ISSN 1453 – 7303 **"HIDRAULICA" (No. 2/2018)**
Magazine *of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics*

Analysis of Intelligent Control and Interface in Pressurized Liquid Injection Systems for Competitive Technical Solutions

PhD. Eng. **Iosif FERENȚI**[1], Prof. PhD Eng. **Dan OPRUȚA**[2],
Lect. PhD. Eng. **Doru-Laurean BĂLDEAN**[2,*]

[1] Intercars, Department of Automotive Engineering, Corneliu Coposu Street, Nr: 167A, Cluj-Napoca, 400228, Cluj county, România. e-mail: iosif.ferenti@yahoo.de

[2] Technical University of Cluj-Napoca, Department of Automotive Engineering and Transports, Muncii Blvd, no. 103-105, Cluj-Napoca, 400641, Cluj county, Romania. Corresponding author* e-mail: doru.baldean@auto.utcluj.ro

Abstract: *In this scientific paper, am approach based on Engine Digital Scanning (EDS) was applied in order to underline the performances of more than ten engine speed regimes on the same rally car, but with various intake manifold pressures, fuel injection duties and ignition advances. A specific study of trend lines and parameter variation was developed to highlight internal combustion engine's (ICE) operational indicators and to define the optimal regime with increased intake pressure, improved combustion and lower pollution influencing conditions. Manifold pressure dictates the base condition for air-fuel mixture formation and for lambda value before engine intake process in the case of port fuel injection (PFI). Fuel injection duty expresses the operational sequence time in relation with a base parameter in the engine working process. Ignition advance is adapted to the hydraulic-fuel charge, as well as engine load and speed so it is analysed.*

Keywords: *Automotive, diagnosis, hydraulic, fuel injection system*

1. Introduction

In the last forty years, the port fuel injection systems have been developed and optimised for different types of applications in automotive and industrial sectors, but in order to maintain performances and to increase power output when lowering masses and inertia it has to be further studied and digitally controlled. Potential of injection system development is yet to be explored and materialized due to the spectrum of recent achievements in hydraulic control and Computational Fluid Dynamics – CFD [1-5].

Digital or intelligent control in fluid systems in both general technical applications and industrialized units has a beneficial impact on efficiency and performance adaption accuracy. Electronic control of power-train operation creates an opportunity for developing engine-working protocols for better performances in specific regimes [4-9].

Some developments of new features in the context of studying port fuel injection aimed to improve powertrain performances and fuel economy, to simplify engine auxiliary systems are mandatory for increasing efficiency and for lowering pollution [5].

The challenge for researchers and CFD specialists is to formulate an optimal tuned up digital map. This endeavour is based on a rigorous analysis with mathematical and graphical apparatus that leads to the improvement of software aided engineering process control of motor-sport fuel supply systems, especially in the whole track follow-up of a rally competition with some specific constraints due to the extreme speeds, inertia and mechanical stress.

The fuel supply systems with port fuel injection are structured from three significant parts: which comprise a sensors group, electronic control module and an actuators group of elements.

In the computer aided testing and evaluation of the fuel supply systems: specific system parameters, structural variables, digital tools and decision mapping indicators [5-8] are implemented to validate the optimal electronic controlled map model for specific engine-regime scenario.

The main objective of the present paper is to outline the correlation in the fluid control and the electronic or digital mapping in order to track the trend-line for features of the electronic control module. Specific targets of the research are as follows: analyse of fuel injector duty, intake fluid pressure in manifold, ECU auxiliary duty and ignition advance versus engine speed.

2. Research methodology

In order to conduct the research (on electronic or digital control of the fluid intake and hydraulic performances of the injection system adapted to the rally powertrain of the Mitsubishi Evo that has been studied) there were previously installed some hardware components and software features, which facilitate the method of, analyse by experimental measurement and testing as well as trend-line interpretation. The track of the signals and the methodological pathway of the input/output parameters is shown in a simplified schematic of the vehicle’s power-train (figure 1).
The actuator group of elements (injectors and spark plugs) is controlled by the electronic control unit/module (ECU/ECM), which takes data from input devices, process all the acquired information and then make a decision in order to perform/actuate a specific task in the field of hydraulics or fluid dynamics, when opening the injectors and fuel pressure regulator.

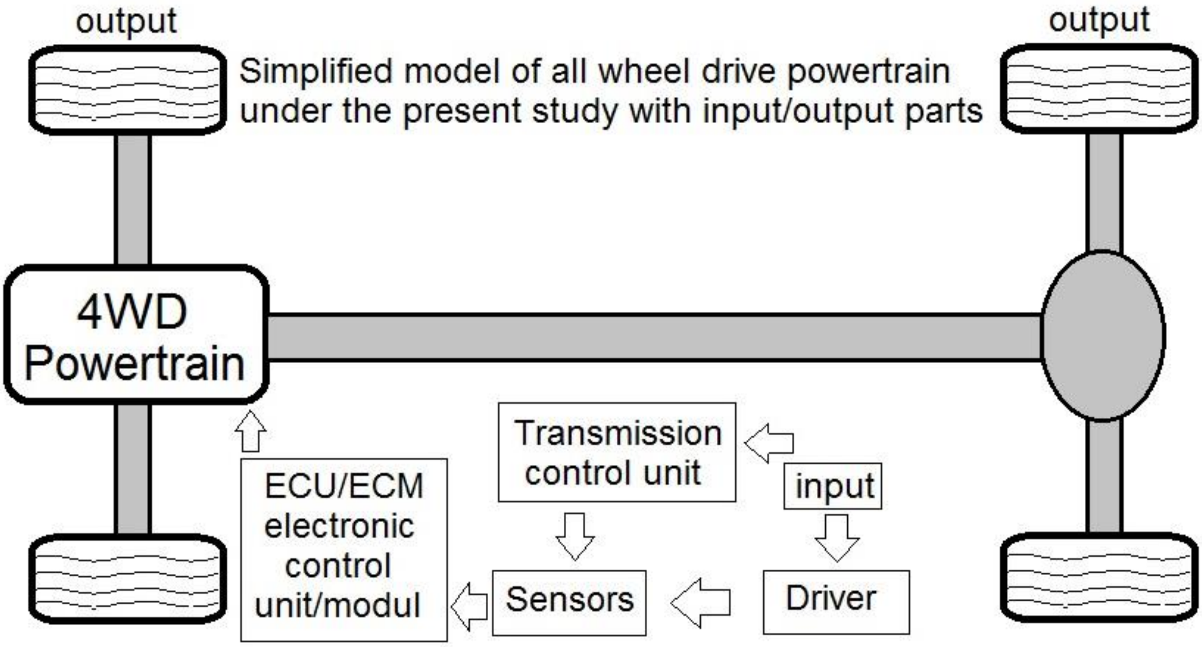

Fig. 1. Structural assembly of control system for hydraulic and mechanical parts in the vehicle’s powertrain

The research methodology (figure 1) following the sequences of the documentation and practical tests on the rally vehicle leads to final valid results after a certain number of repetitions or applications of this cycle.

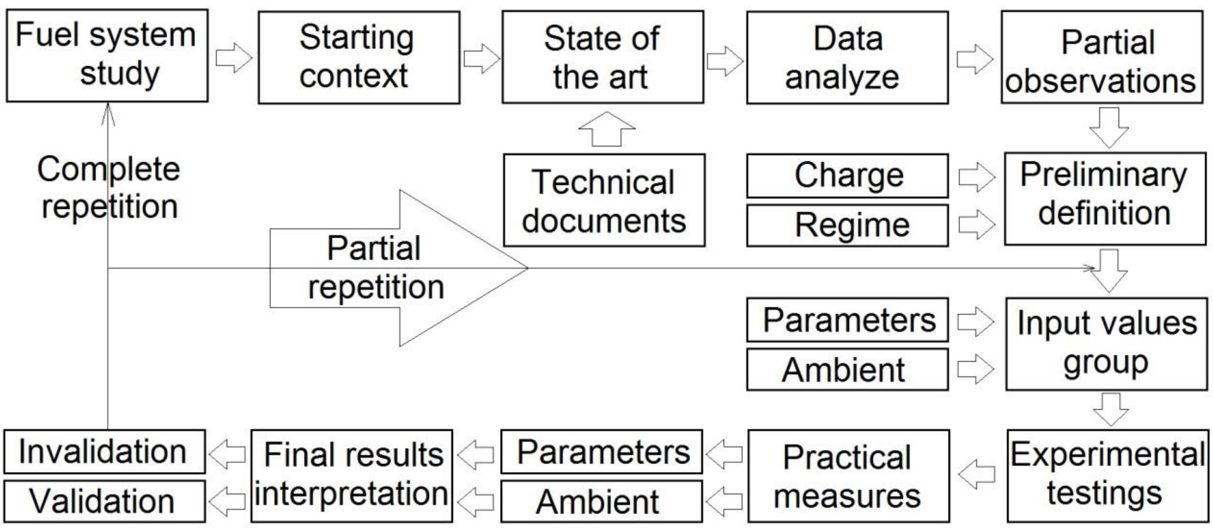

Fig. 2. Structural assembly of control system for hydraulic and mechanical parts in the vehicle’s powertrain

2.1 The study at specific temperature value for engine and air intake

The engine is wormed up and ready for measurements when starting the practical measures in experimental testing (figure 3). The indicator/pointer on the graph is placed at 24:14:50 minutes from start.

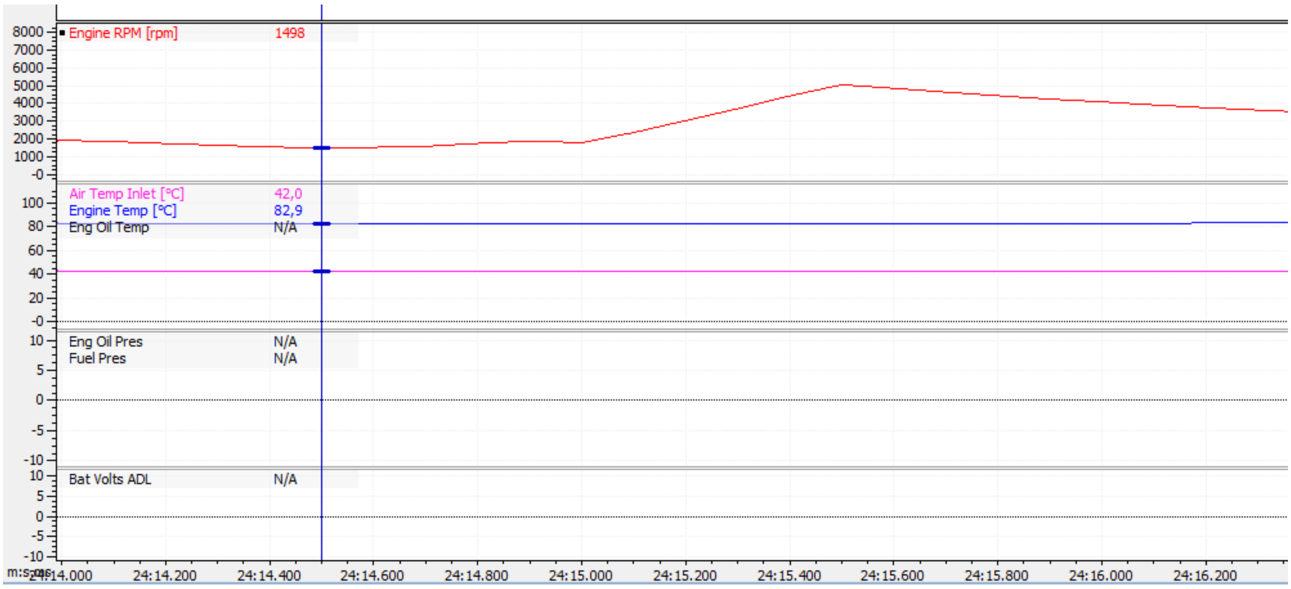

Fig. 3. Graphic capture from ECM with engine speed variation and engine’s fluid temperatures

Parameter readings and data acquisition are targeted also toward the inspection of manifold pressure, throttle position, fuel injection duty and ignition advance angle.

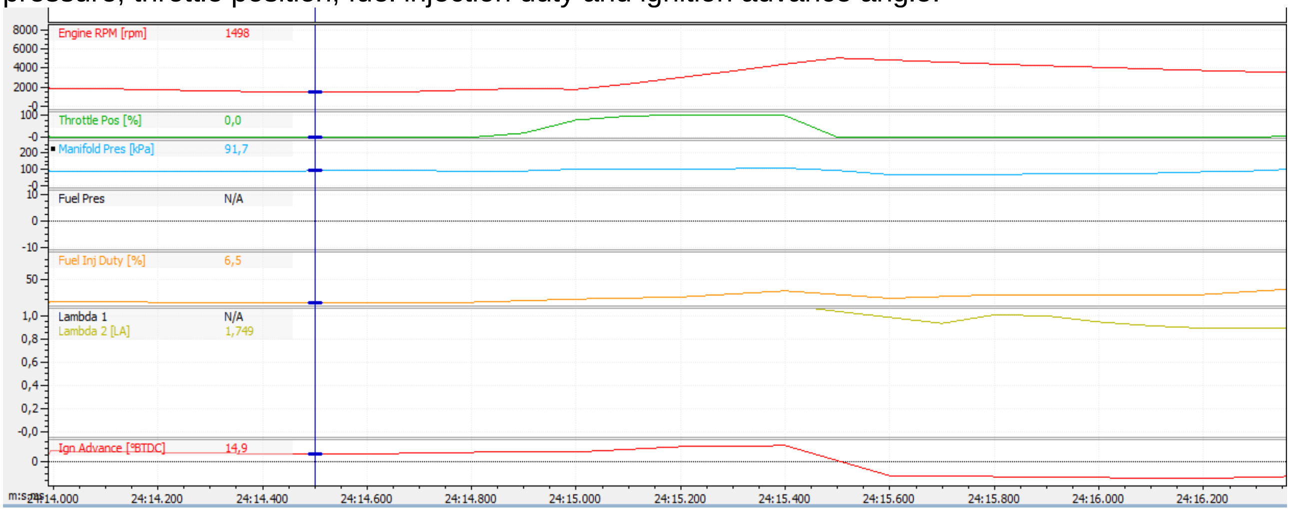

Fig. 4. Graphic capture from ECM with manifold pressure and ignition advance angle before BTDC

2.2 The study of mathematical models

The significant aspect that is analyzed and highlighted for comprehensive approach consists in fuel injection duty correlated to engine’s speed, as a percent of total mass of fuel injected when vehicle is full loaded and driven with maximum speed, as it is expressed by formula (1):

$$F_{id} = 2.2 \cdot 10^{3} \cdot x + 3.22 \ , [\%] \qquad (1)$$

The other important aspect, which has to be pointed out for this scientific approach of the specific control in rally engine, is ignition advance related to fuel injection duty, as it is given by formula (2):

$$F_{id} = 3.45 \cdot x - 7.43 \ , [^{\circ}BTDC]. \qquad (2)$$

3. Research results

The studied engine is warmed up and ready for measurements when starting the practical measures in experimental testing (figure 5). Digital indicator on the graph is located at 24:14:50 minutes from start, but the data acquisition goes on through entire track.

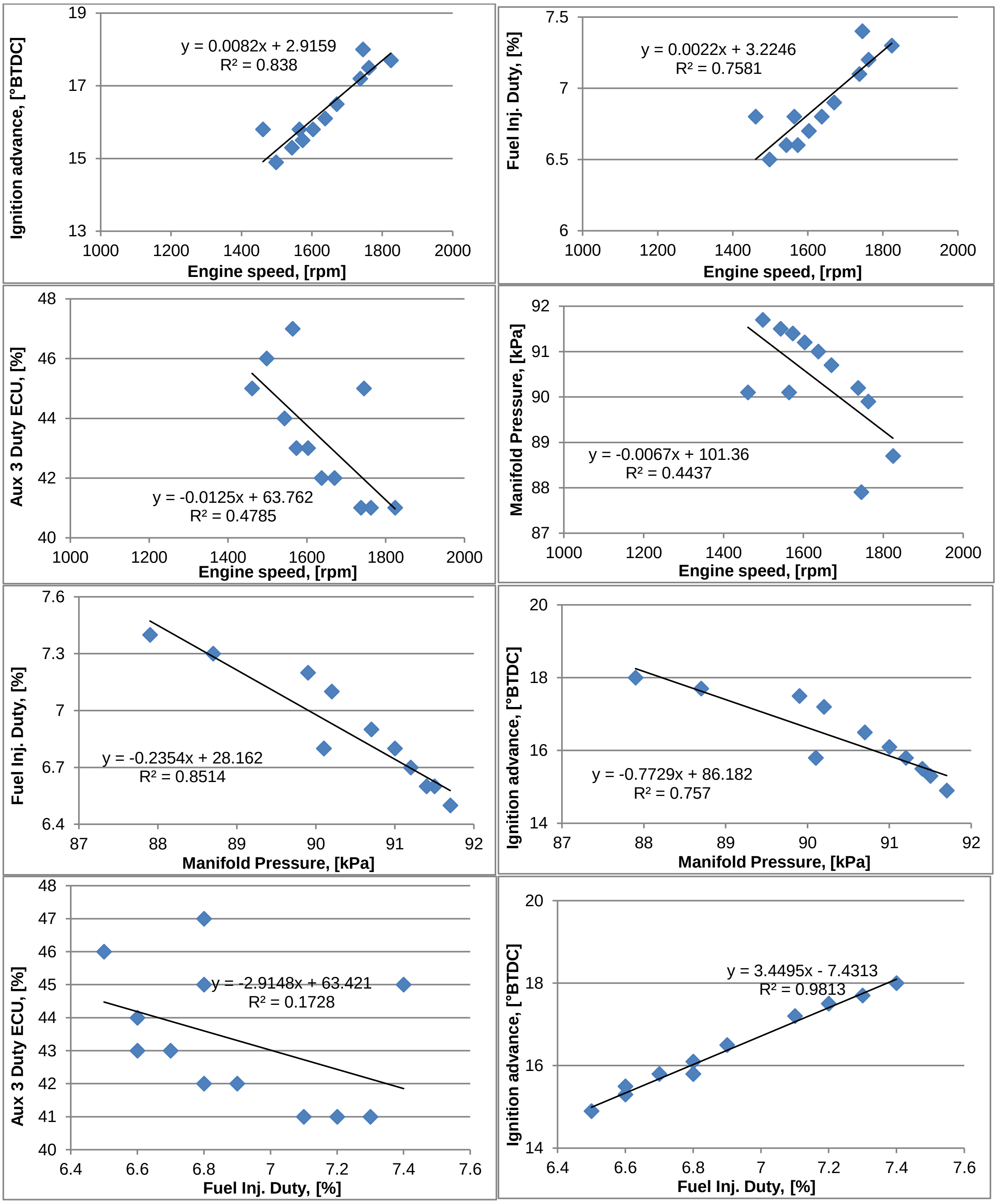

Fig. 5. Results of computer aided testing and measurements regarding fuel injection duty, air pressure in the intake manifold

The experimental measuring tests were developed on a Mitsubishi Lancer with technical details that are given in the table 1.

Table 1: Engine technical details

Parameter	Actual Value	Unit of measurement
Model Production Duration	March 2005 – January 2007 & 2008	year
Body and chassis - Platform	CT9A	-
Powertrain - Engine	2.0 L 4G63T I4 Turbocharged	-
Powertrain - Transmission	6-speed manual	gears
Wheelbase	2625	mm
Length	4490	mm
Width	1770	mm
Height	1450	mm
Weight	1350	kg

After considering the measurements and trend-lines of the recorded values some observations and conclusions are drawn.

4. Conclusions

In this technical paper, were studied the performances of multiple hydraulic or fluid lines, electrical and digital controlled, and process features in fuel supply and mixture ignition management in relation with the engine speed, injection duty, spark advance angle and intake manifold pressure.

The highest ignition advance (at 18°BTDC) was found for the 88.9 kPa manifold pressure of the intake air with 7.4% fuel injection duty, while the lowest spark ignition advance was found for the 6.5% fuel injection duty with 91.75 kPa intake air manifold pressure.

The highest manifold pressure (at 91.8 kPa) was found for the 1480 rpm and 15°BTDC ignition advance, while the lowest intake air manifold pressure was found for the highest ignition advance.

The lowest fuel injection duty was found for the 14.9°BTDC ignition advance angle, while the maximum fuel injection duty was found for the operating regime with 18°BTDC ignition advance.
This research study has performed an elaboration of the testing and measurement procedure correlated with the fuel system with variable parameters applied in automotive sector on the rally cars. Computer aided testing and evaluation was realized to predict the trend-line of fluid dynamics and ignition advance behaviour of fuel injection system, corresponding to different operation scenarios, in order to improve the overall systemic performance for a feasible strategy within a prescribed context.

A new possible strategy to improve the port fuel injection systems for performance regimes in rally powertrains can be developed through the application of an adapted solution for optimized correlation between ignition advance angle and manifold intake pressure and charge instead of the conventional mapping. A digital tuning of the engine's electronic management module in fuel supply maps is beneficial in order to a better definition of quantities sprayed on the intake port. It leads to an improved mixture quality and thus to a better combustion process if properly adapted with spark ignition advance during each operational cycle.

The experimental results revealed that the optimal economical and best performance regime (situated for this specific case at 16°BTDC ignition advance angle) provides a lower fuel quantity sprayed on the intake port and higher heat release ratio than the 18°BTDC regime, and thus leads to better average working performance and an alternative to run in time conditioned situations. Defining of the optimal working model with the minimum number of experimental tests and measurements through the tracing of evolution equations, trend-lines and the adapted value would also be known as engine electronic control module tuning objectives with the future researches.

Financial disclaimer: The authors have no financial or ownership benefits in any systems or components specified.
Competition interests: The paper’s authors declare that they have no considerable inherent economic, professional or personal profits that could have determined the outputs or trend-lines of the analyze presented in this paper.

References

[1] Basshuysen, R. van. *Gasoline Engine with Direct Injection. Processes, Systems, Development, Potential*. Wiesbaden, Vieweg+Teubner, GWV Fachverlage GmbH, 2009.
[2] Băldean, Doru, Nicolae Vlad Burnete, Dan Moldovanu, Ferenc Gaspar, Adela-Ioana Borzan, and Mihai-Aurel Crișan. “Experimental Research Regarding the Possibility of Biofuel Fumigation Supply Method on a Single Cylinder Compression Ignited Engine.” Paper presented at the 12th International Congress of Automotive and Transport Engineering CONAT-2016, Brasov, Romania, October 26-29, 2016.
[3] Bățaga, N., et al. *Internal combustion engines/Motoare cu ardere internă*, ISBN 973-30-4922-0. București, Didactic and Pedagogical Publishing House, 1995, pp. 182÷189.
[4] Cordoş, N., et al. *Automobiles.Construction.Wear.Evaluation/Automobile.Construcţie.Uzare.Evaluare.* Cluj-Napoca, Todesco Publishing House, 2000.
[5] Ferenți, Iosif and Doru-Laurean Băldean. *Artificial intelligence implemented in rally vehicles pentru increasing energetic efficiency in competitions/Inteligența artificială implementată în autovehicule de raliuri pentru creșterea eficienței energetice în competiții*, May 29, 2018. Accessed June 3, 2018. https://stiintasiinginerie.ro/34-18-inteligenta-artificiala-implementata-in-autovehicule-de-raliuri-pentru-cresterea-eficientei-energetice-in-competitii/.
[6] Ferenți, Iosif and Doru-Laurean Băldean. *The analyze of specific parameters for spark ignited engine operational cycle depending on altitude/Analiza mărimilor specifice ciclului funcțional al unui motor cu aprindere prin scânteie în raport cu altitudinea*, January 31, 2015. Accessed June 3, 2018. http://stiintasiinginerie.ro/26-46-analiza-marimilor-specifice-ciclului-functional-al-unui-motor-cu-aprindere-prin-scanteie-in-raport-cu-altitudinea/.
[7] Ferenți, I., Adela-Ioana Borzan, D.-L. Băldean, and Ioan-Aurel Chereches. *Analizing a thermal management solution of engine as embedded technology in rally vehicles*/*Analiza unei soluții de management termic al motorului ca tehnologie integrată în autovehiculul de raliu*, May 3, 2017. Accessed June 3, 2018. https://stiintasiinginerie.ro/31-58-analiza-unei-solutii-de-management-termic-al-motorului-ca-tehnologie-integrata-in-autovehiculul-de-raliu/.
[8] Toader, G.-V., Chereches A.-I., Kocsis L.-B., Gaspar F. and Adela-Ioana Borzan. *Contributions to the experimental research of injection fuel supply system from 3.0i engine of BMW X5 road vehicles/ Contribuții la cercetarea experimentală a parametrilor sistemului de alimentare prin injecție de la motorul 3.0i al automobilului BMW X5*, May 4, 2017. Accessed June 5, 2018. https://stiintasiinginerie.ro/31-70-contributii-la-cercetarea-experimentala-a-parametrilor-sistemului-de-alimentare-prin-injectie-de-la-motorul-3-0i-al-automobilului-bmw-x5/.
[9] ***. *Mitsubishi Lancer Evolution*, May 4, 2017. Accessed June 5, 2018. https://stiintasiinginerie.ro/31-70-contributii-la-cercetarea-experimentala-a-parametrilor-sistemului-de-alimentare-prin-injectie-de-la-motorul-3-0i-al-automobilului-bmw-x5/.