

APPLYING METHODS OF ACQUISITION OF INFORMATION FROM VEHICLE ELECTRONIC COMPONENTS TO IMPROVE WORK PARAMETERS OF DUAL FUEL ENGINE

Krzysztof SZCZUROWSKI, Stanisław RADKOWSKI, Damian WALCZAK, Michał TROJGO,

Łukasz ZIELIŃSKI

Warsaw University of Technology, Institute of Vehicles,

Narbutta 84, 02-524 Warsaw, Poland

e-mail: d.walczak@mechatronika.net.pl, lzielinski@mechatronika.net.pl

Summary

This article presents methods of acquisition of information from vehicle electronic components, with the purpose of its use to control the additional devices. These additional devices can comprise an LPG fitting, which was installed on a tested vehicle. Also, the way of modifying the contents of the engine control unit has been shown in order to examine the influence of the serial settings of the injection timing. Information that can be obtained from the CAN (Controller Area Network) allow for the lack of interference with the original manufacturer wiring, not disturbing the analogue signals at the same time. Modification of controller memory contents enables the improvement of performance parameters, especially in the case of the compression-ignition engine being fuelled with the addition of LPG. In the Summary section, the dynamometer test results of the modified vehicle have been presented. The tests were conducted for different control parameters during powering with Diesel fuel exclusively, as well as with the addition of LPG.

Keywords: acquisition of information, Diesel, LPG, dual fuel.

WYKORZYSTANIE METOD POZYSKANIA INFORMACJI ZAWARTYCH W ELEKTRONICZNYCH PODZESPOŁACH POJAZDÓW DO POPRAWY PARAMETRÓW PRACY SILNIKA DWUPALIWOWEGO

Streszczenie

W artykule przedstawiono metody pozyskiwania informacji z elektronicznych podzespołów pojazdów w celu wykorzystania ich do sterowania dodatkowymi urządzeniami. Tymi dodatkowymi urządzeniami może być instalacja LPG, która została zainstalowana w badanym pojeździe. Przedstawiono również sposób modyfikacji zawartości jednostki sterującej silnika w celu zbadania wpływu seryjnych nastaw kąta wyprzedzenia wtrysku. Informacje, które można pozyskać z sieci CAN pozwalają na brak ingerencji w fabryczną instalację elektryczną, nie zakłócając tym samym sygnałów analogowych. Modyfikacja zawartości pamięci sterownika pozwala na poprawę parametrów użytkowych, zwłaszcza w przypadku zasilania silnika o zapłonie samoczynnym dodatkiem LPG. W podsumowaniu zaprezentowano wyniki badań hamownianych modyfikowanego pojazdu. Badania przeprowadzono dla różnych parametrów sterowania podczas zasilania wyłącznie olejem napędowym jak również z dodatkiem LPG.

Słowa kluczowe: pozyskanie informacji, Diesel, LPG, dwupaliwowy.

1. INTRODUCTION

High prices of fuel influencing high costs of transport, as well as new norms on toxic substance emissions [1] result in a more intensive search of effective solutions regarding fueling and controlling combustion engines. One of the ways to reduce the emission of such compounds can be the duel fuel engines, in which, for instance, the basic fuel is diesel fuel, whereas the additional fuel can be LPG, biogas, etc., which are far cheaper fuels in comparison with diesel fuel, and generate less numerous toxic compounds. One of the well-known solutions is fueling the compression-ignition engine with diesel fuel with the addition of LPG [4].

On the market, there has been a tendency observed of growing popularity of such fittings, which is a result of a saving policy, as well as the expected reduction of toxic compounds. The fittings offered by different companies allow for the addition of up to approximately 30% of propane-butane. This proportion results from control of the combustion process, especially from the proneness to detonation combustion and the tendency of the exhaust gases temperature to increase. In commercial solutions for such installations, operation of the control system is based on controlling the composition of the mixture, using the signal from the acceleration pedal potentiometer, or the signal from the fuel pressure sensor in the container tank. These signals are gauged and, subsequently, the foster signals are

generated, that reach the manufacturer controller. Such a way of controlling the LPG addition is relatively easy and resistant to failure, however, such a low integrity with the manufacturer system leads to certain limitations. The lack of possibility to influence parameters such as injection timing, or dividing the doses, does not enhance the optimal dual fuel work, from the point of view of efficiency and maximal LPG share [4, 5, 6, 7, 8].

Using the tools designed for reading the memory contents in vehicle electronic components, an attempt was made to modify the software controlling the engine, in order to improve the performance parameters of the dual fuel engine. The tested engine is a compression-ignition unit working with the addition of LPG. The modifications were performed on the VW 1.4 TDI engine. The LPG addition fitting uses information acquired from the vehicle's on-board diagnostic system to calculate the LPG dose. One of the analysed issues was devoted to the influence of the diesel fuel injection timing on the performance parameters, including the torque measured on the vehicle's wheels. Within the framework of the research, the assumption was made to increase the angle of injection. Changing the injection timing compared with the serial map was performed by means of modification of the maps registered in the engine controller. The previous tests showed that the injection timing delay causes decrease in the maximal pressure of the combustion process, which results in the decrease of the torque value. The next step was to test the influence of the LPG addition on the same parameters.

Comparison of these results will enable an attempt to determine the optimal control parameters regarding the generated torque.

Presented modification of factory ECU which gives possibility to change the engine control program depending on currently fuel used.

This article presents the dynamometer test results and shows the modification methods of engine work parameters such as injection timing, diesel fuel doses, and boost pressure.

2. TOOLS AND METHOD OF DATA MODIFICATION IN THE MANUFACTURER CONTROLLER MEMORY

Analysing the commercially offered installations enables the observation that part of them modify signals reaching the original engine controller, the remaining installations, however, deliver LPG as an addition to the dose of diesel fuel, which was determined by the manufacturer for the momentary conditions of the engine work.

Potentially, the possibility of modifying the manufacturer parameters of a combustion engine work would guarantee far greater advantages as well as the possibility of LPG burning in engines with the compression-ignition, which was the motivation to create this work.

The tests were conducted on a private vehicle, driven on public roads. The vehicle was equipped by its manufacturer with a BOSCH EDC15P+ engine controller, which is designed for the VAG group engines with the fuelling system based on unit injectors, but its construction and software is built analogically to the remaining models of the EDC15 family, that were mounted in practically all European car makes. Tests performed on stationary engines controlled with the fully programmable units, offer the possibility of editing the work parameters with far less effort. Following the basic assumption, the manufacturer engine computer was equipped with a programme controlling the engine work, adjusted by the manufacturer to the defined limit of exhaust gases emission, the maximal power variant of a given engine, as well as to the equipment version, and it is not easily adaptable to changing individual control parameters by the user or the servicing garage.

After a thorough analysis of available publications regarding the LPG addition to the engines with the compression-ignition, the conclusion was drawn, that the change of such parameters as diesel fuel injection timing or increasing the boost pressure, can induce a positive effect.



Fig. 1. AM29F512 Flash memory on the motherboard of the engine controller

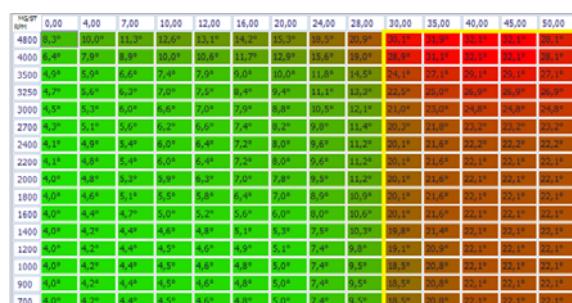


Fig. 2. Exemplary modified injection timing map (yellow indicates the fields of change)

3. USING DATA FROM CAN TO CONTROL LPG ADDITION

The main idea of controlling the LPG addition for the diesel engine is based on using the CAN network to acquire information about momentary parameters of engine work, which is necessary to

calculate the current gas dose. In the controllers available on the market, this information is acquired on the basis of measurements of analogue or time-frequency signals. The main information acquired from the CAN includes:

- engine load;
- engine rotational velocity;
- position of the acceleration pedal;
- engine temperature.

All this information was found by means of comparing the parameter reading with the help of the diagnoscope with the contents of individual values from the CAN frames, are registered using the NI USB 8473s card (Fig. 3).



Fig. 3. CAN Highspeed card, NI USB-8473s

Pre-selection is based on the time charts (Fig. 4). The next step was to compare a larger number of samples to determine the exact relationship or divergence from the linear function (Fig. 5).

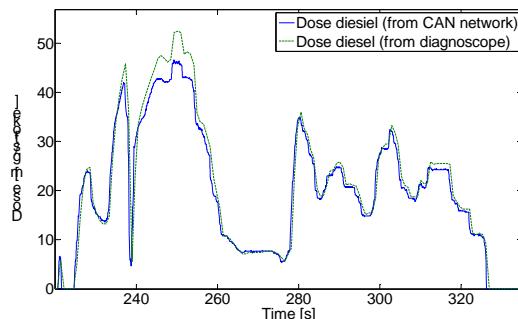


Fig. 4. Curve of time for the CAN dose and for the dose registered by the diagnoscope

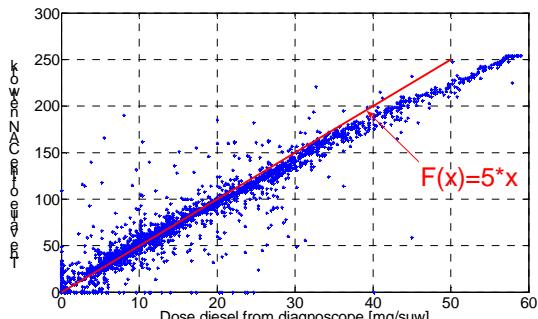


Fig. 5. Comparison of the dose with the value from CAN network

Figure 6 shows comparison of a calculated torque read from the diagnoscope and the values

from the CAN network, which is consistent with the linear function.

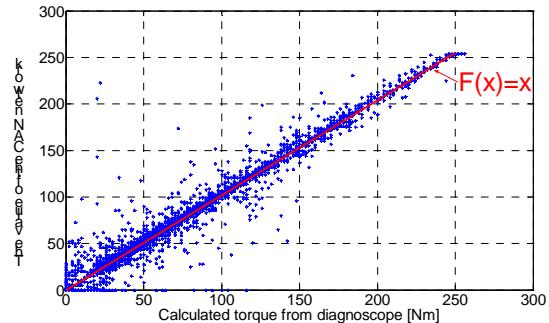


Fig. 6. Comparison of the calculated torque and values from CAN

With the help of the acquired information, the software for the versatile programmable (Fig.7) controller was created, in order to automate the LPG addition. Figure 8 shows the block diagram of the control system with the direction of signal flow marked.

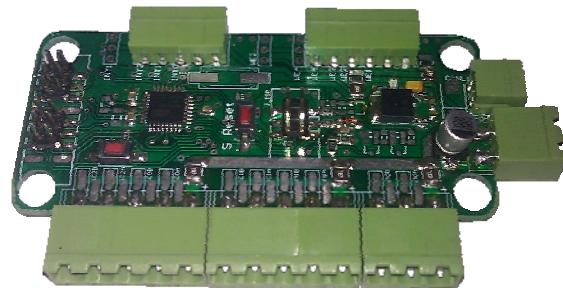


Fig. 7. Programmable controller used to automate the LPG fitting

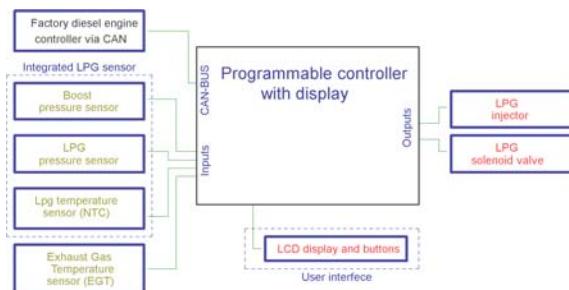


Fig. 8. Block diagram of the control system of the target fitting

4. INFLUENCE OF CHANGING THE INJECTION TIMING ON THE SINGLE FUEL AND DUAL FUEL WORK

The comparison of performance parameters is shown in the three-dimensional diagrams (Fig. 9-11), where the torque, rotational velocity, and the change of the injection timing are respectively presented, in relation to the factory settings. The chart of the generated torque shows the curve of the growing torque depending on the injection timing for different shares of gas fuel, starting with powering with diesel fuel only.

With using diesel fuel only, the control parameters registered in the engine controller by the manufacturer are the most effective. In the case of using fuels consisting of diesel fuel and LPG, with little shares of LPG (about 10%), increasing the angle of injection by 4° compared with the factory

settings, proved the most profitable. For greater shares of LPG, increasing the angle by the further 1° proved advantageous, and further increasing the angle of injection caused decrease in the generated torque.

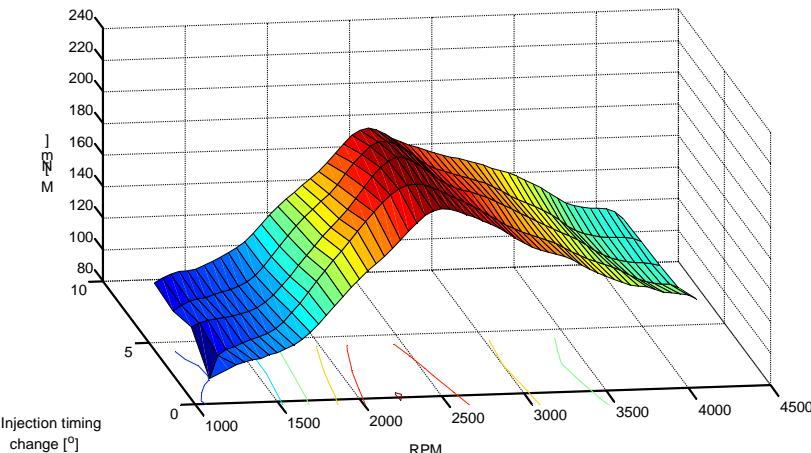


Fig. 9. Torque as a function of rotational velocity and injection timing, diesel fuel only

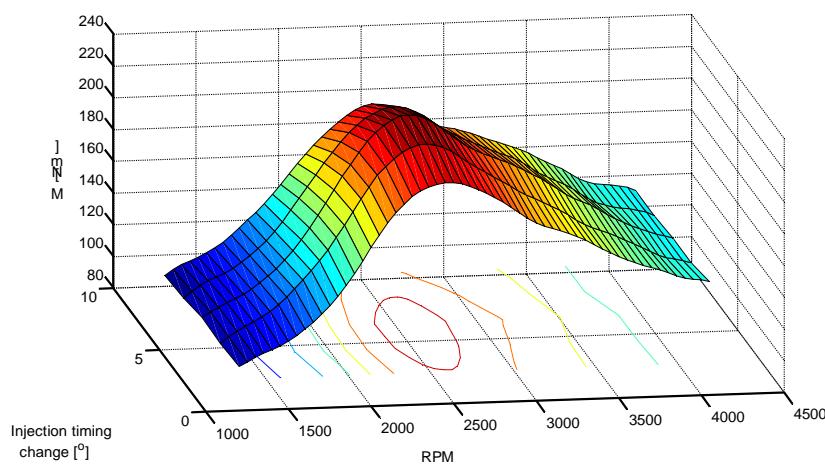


Fig. 10. Torque as a function of rotational velocity and injection timing, 10% LPG

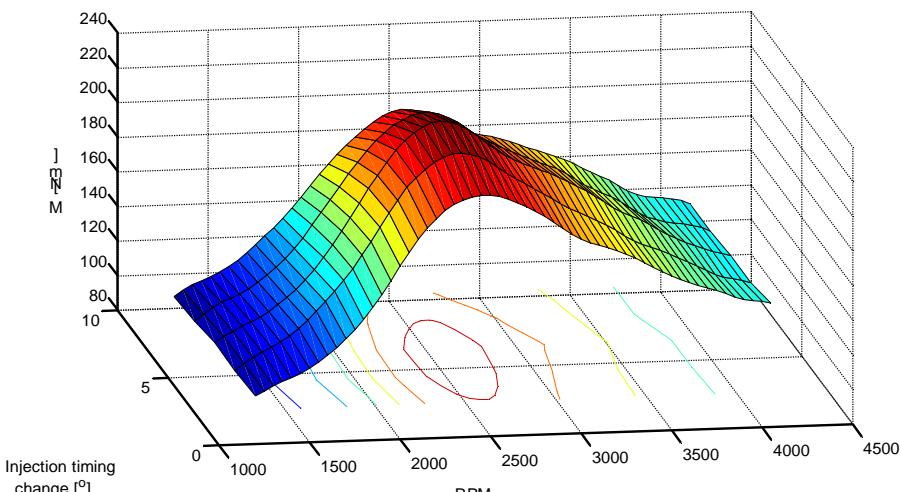


Fig. 11. Torque as a function of rotational velocity and injection timing, 15% LPG

5. CHANGE MAPS OF FACTORY CONTROL UNIT DURING ENGINE OPERATION

In analyzing the survey results may be noted that the modification of parameters controlling the operation of the diesel-LPG engine brings tangible benefits. However, the parameters chosen for dual-fuel operation are not always optimal for supplying the diesel fuel. To recognize the encountered problems the draft modification of the factory engine control unit EDC15P + with the ability to toggle between the two memory banks containing data responsible for the selection of all parameters controlling the motor has been developed and produced (Fig. 12).



Fig. 12. Modified ECU main board

The first step to implement the system which changes the current parameters controlling engine work was thorough analysis of the FLASH memory device. Measurements were gained from the electrical signals reaching the original application which provided the necessary information to design the module.

Developed system switches between the two banks of memory by giving ground (GND) on the corresponding connection module installed. Chief executive system is based on NOT logic gates included in an integrated system, which eliminates the possibility of transients while switching sets of maps. No transients and short duration of action of the switch allow you to change parameters during engine operation (Fig. 13). Switching achieved by giving appropriate GND signal to pin module allows changes of the complete characterization of a motor. It can be managed by LPG controller.



Fig. 13. Installing the performing switching maps

Ability to change the complete characterization of the engine during operation connected with obtaining information about current control parameters from the CAN network enables highly precise adjustment of the installation of the LPG addition to diesel engine. Existing solutions based on emulation signals or based on the addition of propane-butane fuel delivery to the factory gave no possibility of changing the control parameters such as the main injection timing, or change boost pressure turbocharged engines. The design of the module has left the possibility for programming the contents of individual memory banks via the diagnostic connector of the vehicle in which it is mounted. It can be programmed using the communication line K-Line also makes it possible to prepare the driver for a particular vehicle before it is mounted.

6. CONCLUSIONS

The data which can be obtained from the vehicle's CAN provides plenty of necessary parameters used to control the work of the LPG addition installation in the compression-ignition engines. The information about the recent torque computed by the engine controller, the coolant temperature, or the acceleration pedal position enables a precise determination of the gas injector opening time in order to deliver the defined LPG dose.

The received contents of the Flash memory of the original controller has plenty of data in the form of so-called maps responsible for basic parameters of engine work control. Modification of the value of the main injection timing resulted in the improvement of performance parameters of the engine during supplying with dual fuel. For ten-percent LPG share, the most advantageous solution was increasing the angle of injection by 4° compared with the original value.

Development and installation of the module which allows to switch between two banks of memory while engine is operating made possible to choice optimized set of maps depending on fuel used.

BIBLIOGRAPHY

1. Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information.
2. Myung C. L., Lee H., Choi K., Lee Y. J., Park S. *Effects of gasoline, diesel, LPG, and low-carbon fuels and various certification modes on nanoparticle emission characteristics in light-duty vehicles.* International Journal of

- Automotive Technology, Vol. 10, No. 5, pp. 537–544, 2009
3. Rao G. A., Rajub A. V. S., Raoc C. V. M., Rajulud K. G. *Effect of LPG content on the performance and emissions of a diesel-LPG Dual-Fuel Engine.* Bangladesh Journal of Scientific and Industrial Research, Vol 46, No 2, pp. 195-200, 2011
 4. Lejda K., Jaworski A. *Zasilanie gazowe silników rolniczych.* MOTROL, No. 8, pp. 131-138, 2006.
 5. Śmieja M., Wierzbicki S., Mamala J.: *Sterowanie dawką wtryskiwanego paliwa w układzie Common Rail z wykorzystaniem środowiska LabView.* Combustion engines, 154(3)/2013, s. 542-548.
 6. Wierzbicki S., Śmieja M., Grzeszczyk R. *Zintegrowane sterowanie stanowiskiem badawczym silników o ZS w środowisku fast prototyping.* Combustion engines, 154(3), s. 536-541.
 7. Wierzbicki S., Śmieja M.: *Visualization of the parameters and changes of signals controlling the operation of Common Rail injectors.* Solid State Phenomena. Mechatronic Systems, Mechanics and Materials II, Vol. 210 (2014), p. 136-141
 8. Deo Raj Tiwari, Gopal P. Sinha. *Performance and emission study of LPG diesel dual fuel engine,* International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249 – 8958, Vol. 3, No. 3, February 2014.



Doc. Eng. **Krzysztof SZCZUROWSKI**, PhD is a postdoctoral manager at Integrated Laboratory of Mechatronics System of Vehicles and Construction Machinery of Warsaw University of Technology. His scientific interests include computational mechanics, sound and vibration and mechatronics.



Prof. **Stanislaw RADKOWSKI**, a professor in Institute of Vehicles of Warsaw University of Technology, manager of the Technical Diagnosis and Risk Analysis scientific team, Chairman of Polish Society of Technical Diagnosis. In his scientific work he deals with vibroacoustic diagnosis and technical risk analysis.



Damian WALCZAK, Msc student of Mechatronics in Institute of Vehicles of Warsaw University of Technology. His research interest is focused on the electronic engine control systems.



Michał TROJGO, Msc student of Mechatronics in Institute of Vehicles of Warsaw University of Technology. His research interest is focused on the electronic engine control systems.



Łukasz ZIELIŃSKI, candidate for PhD programme in Integrated Laboratory of Mechatronics System of Vehicles and Construction Machinery of Warsaw University of Technology. His research interest is focused on control of combustion engine and alternative fuels.