LOGI – Scientific Journal on Transport and Logistics
Vol. 13 No. 1 2022 DOI: 10.2478/logi-2022-0013
© 2022 J. Caban *et al.* This is an open access article licensed under the Creative Commons Attribution-NonCommercial-NoDerivs License (http://creativecommons.org/licenses/by-nc-nd/3.0/).

The Performance of a Car with Various Engine Power Systems – Part II

Viktor Slavin[1], Yevheniy Shuba[2], Jacek Caban[3*], Jonas Matijosius[4], Alfredas Rimkus[4], Anatolii Korpach[2] and Serhiy Gutarevych[2]

[1]*Chernivtsi Research Forensic Center Ministry of Internal Affairs of Ukraine, Chernivtsi, Heroes of the Maidan Str. 77D, Ukraine, Email: slavinmail@ukr.net*
[2]*National Transport University, Faculty of Automotive and Mechanical Engineering, 01010 Kyiv, Mykhaila Omelianovycha-Pavlenka Str. 1, Ukraine, Email: shuba@ntu.edu.ua*
[3]*Lublin University of Technology, Faculty of Mechanical Engineering, 20-618 Lublin, Nadbystrzycka Str. 36, Poland; Email: j.caban@pollub.pl*
[4]*Vilnius Gediminas Technical University, Faculty of Transport Engineering, LT-03224 Vilnius, J. Basanavičiaus Str. 28, Lithuania, Email: jonas.matijosius@vilniustech.lt; alfredas.rimkus@vilniustech.lt*

***Corresponding Author:** Jacek Caban

Received: 23 February 2022; Revised: 23 March 2022; Accepted: 22 May 2022; Published: 25 August 2022

Abstract: Reducing exhaust emissions from motor vehicles has become a major task in the design of modern motor vehicles. Internal combustion engines, despite the increasingly frequent restrictions on, for example, entry to city centers, still constitute the majority of the used motor vehicles. For these reasons, it is very important to properly operate and control the used motor vehicles, especially in the field of exhaust emissions. One way is to replacement of the vehicle fleet and individual cars with newer generation vehicles. Unfortunately, due to economic differences in the world, the rolling stock replacement process is not the same in all countries. However, despite these differences, even in less developed countries, efforts are being made to reduce vehicle emissions. This work presents road, bench and computational comparative tests of the fuel, economic, environmental and energy characteristics of a series car with a standard carburetor supply system and equipped with an electronic gasoline injection system and a three-component catalyst under operating conditions.

Keywords: Gasoline engine, injection system, fuel economy, European urban ride cycle.

1. Introduction

Currently, the automotive industry is undergoing major changes related to the development of internal combustion engines, especially in terms of ensuring lower and lower levels of exhaust emissions. The development of internal combustion engines is visible in the improvement of their

design [1,2] and the improvement of the combustion process in a spark-ignition engine and a diesel engine [3-6]. A lot of research is carried out in the area of using various fuels to power internal combustion engines. Among these studies, it is worth mentioning the works related to the use of popular gaseous fuels such as LPG [7,8], biogas [9], natural gas [10,11], CNG and LNG [12-15]. Interesting studies were presented as alternative fuels for diesel fuel, inter alia, in early [16] and newer papers [17-19]. The issues of biofuel production were also the subject of research in the following works [20,21]. Development and operational tests are also ongoing in the case of other operating fluids. In this regard, it is worth mentioning the tests of engine oils [22-24] and brake fluids [25].

Many scientific works have been devoted to the issues of exhaust emissions, including [26-30]. One way to reduce emissions is to replace the fleet of trucks and private cars with newer generation vehicles. This solution is good in less developed countries, where the inflow of the latest technologies related to, for example, electric vehicles. As already mentioned, the most effective seems to be replacing the carburetor system with a modern gasoline injection system with a system for reducing the toxicity of the three main harmful components: carbon monoxide CO, hydrocarbons CmHn, nitrogen oxides NOx. Neutralization systems consist of devices that provide more than 90% effective cleaning of engine exhaust gases from toxic components [29]. As is known, the efficiency of a three-component catalyst is influenced by the composition of the air-fuel mixture. For this causes, in this study, it was proposed to change the fuel supply system of a spark-ignition engine operated in large numbers of older vehicles in Ukraine. The first part of the article [30], presents the theoretical basis, research methodology and a laboratory test stand, in this part we present the more obtained results.

2. Data and Methods

The tests were carried out on the VAZ-21051 passenger car with a carburetor engine, model 2101, widely used in Ukraine. Adaptive electronic injection system LH-Motronic was selected as the injection system. As a device for reducing exhaust toxicity, a modern three-component catalytic converter is used. To study the engine performance, we used a stationary loading stand SGEU-55 with a three-phase current motor, 55 kW power and a nominal rotor speed of 3000 rpm, which is actuated from the control panel. Fuel consumption was determined by weight. The torque *Mk* is determined by an electric dynamometer, its pulses, which were converted from electric to analog, watched the current value of *Mk*. Air flow rate was determined by a rotary WG-100-1 volumetric gas meter. To measure the NO_x content of the exhaust gas, a 344-CL-14 gas analyzer was used, which implemented a chemiluminescent method. To determine the concentrations of CO, CHH and CO_2 in the exhaust gases of the engine, the gas analyzer META Autotest-01.03 was used.

Measuring range for CO – 0...7%; C_mH_n – 0…3000 mln^{-1}; CO_2 – 0...16%. During the experimental studies, a series of loading characteristics, speed characteristics of active idling of the engine with different power systems were obtained.

3. Results and Discussion

This section presents comparative tests of a spark ignition engine equipped with a standard fuel supply and injection system in terms of engine operation in laboratory test stand (Fig. 1.).

The measurement uncertainty during bench and road vehicle studies with different power systems showed the following errors (Table 1).

Table 1 Measurement errors. Source: authors

Engine test bench			Road tests	
	Power [kW]	Specific fuel consumption [g/kWh]	Carburetor	Injection system
			Fuel consmuption [dm^3/100 km]	
			Average speed [km/h]	
Bonduary absolute error	0.217	± 16.18	0.528	0.366
			1.989	2.321
Bonduary relative error	± 1.293%	± 0.481%		
Rms absolute error	± 0.072	± 5.393	± 0.176	± 0.122
			± 0.663	± 0.773
Rms relative error	± 0.431%	± 0.16%		
The most likely absolute error	± 0.048	± 3.595	± 0.118	± 0.082
			± 0.447	± 0.522
The most probable relative error	± 0.287%	0.106%	$\pm 1.49 \cdot 10^{-2}$	$\pm 1.117 \cdot 10^{-2}$
			$\pm 1.41 \cdot 10^{-2}$	$\pm 1.7 \cdot 10^{-2}$



Fig. 1 The car during the simulation of the driving cycle. Source: authors

According to the results of the conditional movement of the car on a dynamometer, the fuel consumption value is obtained (Table 2).

Table 2 Fuel consumption in the European Driving Cycle. Source: authors

Performance of the car	Value
Fuel consumption G_{cycle} [g/cycle]	74.29
Fuel consumption G_f [dm^3/100 km]	9.84
Test duration – t [s]	194
Average speed – V [km/h]	18.79
The path – S [m]	1025.5

A fragment of the results of the fuel flow measurement with the injection system is shown in Fig. 2.

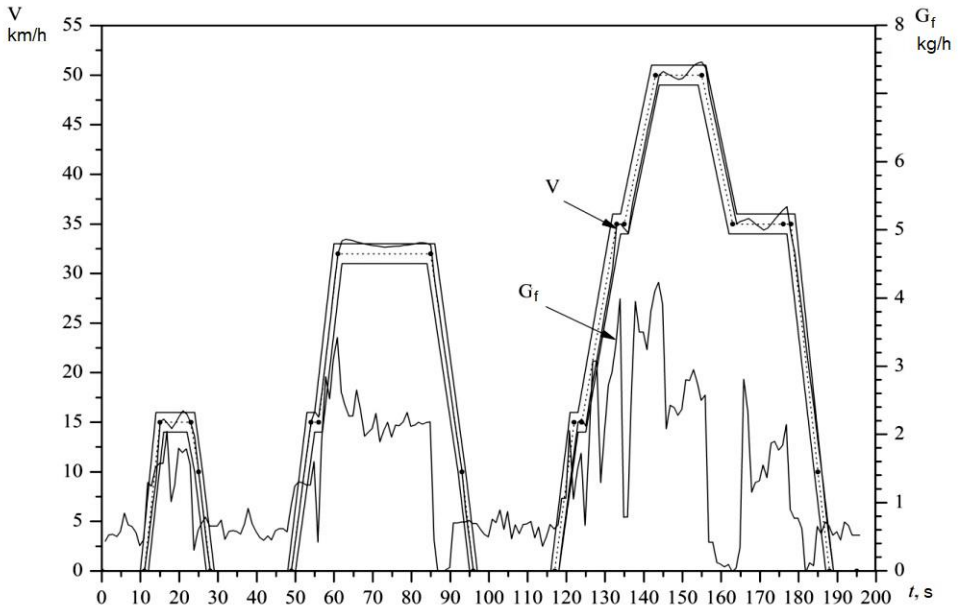


Fig. 2 Fragment of a car movement on a driving cycle. Source: authors

The specific emissions of harmful substances (g/km) during the driving cycle on the roller stand were determined using the HORIBA model full-flow exhaust gas mixing system (Constant volume system) and the MEXA7400DEGR gas analytic system.

Depending on the test program, a continuous measurement of concentrations of: CO, CO_2, NO_x, HC. Exhaust gas in the ride cycle mixed with ambient air. Specific concentrations of harmful substances in the environment (background level) and volume of diluted exhaust gas over the test period were determined by the specific emissions of gaseous substances (g/km).

The input data for the calculation of the specific mass emissions of substances (g/km) based on the results of the car movement along the driving cycle are given in Table. 3.

Table 3 Results of measured concentrations of substances per test. Source: authors

European driving cycle (City cycle number)	Value			
	CO [ppm]	THC[1] [ppm]	NO_x [ppm]	CO_2 [%]
No 1-2	290.99	154.39	34.85	0.83
Background levels of harmful substances in two cycles	2.55	8.18	0.00	0.05
No 3-4	24.52	49.18	20.09	0.72
Background levels of harmful substances in two cycles	1.39	7.26	-0.03	0.05

[1] THC – total hydrocarbons.

To calculate the amount of harmful substances in the exhaust gas, the concentration was taken for cycles 3 and 4. Emission mass (g/km) for the test was determined by the formula:

$$M_i = \frac{V_{mix} \cdot Q_i \cdot K_h \cdot C_i \cdot 10^{-6}}{d}, \quad (1)$$

where: *Mi* is mass of emissions of pollutant i-th substance [g/km]; *Vmix* is the amount of diluted exhaust gas expressed in m3/h for the test period; *Qi* is density of contaminant i-th substance under normal physical conditions [g/cm3]; *Kh* is the humidity correction required to calculate the NOx mass emissions; *Ci* is the concentration of the pollutant i-th substance in the diluted exhaust gas [ppm], and adjusted by the amount of pollutant i-th substance in the air for mixing [ppm]; *d* is the distance traveled by the vehicle within the operating cycle [km].

The specific emissions of harmful substances for the test are given in Table 4. The table shows that the specific emissions of harmful substances of the car with the injection system do not exceed the permissible normalized values of the i-th substance, which confirm its compliance with the environmental standards of the level Euro-2. Subsequent tests were to determine the urban vehicle's fuel consumption. During road tests, fuel consumption was measured with a volumetric fuel flow meter. The length of the route was 6 km. For both power systems, 7 comparative races were conducted at the same time for two days.

Table 4 Calculated environmental performance of the vehicle over the European Driving Cycle, with injection system [g/km]. Source: authors

Performance of the car	Euro-2 norms [g/km]	Injection system
G_{CO}	2.2	1.08
G_{CmHn}	$\Sigma C_mH_n + NO_x = 0.5$	0.21
G_{NOx}		0.17
G_{CO2}	-	211.52
$G_{\Sigma CO}$	-	8.93

The results of the road tests characterizing the fuel economy of the car are shown in Table 5. The Table 5 shows that the use of the injection system reduces fuel consumption in urban environments by an average of 7.3%.

Table 5 Test results of the car in city conditions. Source: authors

check in	Injection system			Carburetor			Qs [%]
	Qs [dm^3/100 km]	V [km/h]	t_{av} [s]	Qs [dm^3/100 km]	V [km/h]	t_{av} [s]	
	7.948	27.238	793	7.292	33.23	650	
2	7.380	29.916	722	8.579	28.761	751	
3	7.065	32.238	670	8.440	31.395	688	
4	7.544	31.718	681	8.037	33.23	650	
5	7.204	29.15	741	8.049	29.875	723	
6	7.443	31.0	697	7.683	32.628	662	
7	7.002	33.282	649	7.570	32.628	662	
Average	7.37	30.65	707.571	7.95	31.678	683.714	-7.3%
σ_x 1)	±0.122	±0.773	±18.441	±0.176	±0.663	±14.884	
ρ_x 2)	±0.082	±0.522	±12.438	±0.118	±0.447	±10.039	
σ_{max} 3)	0.366	2.321	55.324	0.528	1.989	44.654	
δ 4)	$\pm 1.117 \cdot 10^{-2}$	$\pm 1.7 \cdot 10^{-2}$	$\pm 1.75 \cdot 10^{-2}$	$\pm 1.49 \cdot 10^{-2}$	$\pm 1.41 \cdot 10^{-2}$	$\pm 1.468 \cdot 10^{-2}$	

1) Mean-absolute error;
2) Part of the rms error;
3) Boundary absolute error;
4) Relative error.

Steady motion of the car was performed at an interval of 20 km/h, with the initial speed was 20 km/h, and the final 100 km/h, which are common in operating conditions, as shows in Fig. 3.

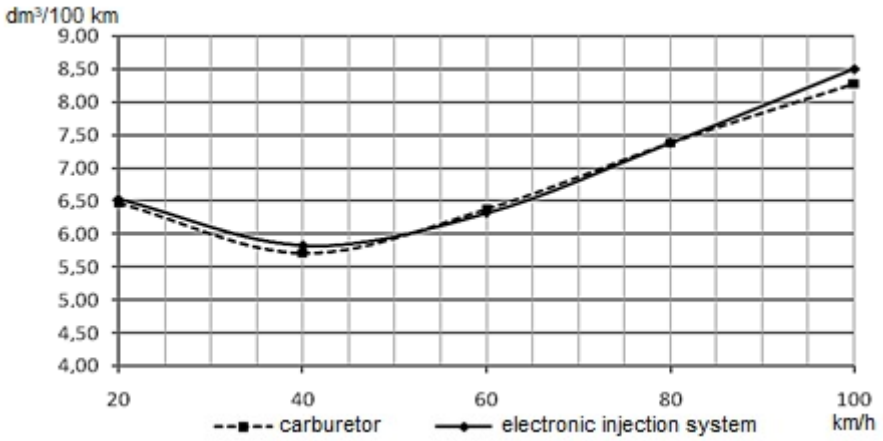


Fig. 3 Fuel characteristics of the car. Source: authors

As can be seen from Fig. 3, the dependences of the specific fuel consumption in steady motion coincide. Due to its performance, technically sound and adjustable according to the manufacturer's recommendations, the carburetor consumes no more gasoline than the electronic injection system at constant speed.

It is known that the type of power system affects the engine power, characterizing the traction and speed properties of the car. To test this, comparative studies were conducted to determine the acceleration of the vehicle to 90 km/h with a carburetor and injection system at intermediate throttle position (= 70%), which is widely used in operating conditions. The results of the road tests are shown in Table 6. As can be seen from these data, the transition to the injection system reduces the acceleration time by 4.81%, while the fuel consumption for acceleration is reduced by 7.75%.

Table 6 Results of the car acceleration dynamics study. Source: authors

Check in	Carburetor		Injection system		Change parameters [%]	
	Average time [s]	Average fuel consumption [cm^3]	Average time [s]	Average fuel consumption, [cm^3]	Time [s]	Fuel consumption [cm^3]
1	24.09	68.3	22.93	63	4.81%	7.75%
2	24.50	73	23	60		
3	23.75	72	23.48	70		
4	24.08	64	22.61	60		
5	24.29	67	23.55	63		
6	23.54	67	22.58	60		
7	24.42	67	22.41	65		
Average	24.095	68.328	22.94	63		
σ_x	0.132	0.877	0.203	1.380		

After making changes to the mathematical model, the comparative figures of a car with different power systems when driving under the modes of the European driving cycle were calculated. As an example, a graphical representation of the hourly fuel consumption (G_f) is shown in Fig. 4. From Fig. 4 it can be seen that the fuel consumption is lower when the injection system is used, in particular in idle, steady-state and forced-idle modes. In the Table 7 presents the results of the calculation of fuel consumption by a mathematical model of a car with a carburetor system and an injection system when driving according to the modes of the European Driving Cycle.

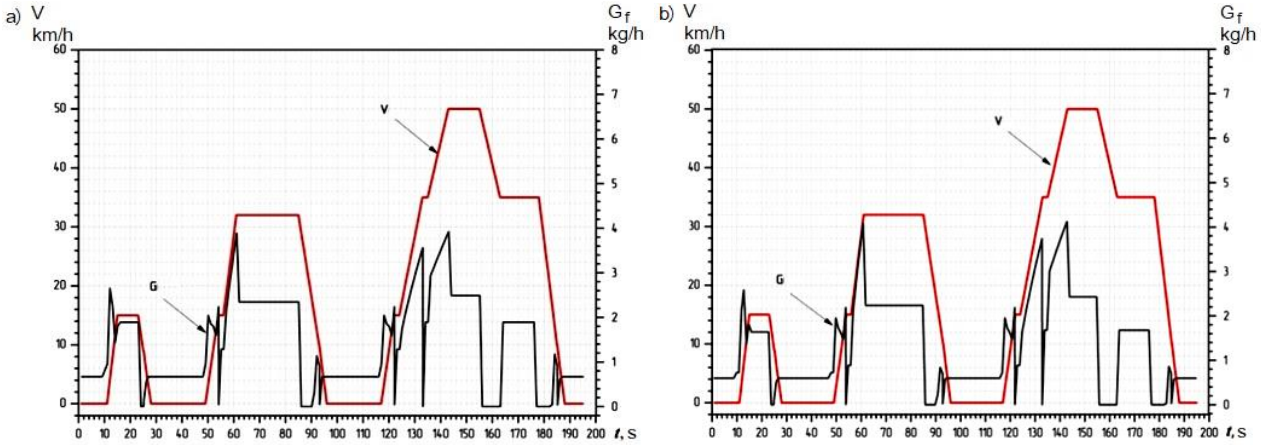


Fig. 4 Dependence of fuel consumption on the mode of movement of the car in the urban cycle: a) carburetor b) injection system. Source: authors

Table 7 Results of calculation studies of the fuel consumption of the car while driving on the European Driving Cycle. Source: authors

Indicators	System type		Change indicators [%]
	Carburetor	Injection system	
Fuel consumption, G_{cycle}, g/cycle	78.624	73.56	6.44
Fuel consumption, G_f, dm^3/100 km	10.489	9.813	6.44

As you can see, the fuel consumption is lower with the petrol injection system. Fuel consumption by a vehicle depends on many factors, technical, road, technical condition of the engine and accessories as well as other vehicle systems [32,33,34]. The results of the calculation of the mathematical model of environmental performance of the car in motion according to the modes of the European driving cycle are shown in Table 8.

Table 8 Estimated performance of a car with different engine power systems in motion European Driving Cycle [g/km]. Source: authors

Indicators	Euro-2, emission rate, g/km	Power System Type	
		Carburetor	Injection system
G co	2.2	8.94	1.434
G c_mH_n	$G\ c_mH_n + G_{Nox} = 0.5$	0.27	0.19
G_{Nox}		0.49	0.157
G_{CO2}	-	213	237.822
Total pollutants reduced to the level of CO aggressiveness	-	29.98	8.493

Table 8 shows that the obtained results indicate a significant reduction in the emission of all harmful substances after replacing the carburetor with the injection system. Total emissions that are reduced to the level of CO aggressiveness have decreased by 3.5 times. Therefore, the neutralization system works most effectively with the injection system. Comparative studies of the car with different power systems and exhaust gas neutralization systems have shown that the use of electronic feedback systems, unlike carburetor systems, will provide an environmental level of the Euro-2 and reduce the socio-economic damage by 3.5 times.

4. Conclusion

Comparative studies of the gasoline engine on the loading stand with different power systems showed that the engine with the injection system allows to reduce fuel consumption, on average by the characteristic of idling, by 11.1%, by the loading characteristic by an average of 5%, and the energy performance of the engine increased full load, capacity increased by 6.6%.

The experimental data obtained during the test on a simulator roller stand under the modes of the European Urban Ride Cycle indicate an increase in the environmental level of the engine car

with an injection system and a lower fuel consumption per cycle compared to a regular engine power system. Comparative tests of the VAZ-21051 with a regular power system and gasoline injection system showed that the use of the injection system reduces urban fuel consumption by 7.3%. When driving at a constant speed, fuel consumption is the same for both power systems. The acceleration dynamics of the car are improved with the engine's gasoline injection system. The transition to the injection system reduces the acceleration time by 4.81%, while the fuel consumption for acceleration is reduced by 7.75%.

References

[1] Kukuča, P., Barta, D., Labuda, R. & Gechev, T. (2018). Engine with unconventional crank mechanism FIK1. MATEC Web of Conferences 244, 03004. DOI: 10.1051/matecconf/201824403004.

[2] Mieczkowski, G., Szpica, D., Borawski, A., Diliunas, S., Pilkaite, T. & Lesis, V. (2021). Application of smart materials in the actuation system of a gas injector. Materials 14(22), 6984. DOI: 10.3390/ma14226984.

[3] Babadi, M.N., Kheradmand, S. & Bae, C. (2020). Experimental and computational investigation of diesel and gasoline injection in a direct injection compression ignition engine. International Journal of Automotive Technology 21(1), 23–32. DOI: 10.1007/s12239-020-0003-1

[4] Aulin, D., Klymenko, O., Falendysh, A., Kletska, O. & Dizo, J. (2020). Improvement of diesel injector nozzle test techniques. IOP Conference Series: Materials Science and Engineering 985(1), 012031. DOI: 10.1088/1757-899X/985/1/012031.

[5] Droździel, P. (2008). The influence of the vehicle work organization conditions on the engine start-up parameters. Eksploatacja i Niezawodnosc – Maintenance and Reliability 37(1), 72-74.

[6] Eliasz, J., Osipowicz, T., Abramek, K.F., Matuszak, Z. & Mozga, L. (2020). Fuel pretreatment systems in modern ci engines. Catalysts 10(6), 696. DOI: 10.3390/catal10060696.

[7] Szpica, D. (2018). Investigating fuel dosage non-repeatability of low-pressure gas-phase injectors. Flow Measurement and Instrumentation 59, 147-156. DOI: 10.1016/j.flowmeasinst.2017.12.009.

[8] Šarkan, B., Jaśkiewicz, M., Kubiak, P., Tarnapowicz, D. & Loman, M. (2022). Exhaust emissions measurement of a vehicle with retrofitted LPG system. Energies 15(3), 1184. DOI: 10.3390/en15031184.

[9] Wierzbicki, S. & Śmieja, M. (2018). Use of biogas to power diesel engines with common rail fuel systems. 17th International Conference Diagnostics of Machines and Vehicles, MATEC Web of Conference 182, 01018. DOI: 10.1051/matecconf/201818201018.

[10] Ding, S.L., Song, E.Z., Litak, G., Yang, L.P., Wang, Y.Y. & Ma, X.Z. (2017). Analysis of chaos in the combustion process of premixed natural gas engine. Applied Thermal Engineering 121, 768-778. DOI: 10.1016/j.applthermaleng.2017.04.109.

[11] Lebedevas, S. & Čepaitis, T. (2021). Parametric analysis of the combustion cycle of a diesel engine for operation on natural gas. Sustainability 13(5), 2773. DOI: 10.3390/su13052773.

[12] Biały, M., Wendeker, M., Magryta, P., Czyż, Z. & Sochaczewski, R. (2014). CFD model of the mixture formation process of the CNG direct injection engine. SAE Technical Papers 109725. DOI: 10.4271/2014-01-2575.

[13] Dziewiątkowski, M. & Szpica, D. (2021). Evaluation of the conversion rate regarding hydrocarbons contained in the exhaust eases of an engine fuelled with compressed natural gas (CNG) using different catalysts operating at different temperatures. Mechanika 27(6), 492-97.

[14] Jurkovic, M., Kalina, T., Skrucany, T., Gorzelanczyk, P. & Luptak, V. (2020). Environmental impacts of introducing LNG as alternative fuel for urban buses - case study in Slovakia. Promet-Traffic & Transportation 32(6), 837-847. DOI: 10.7307/ptt.v32i6.3564.

[15] Langshaw, L., Ainalis, D., Acha, S., Shah, N. & Stettler, M.E. (2020). Environmental and economic analysis of liquefied natural gas (LNG) for heavy goods vehicles in the UK: A Well-to-Wheel and total cost of ownership evaluation. Energy Policy 137, 111161. DOI: 10.1016/j.enpol.2019.111161.

[16] Labaj, J. & Barta, D. (2006). Unsteady flow simulation and combustion of ethanol in diesel engines. Komunikacie 8(2), 27-37.

[17] Duda, K., Wierzbicki, S., Mikulski, M., Konieczny Ł., Łazarz, B. & Letuń-Łątka, M. (2021). Emissions from a medium-duty crdi engine fuelled with diesel-biodiesel blends. Transport Problems 16(1), 39-49. DOI: 10.21307/tp-2021-004.

[18] Górski, K., Sander, P. & Longwic, R. (2018). The assessment of ecological parameters of diesel engine supplied with mixtures of canola oil with n-hexane. IOP Conference Series: Materials Science and Engineering 421(4), 042025. DOI: 10.1088/1757-899X/421/4/042025.

[19] Hunicz, J., Mikulski, M., Shukla, P.C. & Gęca, M.S. (2022). Partially premixed combustion of hydrotreated vegetable oil in a diesel engine: Sensitivity to boost and exhaust gas recirculation. Fuel 307, 121910. DOI: 10.1016/j.fuel.2021.121910.

[20] Orynycz, O. & Świć, A. (2018). The Effects of material's transport on various steps of production system on energetic efficiency of biodiesel production. Sustainability 10(8), 2736. DOI: 10.3390/su10082736.

[21] Szmigielski, M., Zarajczyk, J., Węgrzyn, A., Leszczyński, N., Kowalczuk, J., Andrejko, D., Krzysiak, Z., Samociuk, W. & Zarajczyk, K. (2018). Testing the technological line for the production of alternative fuels. Przemysł Chemiczny 97(7), 1079-1082.

[22] Hurtová I., Sejkorová, M. & Verner, J. (2019). A study of diesel particulate filter impact on engine oil quality. Transport Means - Proceedings of the International Conference, 691-695.

[23] Sejkorova, M. & Hurtova, I. (2019). Engine oil analysis - effective instrument to evaluate reliability of tractor engines. Engineering for Rural Development 18, 971-976.

[24] Wolak, A., Zając, G. & Słowik, T. (2021). Measuring kinematic viscosity of engine oils: A comparison of data obtained from four different devices. Sensors 21(7), 2530. DOI: 10.3390/s21072530.

[25] Sejkorová, M., Verner, J., Sejkora, F., Hurtová, I. & Senkýř, J. (2018). Analysis of operation wear of brake fluid used in a Volvo car. Transport Means - Proceedings of the International Conference, 2018-October, pp. 592-596.

[26] Verner, J. (2021). Overview of the development of emission standards for the reduction of air pollution by nonroad mobile machinery (in Czech). Prener's Contacts 16, 2, DOI: 10.46585/pc.2021.2.1742.

[27] Wasilewski, J., Szyszlak-Bargłowicz, J., Zając, G. & Szczepanik, M. (2020). Assessment of CO_2 emission by tractor engine at varied control settings of fuel unit. Agricultural Engineering 24(4), 105-115. DOI: 10.1515/agriceng-2020-0040.

[28] Pielecha, J., Skobiej, K. & Kurtyka, K. (2020). Exhaust emissions and energy consumption analysis of conventional, hybrid, and electric vehicles in real driving cycles. Energies 13(23), 6423. DOI: 10.3390/en13236423.

[29] Kritsanaviparkporn, E., Baena-Moreno, F.M. & Reina, T.R. (2021). Catalytic converters for vehicle exhaust: fundamental aspects and technology overview for newcomers to the field. Chemistry 3(2), 630-646. DOI: 10.3390/chemistry3020044.

[30] Slavin, V., Shuba, Y., Caban, J., Matijosius, J., Rimkus, A., Korpach, A. & Gutarevych, S. (2022). The performance of a car with various engine power systems – part I. LOGI – Scientific Journal on Transport and Logistics 13(1), DOI: 10.2478/logi-2022-0012

[31] Šarkan, B., Hudec, J., Sejkorova, M., Kuranc, A. & Kiktova, M. (2021). Calculation of the production of exhaust emissions in the laboratory conditions. Journal of Physics: Conference Series 1736(1), 012022. DOI: 10.1088/1742-6596/1736/1/012022.

[32] Gutarevych, Y., Shuba, Y., Matijošius, J., Karev, S., Sokolovskij, E. & Rimkus, A. (2018). Intensification of the combustion process in a gasoline engine by adding a hydrogen-containing gas. International Journal of Hydrogen Energy 43, 16334-16343. DOI: 10.1016/j.ijhydene.2018.06.124.

[33] Jereb, B., Stopka, O. & Skrúcaný, T. (2021). Methodology for estimating the effect of traffic flow management on fuel consumption and CO2 production: A case study of Celje, Slovenia. Energies 2021, 14(6), 1673. DOI: 10.3390/en14061673.

[34] Skrucany, T., Stopková, M., Stopka, O., Kalašová, A. & Ovčiarik, P. (2021). User's determination of a proper method for quantifying fuel consumption of a passenger car with compression ignition engine in specific operation conditions. Open Engineering 11(1), 151-160. DOI: 10.1515/eng-2021-0018.