

Evaluation of Ethanol-Containing Fuel Supply Control Efficiency in Spark Ignition Engine

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Abstract

he article is devoted to investigation of fuel supply control efficiency in a spark ignition engine equipped with a catalytic converter during use of ethanol-containing fuels with different ethanol content. The study involves determining the efficiency of fuel supply controlling algorithm for the engine, which is powered by conventional petrol and non-adapted for using fuels with high ethanol content. Within the study the following fuels were used: petrol, ethanol and fuel blends with ethanol content varying from 15 to 90%. The efficiency of fuel supply control is evaluated in terms of providing the specified fuel-air mixture composition, fuel consumption and emissions in transient engine operation modes during vehicle motion in the driving cycle.

The data obtained during the engine bench tests using petrol and ethanol-containing fuels were used for evaluation. The data of the engine operation parameters measurements for transient vehicle motion modes under real road conditions are also used. Methods and experimental equipment are described.

An original designed test device was used during the vehicle road tests. The device allows controlling the on-board diagnostic system data (OBD-II standard) at certain time intervals and parameters of satellite system of vehicle positioning (GPS standard), transmit this data by wireless communication to the information device on vehicle control panel and store them. For this purpose, the information device has an original author application for processing and storing the received data.

Evaluation of the influence of the fuel supply controlling algorithm on the fuel consumption and emissions during use of different ethanol-containing fuels is carried out on the basis of vehicle performance in the driving cycle mathematical modeling. The description and features of mathematical model of the engine operating process are given. This model takes into account the available fuel supply controlling algorithm and ethanol content in the fuel.

The dependencies of fuel consumption and exhaust gases emissions for the vehicle motion in the driving cycle using the studied fuel compositions, obtained using mathematical modeling, are presented.

Introduction

problem of improvement motor transport environmental performance under operating conditions can be solved by using ethanol-containing fuel (ECF) [1] due to biological origin of some ECF components, in particular ethanol. Biological origin ethanol is obtained from vegetable feedstock, which consumes carbon dioxide from atmosphere during its life cycle. So, the biological origin ethanol (bioethanol) using as a motor fuel does not break a natural balance of carbon dioxide. This statement is correctly if electrical energy from coal-fired stations is not used for ethanol producing process. Moreover, the life cycle analysis of bioethanol production from waste paper shows that this production

method allows to reduce carbon dioxide emissions by almost 80% compared to waste paper processing in landfills [2]. Also, the use of petrol-ethanol mixtures can directly reduce carbon dioxide emissions from motor transport. Studies show that the use of petrol-ethanol mixtures in spark ignition engines leads to significant reduction of carbon dioxide ($\rm CO_2$) emissions when ethanol content in fuel blends is about 50% or more [3]. However, this significantly increases the mass and volume consumption of blended fuel.

So, bioethanol is considered as full or partial substitute for petroleum fuels. This reduces petroleum fuels demand, and can address fuel availability concerns. The significant effect of ethanol adding on petrol octane number, saturated fuel consumption and emissions in transient engine modes with different dynamics of engine speed and load. Modeling of fuel consumption and harmful emissions by the vehicle for its motion in the UNECE № 83-05 driving cycle using these fuels was also performed. According to the research results, it was found that use of fuel with ethanol content of more than 50% is not appropriate. It mainly leads to reduction of the engine and vehicle performance. The reasons for reduction are decrease of the fuel heat of combustion and the low adaptation of engine control parameters to the use of ethanol-containing fuels in transient modes. It is possible to improve performance of the vehicle with engine non-adapted to ECF use by changing of the engine control system characteristics. This is planned for the further research.

References

- Boichenko, S.V., Pavliukh, L.I., Shkilniuk, I.O., Yakovlieva, A.V., Matvieieva, I.V., and Hudz, A.V., "Analysis of Ecological Properties of Traditional and Alternative Aviation Gas Components," *Science-Based Technologies* 42, no. 2 (July 29, 2019): 195-206. doi:10.18372/2310-5461.42.13752.
- Leung, D.Y.C., Yu, L.C., Lam, G.C.K., Kwok, H.Y.H. et al., "Bioethanol: Is it a Suitable Biofuel for Hong Kong for Reducing its Vehicular Emissions and Carbon Footprint?" *Energy Procedia* 142 (December 2017): 2892-2897, doi:10.1016/j.egypro.2017.12.413.
- 3. Bielaczyc, P., Woodburn, J., Szczotka, A., and Pajdowski, P., "The Impact of Alternative Fuels on Fuel Consumption and Exhaust Emissions of Greenhouse Gases from Vehicles Featuring SI Engines," *Energy Procedia* 66 (2015): 21-24, doi:10.1016/j.egypro.2015.02.011.
- 4. Boichenko, S.V., Yakovlieva, A.V., Tselishchev, O.B., Lanetsky, V.G. et al., "Modification of Motor Gasoline with Bioethanol in the Cavitation Field," *Catalysis and Petrochemistry* 30 (2020): 56-65, doi:10.15407/kataliz2020.30.056.
- Efemwenkiekie, U.K., Oyedepo, S.O., Idiku, U.D., Uguru-Okorie, D.C. et al., "Comparative Analysis of a Four Stroke Spark Ignition Engine Performance using Local Ethanol and Gasoline Blends," *Procedia Manufacturing* 35 (2019): 1079-1086, doi:10.1016/j.promfg.2019.06.060.
- Barakat, Y., Awad, E.N., and Ibrahim, V., "Fuel Consumption of Gasoline Ethanol Blends at Different Engine Rotational Speeds," *Egyptian Journal of Petroleum* 25, no. 3 (September 2016): 309-315, doi:10.1016/j. ejpe.2015.07.019.
- Iodice, P. and Senatore, A., "Cold Start Emissions of a Motorcycle using Ethanol-Gasoline Blended Fuels," *Energy Procedia* 45 (2014): 809-818, doi:10.1016/j.egypro.2014.01.086.
- 8. Sakai, S. and Rothamer, D., "Effect of Ethanol Blending on Particulate Formation from Premixed Combustion in Spark-Ignition Engines," *Fuel* 196 (May 2017): 154-168, doi:10.1016/j.fuel.2017.01.070.
- Sakai, S. and Rothamer, D., "Impact of Ethanol Blending on Particulate Emissions from a Spark-Ignition Direct-Injection

- Engine," *Fuel* 236 (January 2019): 1548-1558, doi:<u>10.1016/j.fuel</u>.2018.09.037.
- Fahrenbruch, A. and Bachmann, J., "Ethanol Sensors for Flex Fuel Operation," MTZ Worldwide 69, no. 9 (September 2008): 46-49, doi:10.1007/bf03227915.
- 11. Marques, D.O., Trevizan, L.S.F., Oliveira, I.M.F., Seye, O. et al., "Combustion Assessment of an Ethanol/gasoline Flex-Fuel Engine," *Journal of the Brazilian Society of Mechanical Sciences and Engineering* 39, no. 4 (July 29, 2016): 1079-1086, doi:10.1007/s40430-016-0609-4.
- 12. Dardiotis, C., Fontaras, G., Marotta, A., Martini, G. et al., "Emissions of Modern Light Duty Ethanol Flex-Fuel Vehicles over Different Operating and Environmental Conditions," *Fuel* 140 (January 2015): 531-540, doi:10.1016/j. fuel.2014.09.085.
- 13. Deng, X., Chen, Z., Wang, X., Zhen, H. et al., "Exhaust Noise, Performance and Emission Characteristics of Spark Ignition Engine Fuelled with Pure Gasoline and Hydrous Ethanol Gasoline Blends," *Case Studies in Thermal Engineering* 12 (September 2018): 55-63, doi:10.1016/j.csite.2018.02.004.
- Suarez-Bertoa, R., Zardini, A.A., Keuken, H., and Astorga, C., "Impact of Ethanol Containing Gasoline Blends on Emissions from a Flex-Fuel Vehicle Tested over the Worldwide Harmonized Light Duty Test Cycle (WLTC)," Fuel 143 (March 2015): 173-182, doi:10.1016/j. fuel.2014.10.076.
- 15. Ambrós, W.M., Lanzanova, T.D.M., Fagundez, J.L.S., Sari, R.L. et al., "Experimental Analysis and Modeling of Internal Combustion Engine Operating with Wet Ethanol," *Fuel* 158 (October 2015): 270-278, doi:10.1016/j.fuel.2015.05.009.
- 16. Redziuk, A.M., Ustymenko, V.S., Klymenko, O.A., and Hutarevych Yu, F., "The Impact of the High-Octane Additive Containing Oxygen to Petrol for Fuel Economy and Environmental Performance of Vehicles," Automotive and Road Journal of Ukraine, The Herald of North Scientific Center Transport Academy of Ukraine 6 (2003): 34-35.
- 17. Hutarevych Yu, F., Korpach, A.O., Hovorun, A.H., and Zakharchenko, O.M., "The Impact of Ignition Timing Advance Angle for the Engine Performance using Mixtures of Fuels with Different Ethanol Content," *Automotive and Road Journal of Ukraine* 1 (2006): 19-21.
- Shcherbatiuk, V.B., "Improving of Engines Environmental Performance by Heating of Air Charge when using Gasoline with Ethanol Additive," PhD thesis, National Transport University, 2013.
- 19. Popov, D.V., "The Experimental Research Results of C30NE Engine with a Catalytic Converter using the Mixtures of Fuels," *Bulletin of Vinnytsia Polytechnic Institute, Scientific journal*, no. 4 (2007): 147-148.
- 20. Kulbako, V.P., Dobrovolskyi, O.S., Syrota, O.V., and Tsiuman, M.P., "Feasibility Research of the Fuels Mixtures using in Engines with Different Fuel Systems," *Problems of transport, Collection of scientific papers* 7 (2010): 128-133.
- 21. Tsiuman, M.P., Shevchyk, I.O., Artemenko, R.V., and Borysko, S.H., "The Research of Spark Ignition Engine Fuel Economy and Environmental Performance with Using the Fuel Containing Ethanol," *Herald of National Transport*

- University, Technical Sciences Series, Scientific and Technical Collection 37 (2017): 424-433.
- 22. Tsiuman, M.P., and Shevchyk, I.O., "Evaluation of Spark Ignition Engine Environmental Safety Indicators with using the Fuel Containing Ethanol," in *Problems of Chemmotology. Theory and Practice of Rational Use of Traditional and Alternative Fuel and Lubricants (Monograph)*, (Kyiv: Center of Educational Literature, 2017), 364-367.
- 23. Tsiuman, M., "Evaluation of Fuel Consumption and Harmful Substances Emissions by Vehicle with Spark Ignition Engine under Operation Conditions with using of Fuel Containing Ethanol," Selected Aspects of Providing the Chemmotological Reliability of the Engineering (2019): 299-314, doi:10.18372/38237.
- VAG Tool 2.0.9. https://vagcom.com.ua/programmy/ programmy-dlya-vag-vw-audi-seat-skoda/vag-tool-209/
- Gritsuk, I., Volkov, V., Mateichyk, V., Gutarevych, Y. et al., "The Evaluation of Vehicle Fuel Consumption and Harmful Emission using the Heating System in a Driving Cycle," SAE International Journal of Fuels and Lubricants 10, no. 1 (2017), https://doi.org/10.4271/2017-26-0364.
- Dadam, S.R., Jentz, R., Lenzen, T., and Meissner, H.,
 "Diagnostic Evaluation of Exhaust Gas Recirculation (EGR)
 System on Gasoline Electric Hybrid Vehicle," SAE Technical
 Paper 2020-01-0902 (2020), https://doi.org/10.4271/2020-01-0902.
- Jentz, R., Lenzen, T., Dadam, S., Meissner, H., and Hancock, K., "Method and System for Exhaust Gas Recirculation System Diagnostics," US Patent 10,632,988 B2, April 28, 2020.
- 28. Dadam, S., Ravi, V., Jentz, R., Kumar, V. et al., "Assessment of Exhaust Actuator Control at Low Ambient Temperature Conditions," SAE Technical Paper 2021-01-0681 (2021), https://doi.org/10.4271/2021-01-0681.
- Zhu, D., Pritchard, E., Dadam, S.R., Kumar, V. et al.,
 "Optimization of Rule-Based Energy Management Strategies

for Hybrid Vehicles using Dynamic Programming," *Combustion Engines* 184, no. 1 (2021): 3-10, doi:10.19206/CE-131967.

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Definitions/Abbreviations

OBD - on-board diagnostic

GPS - Global Positioning System

ECF - ethanol-containing fuel

NEDC - New European Driving Cycle

WLTC - Worldwide harmonized Light vehicles Test Cycle

EG - exhaust gas

ECU - electronic control unit

CAN - Controller Area Network

UNECE - United Nations Economic Commission for Europe