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EOBD USAGE IN LPG CONVERSIONS

EOBD IN PREDELAVA VOZIL NA AVTOPLIN

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Abstract

Aftermarket conversions of gasoline engines to also run on LPG are a way of reducing greenhouse gas emissions. The correct setup of the LPG system is necessary for optimal engine performance. If it is not set up correctly, the engine will not run properly, fuel consumption will increase, and the appearance of diagnostic trouble codes may activate the engine warning light. With European On-Board Diagnostics (EOBD), information from engine sensors throughout the car can be monitored and stored. Engine diagnostic trouble codes can also be read and cleared. This paper shows the usage of EODB for the optimal setup of aftermarket LPG systems. The analysis of the results obtained was made, and the LPG map was modified accordingly.

Povzetek

Eno izmed možnosti v boju proti emisijam toplogrednih plinov predstavlja predelava bencinskih motorjev na avtoplin. Pravilna nastavitev sistema je ključna za optimalno delovanje motorja. Če sistem ni pravilno nastavljen, motor ne deluje pravilno, poveča se poraba goriva, napake pri delovanju pa lahko celo prižgejo opozorilno lučko. S pomočjo EOBD lahko spremljamo ter shranjujemo podatke o delovanju motorja, omogoča pa tudi branje in brisanje napak.
Prispevek prikazuje uporabo EOBD pri optimalnem nastavljanju avtoplinskega sistema. Na podlagi analize pridobljenih podatkov so bile ustrezno korigirane nastavitve avtoplinskega sistema.

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1 INTRODUCTION

Slovenia is the only transition country that has yet to achieve the targets of the Kyoto Protocol. The biggest problem in reducing greenhouse gases lies in traffic, which accounts for more than 25% of emissions [1][2].

LPG (Liquefied Petroleum Gas) is both a naturally occurring product of the natural gas extraction process and an automatic result of the oil refining production process. LPG-powered vehicles produce up to 20% less CO, 30% less CO_2 and around 30% less NO_X in comparison with petrol engines, while the exhaust of comparable diesel engine contains 20-fold greater NO_X and 120-fold greater particulate emissions. As a low-carbon, low-polluting fossil fuel, it is recognized by governments around the world for the contribution it can make towards improved indoor and outdoor air quality and reduced greenhouse gas emissions [3].

There are almost 1.1 million personal vehicles registered in Slovenia, but less than 3000 of them are powered by LPG. LPG conversions with aftermarket kits are therefore one of the easiest options for Slovenia to reduce greenhouse gas emissions. There are over 700,000 vehicles with petrol engines, most of which are suitable for the LPG conversion.

Aftermarket conversion kits require individual LPG ECU (Engine Control Unit) injection parameters settings for each vehicle. Based on our experiences, this is quite complicated for several vehicles. If the map is not set up correctly, the engine will not run properly, fuel consumption will increase, and, in the worst case scenario, the engine warning light will be activated. Despite the fact that the LPG ECU controls and operates all the components of the LPG conversion system, the injection parameters are still set by the main ECU; the LPG ECU merely converts these parameters for appropriate LPG usage. That means that all of engine’s original sensor data are also taken into account when the engine is powered by LPG. The European On-Board Diagnostic (EOBD) allows monitoring the engine performance and therefore also gives vital information about the correct set up of the LPG system.

2 LPG CONVERSION

Aftermarket conversions to LPG are possible for the majority of the petrol-powered cars. Figure 1 shows the locations of an LPG system’s components after conversion (reservoir with multivalve, filling point, reducer, ECU, injectors, pressure sensor and changeover switch).

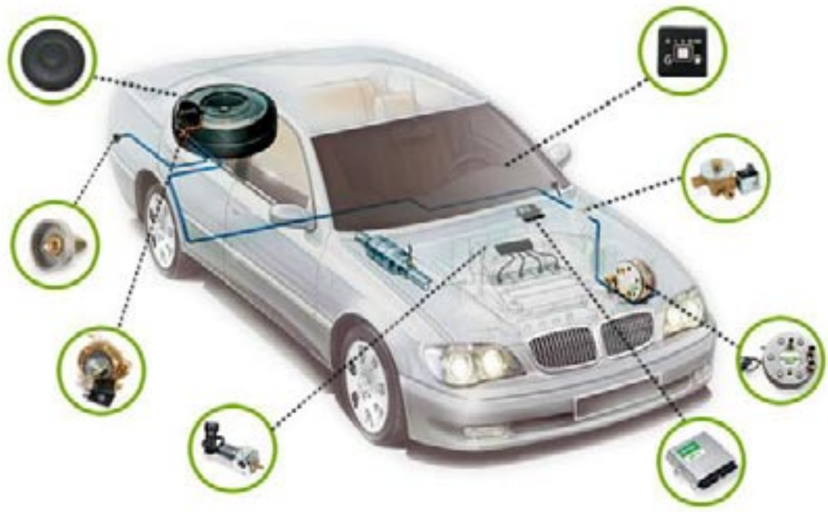

Figure 1: *Components of aftermarket LPG system*

Converted engines start on gasoline and, when all of the following prescribed conditions are achieved, automatically switch to LPG:

- the engine's water temperature must be at least 35-40°C,
- a time delay of 25-30 seconds is necessary for achievement of the lambda probe's working temperature, and
- the engine must be running over the prescribed rpm (1400-1600 rpm).

Some systems are even capable of starting the engine on LPG if the engine temperature is above the prescribed value. Converted engines can be powered with either gasoline or LPG; selecting between them can be easily made with the changeover switch. If there is any LPG in the reservoir, the LPG ECU's priority is operating with LPG. When the LPG tank is empty, a pressure sensor informs the ECU, which automatically switches back to gasoline fuel injection without stopping the engine. All of the LPG system's components are controlled via the LPG ECU. It takes the injection data (start and duration of the injection for each cylinder) directly from the engine's original ECU, adapts them appropriately and sends them to the LPG injectors. To achieve correct quantities of LPG injected in every working point of the engine, several input data are considered: temperature of the reducer, temperature and pressure of the LPG, intake manifold pressure and the engine's RPMs [4]. However, basic injection parameters are always set by the engine's main ECU; the LPG ECU adjusts these parameters so that they are appropriate for LPG injection. All of engine's original sensor data, such as exhaust oxygen sensor, are also considered when running on LPG.

3 OBD LOG

An OBD Log is an innovative small device that plugs directly into the vehicle's diagnostic socket and records all parameters and errors defined according to the EOBD protocol. It continuously records all relevant data while the vehicle is in use.

Technical DATA of the OBD Log:

- EOBD compatibility: complete electrical and mechanical,
- power supply: OBD socket for 12 V vehicles, USB socket for PC,
- current draw: engine on < 100 mA, engine off < 1 mA,
- processor: ARM 32-bit Cortex-M3 with 256 KB DRAM,
- internal memory: 2048 KB,
- operating temperature range: -40°C to +85°C, and
- software: IDC3 PC Suite.

The OBD Log, shown in Figure 2, can record all parameters handled by the EOBD protocol, including vehicle speed, engine speed and load, air and coolant temperature, inlet manifold air and fuel pressure, air mass flow rate, battery voltage and all errors handled by the EOBD protocol. It can record one or all parameters with sampling resolution from 1 up to 5 seconds. Its memory allows 90 hours of recording for eight parameters monitored at a five-second sampling rate.

Figure 2: *OBD Log*

The OBD Log features a cyclical memory; therefore if no error is detected; it writes the new data over the oldest. At the end of the monitoring period, recorded data can be downloaded to a PC using the OBD Log software, and exported into Microsoft Excel for further analysis [5].

4 EXPERIMENT

The experiment was carried out using the OBD Log in a vehicle with an aftermarket conversion LPG kit.

4.1 Vehicle

For the experiment, a Mercedes-Benz CLK 240 was used. It had been converted to run on LPG using the Zavoli Alisei-6S sequential system with AEB 2568 electronics.

Technical data of the vehicle:

- number of cylinders: V6,
- bore and stroke: 89.9 × 68.2 mm,

- displacement: 2,597 ccm,
- compression ratio: 10.5:1,
- power: 125 kW at 5000 rpm,
- torque: 240 Nm at 4500 rpm,
- transmission: 6-speed, manual,
- fuel system: multipoint injection,
- vehicle weight: 1,575 kg,
- acceleration 0–100 km/h: 9.2 s,
- maximal speed: 236 km/h,
- average fuel consumption: 10.8 l/100 km,
- CO_2 emission: 259 g/km.

4.2 OBD Log

The OBD Log was configured to record the following parameters at one-second intervals (Figure 3):

- vehicle speed,
- throttle pedal position,
- engine rpm,
- engine load,
- exhaust oxygen sensor, and
- slow and fast fuel trims of the main ECU.

Selected parameters were recorded during the two road tests. The first road test was performed to determine the current set up of LPG map, while the second road test provided results of the modified LPG map.

Figure 3: *OBD Log configuration*

4.3 Road tests

The purpose of the first road test was to check the current setup of the installed LPG system so that necessary map modifications could be made. After the recorded data analysis, the LPG map was changed accordingly. The second road test was carried out to check the modified setup. The duration of both tests was approximately one hour.

5 RESULTS

The results from OBD Log of the first road test are shown in Figures 4 to 9.

5.1 First road test

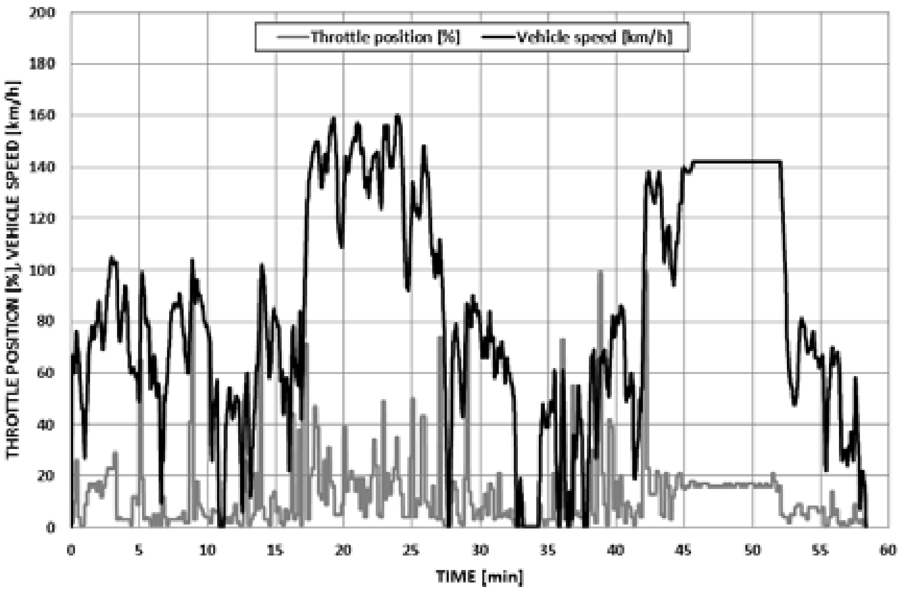

Figure 4: *Throttle position and vehicle speed*

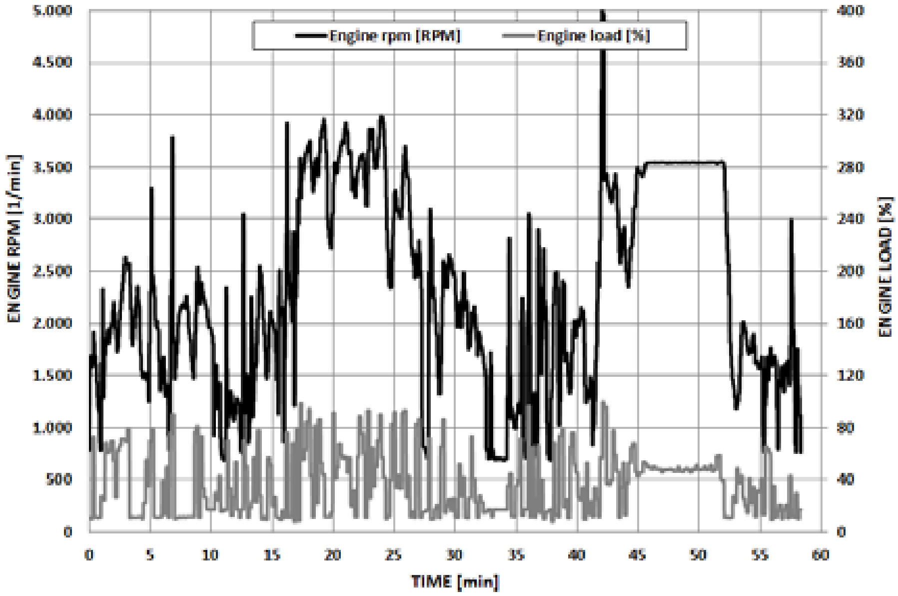

Figure 5: *Engine rpm's and load*

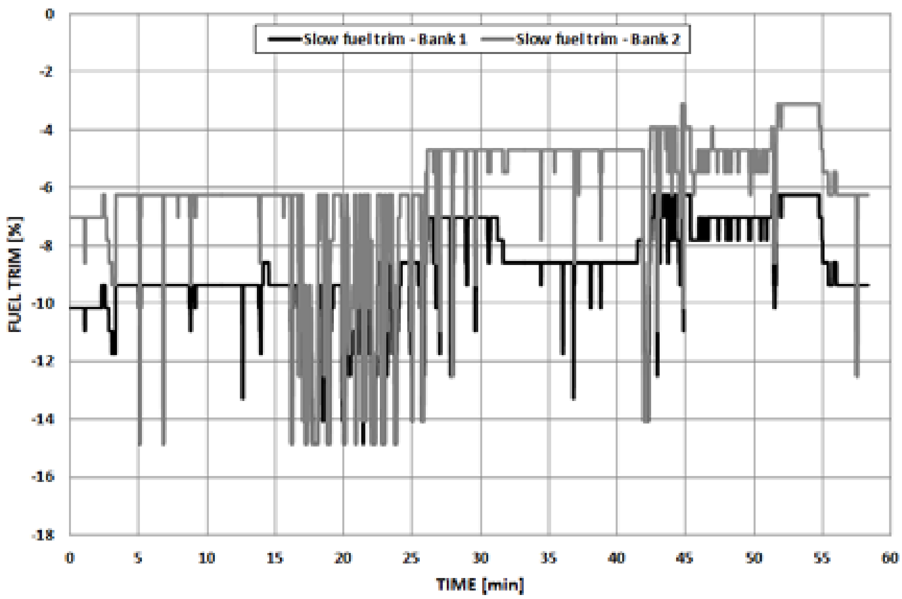

Figure 6: *Slow fuel trims for Banks 1 and 2*

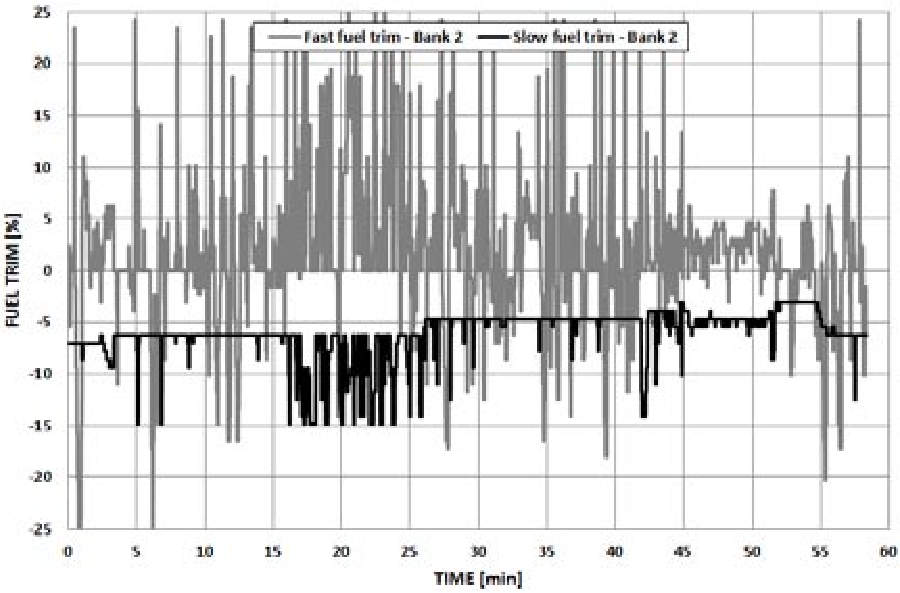

Figure 7: *Fast and slow fuel trims for Bank 2*

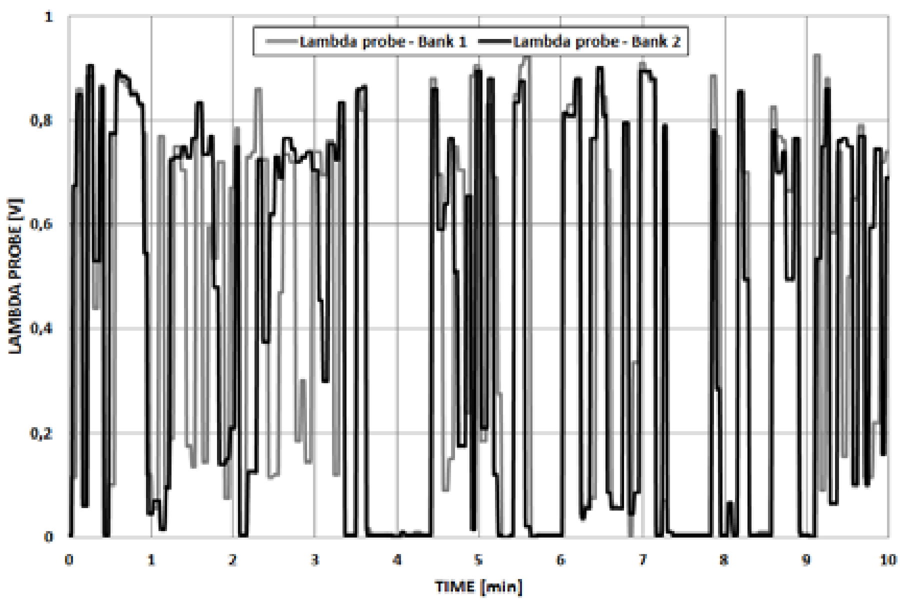

Figure 8: *Lambda probe signal (first 10 minutes of the test)*

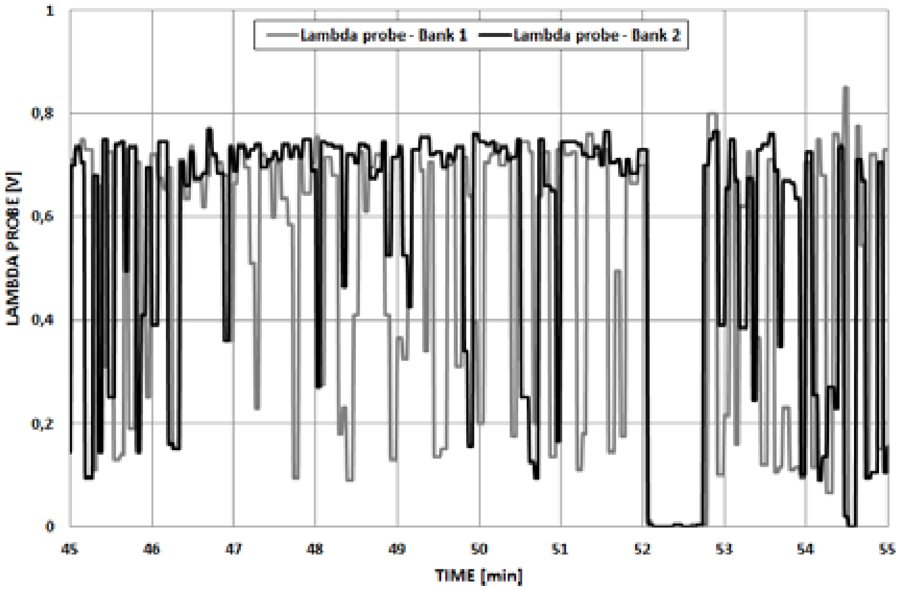

Figure 9: *Lambda probe signal (last 10 minutes of the test)*

Figure 4 shows vehicle velocity and throttle position in Road Test 1. The engine was powered by LPG throughout the test. The average velocity was 83.82 km/h with the average throttle position at 12.95%. Between the 45th and 52nd minutes of the test, the vehicle's cruise control was switched on at 142 km/h. During the test, the average load of the engine was 36.46% with an average of 2310 rpm. Diagrams are shown in Figure 5. Fuel trims of the main ECU are shown in Figures 6 and 7. Because the CLK 240 has a V6 engine, there are two fuel trims, one for each side of the engine: Banks 1 and 2. Figure 6 shows slow fuel trims or long-term fuel regulation for both banks, while Figure 7 shows slow and fast fuel trims or short-term fuel regulation for Bank 2 (left side of the engine). The results show that the LPG map is too high for both banks; therefore, the main ECU reduced slow fuel trims to an average of 8.9% for Bank 1 and -6.2% for Bank 2. Slow fuel trims changed a bit during the test, but the values stayed on the negative side at the end of the test. Slow fuel trims for Bank 1 changed from -10.2 to -9.3 %, and for Bank 2 they changed from -7.0 to -6.3% during the test. If the LPG map was set up correctly, the long-term fuel correction should be around 0%. Fast fuel trims, which define value of slow fuel trims, are controlled with the signal from the lambda probes. Output voltages of both lambda probes are shown in Figures 8 and 9. Figure 8 presents the first ten minutes, while in Figure 9 the last ten minutes of the road test can be seen.

Based on the results, the LPG map was modified accordingly. The values in the map were lowered by 10%.

5.2 Second road test

The results from OBD Log of the second road test with modified LPG map are shown in Figures 10 to 15.

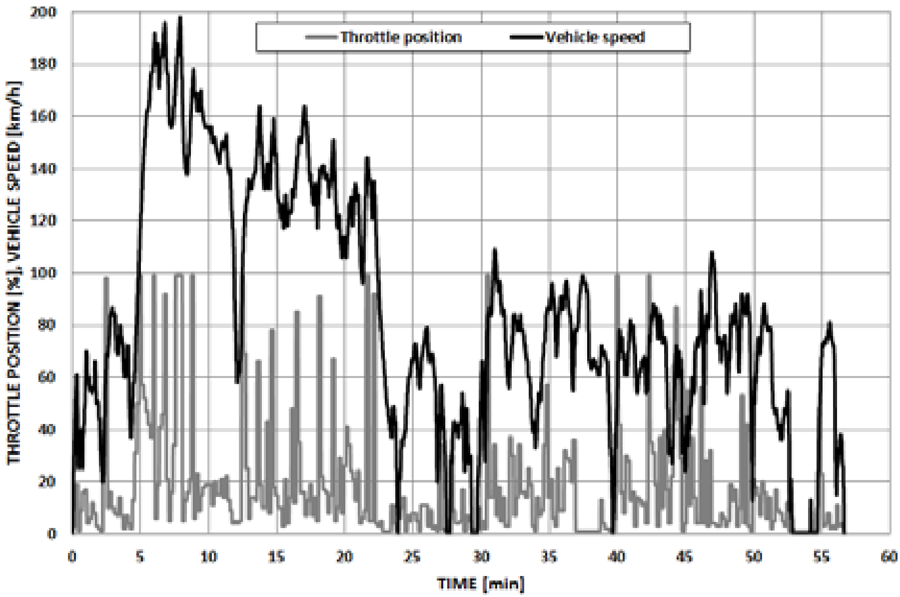

Figure 10: *Throttle position and vehicle speed*

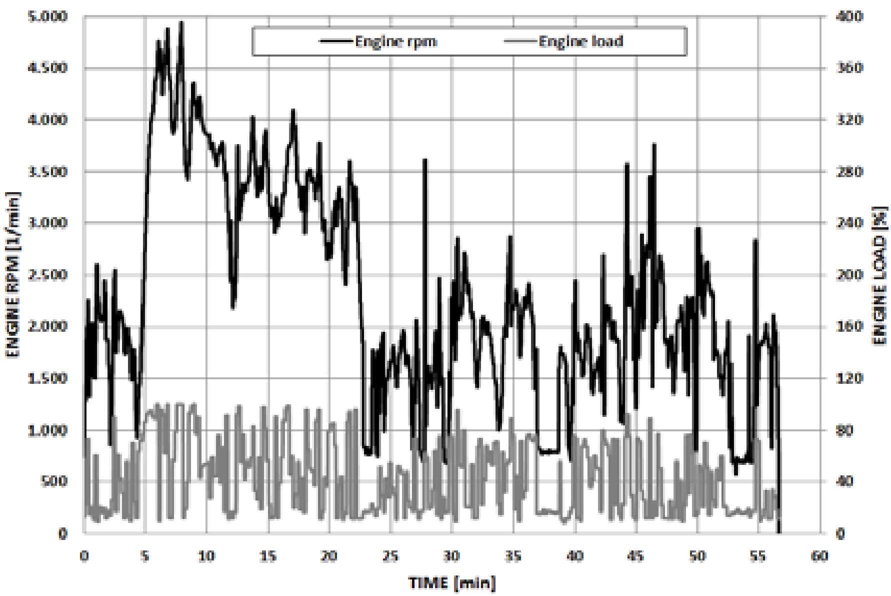

Figure 11: *Engine rpm's and load*

Figure 10 shows vehicle velocity and throttle position during Road Test 2. In this test, the engine was also powered by LPG. The average velocity was 84.06 km/h with the average throttle position at 18.02%. During the test, the average load of the engine was 42.11% with an average of 2286 rpm. Diagrams are shown in Figure 5. Fuel trims of the main ECU are shown in Figures 12 and 13. Figure 12 shows slow fuel trims or long-term fuel regulation for both banks, while Figure 13 shows slow and fast fuel trims or short-term fuel regulation for Bank 2 (left side of the engine). The results show that the modified LPG map is a step in the right direction.

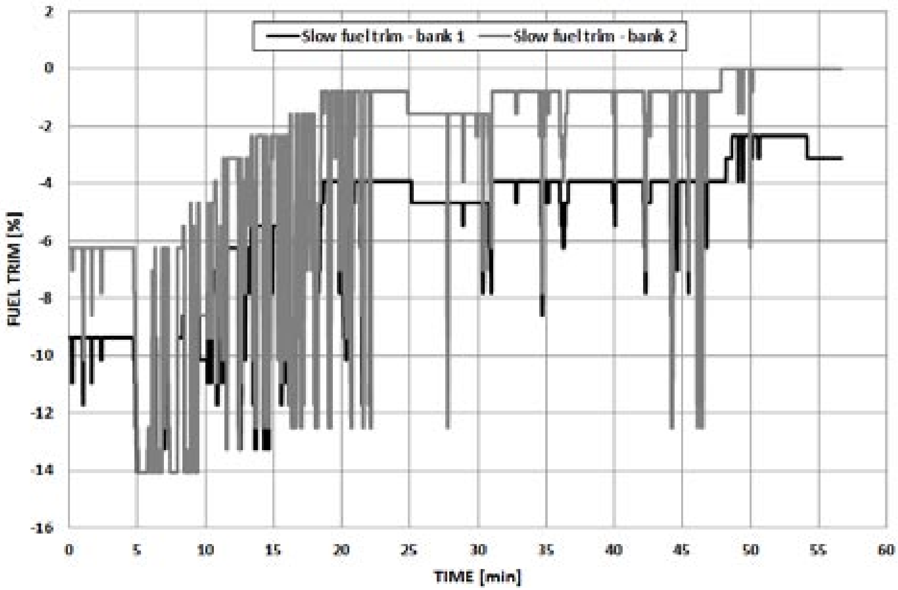

Figure 12: *Engine rpm's and load*

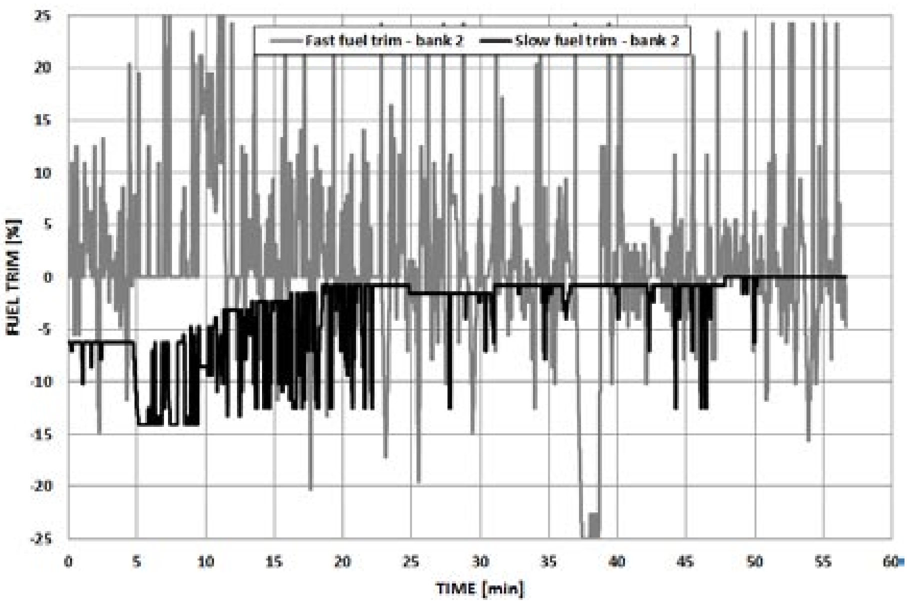

Figure 13: *Fast and slow fuel trims for Bank 2*

The main ECU changed the slow fuel trims from -9.3 to -3.1% for Bank 1 and from -6.3 to 0% for Bank 2. Output voltages of the lambda probes for each side of the engine are shown on Figures 14 and 15. Figure 14 presents the first ten minutes, while in Figure 15 the last ten minutes of the road test can be seen.

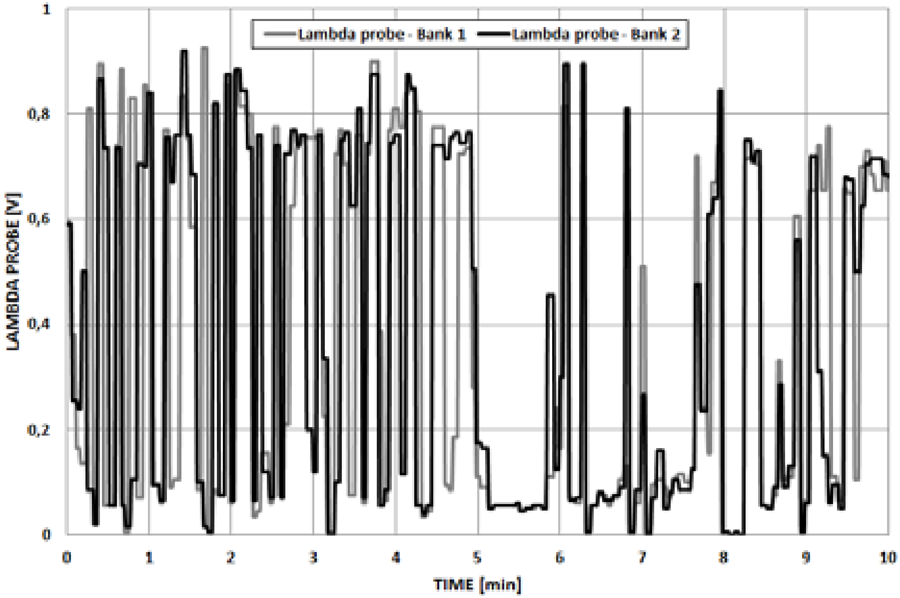

Figure 14: *Lambda probe signal (first 10 minutes of the test)*

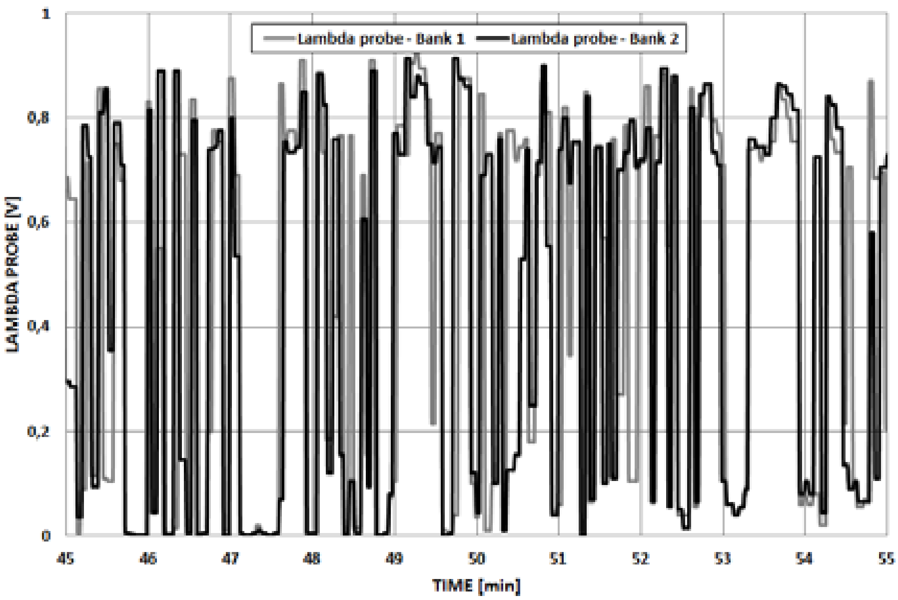

Figure 15: *Lambda probe signal (last 10 minutes of the test)*

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6 CONCLUSIONS

European On-Board Diagnostics (EOBD) was introduced, in line with European Directive 98/69/EC, to monitor and reduce emissions from cars. It can monitor and store information from the engine's sensors throughout the car. Sensor values outside an acceptable range trigger a DTC or Diagnostic Trouble Code. Diagnostic tools can read and interpret these codes, and view the live sensor output.

Aftermarket conversions of petrol-powered cars to run on LPG are extremely popular throughout the world. In comparison with the leading two transport fuels, LPG has two main advantages: lower exhaust emissions and a lower price. The optimal setup of the map on the LPG ECU is crucial for the proper engine performance and its characteristics.

This paper shows that EOBD can also be extremely useful in LPG conversions of petrol-powered cars. Because the main ECU of the engine still has the overall control over the injection characteristics when the engine is switched to LPG, the engine sensors (such as the lambda probe) give vital information about the setup of the LPG system. The OBD Log allows monitoring and recording of sensors' output and data directly from the ECU, such as fuel trims and DTC, while the car is being driven. Based on the recorded data analysis, the LPG map can be modified accordingly. The results presented show that the theory also works in practice. The modified LPG map is reflected in the correction of slow fuel trims of the main ECU. Both long-term regulations moved in the right direction, and while the fuel trim for Bank 2 moved to the ideal 0%, the map for Bank 1 needs another reduction of approximately 5%.

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Nomenclature

EOBD	European On-Board Diagnostic
LPG	Liquefied Petroleum Gas
ECU	Engine Control Unit
rpm	revolutions per minute