wheeled military automotive, MTA REVIEW Vol. XXV, No. 2, Pag.107-114, ISSN 1843-3391
5. Allison Transmissions, Military Series, http://www.allisontransmission.com/transmissions/ models/military-series
6. LuK Transmissions, http://www.luk.com/content.luk.de/en/products/transmission_ components/gearing-systems.jsp
7. *** Using Simulink and Stateflow in Automotive Applications, pag.61-70, 2017, https://www.mathworks.com/