TESTING OF AUTOMOBILE VW GOLF OPERATING ON THREE DIFFERENT FUELS

Ilmars Dukulis, Vilnis Pirs, Zanis Jesko, Aivars Birkavs, Gints Birzietis
Latvia University of Agriculture
Ilmars.Dukulis@llu.lv, Vilnis.Pirs@llu.lv, Zanis.Jesko@llu.lv,
Aivars.Birkavs@llu.lv, Gints.Birzietis@llu.lv

Abstract. Based on the recently developed methods for testing automobiles operating on biofuels and using the automobile VW GOLF previously adapted for using pure rapeseed oil as a fuel, investigation of this car operating on three different fuels was carried out. This article presents results obtained before and after modifying the car in the real road and laboratory experiments. The results of power and torque measurements, as well as the fuel consumption and exhaust gas composition determination are analyzed.

Key words: rapeseed oil, biodiesel, diesel engine, fuel consumption, exhaust gases, emissions

Introduction

During the last decade many researchers have investigated use of biofuels in compression ignition engines. From the practical point of view the researches are mainly focused to the power and torque measurement, as well as to the fuel consumption and exhaust gas composition determination and comparison of them with analogue parameters using fossil fuel. Most of the studies are conducted at the field of biodiesel fuel use, as it by properties is the closest to fossil diesel, but also pure vegetable oil fuel impact on the environment, the car and its performance characteristics are examined. Some of such investigations are mentioned further. The comparative bench testing of a direct injection diesel engine operating on diesel fuel and cold pressed rapeseed oil was performed in Lithuania [1]. The same authors investigated also exhaust emissions operating a diesel engine on rapeseed oil and its blends with diesel fuel [2]. Researches in Turkey were carried out to evaluate the potential of using vegetable oil fuels as fuel for diesel engines [3]. Emission tests on the test bench with rapeseed fuelled tractor Deutz-Fahr were performed in Germany. They show that limiting values of CO, HC and particulate matter of EURO norms for rapeseed oil are met, but emission of NO_x with rapeseed oil fuel is up to 14 % higher than the limiting value [4].

Unfortunately, most of the studies are carried out by testing engines on the bench, but not the entire car, in addition, the results provided by different publications related with the power, fuel consumption and exhaust gas composition changes are very different. Therefore, an automobile VW GOLF was adapted for using pure rapeseed oil as a fuel at the Scientific Laboratory of Biofuels (Latvia University of Agriculture). The car was modified using ELSBETT one-tank conversion kit [5].

Materials and methods

The vehicle was tested before the modifying to run on rapeseed oil and after it. The used fuel properties are summarized in Figure 1.

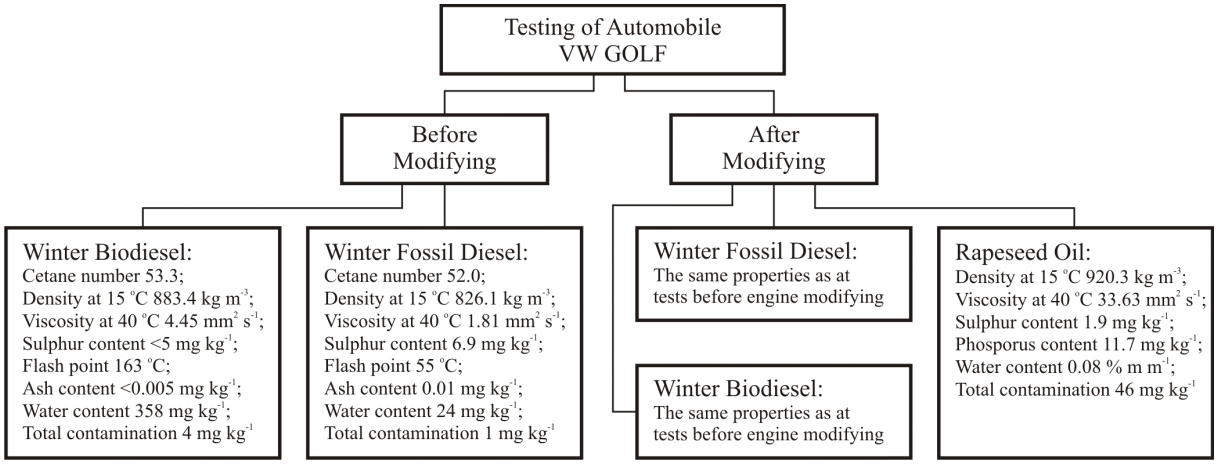

Fig. 1. **Used fuels in testing before and after modifying the engine**

The tests were based on the recent investigations on development of the methods for testing automobiles operating on biofuels [6]. The flow chart of the procedure for automobile testing is shown in Figure 2, but the used laboratory equipment – in Figure 3.

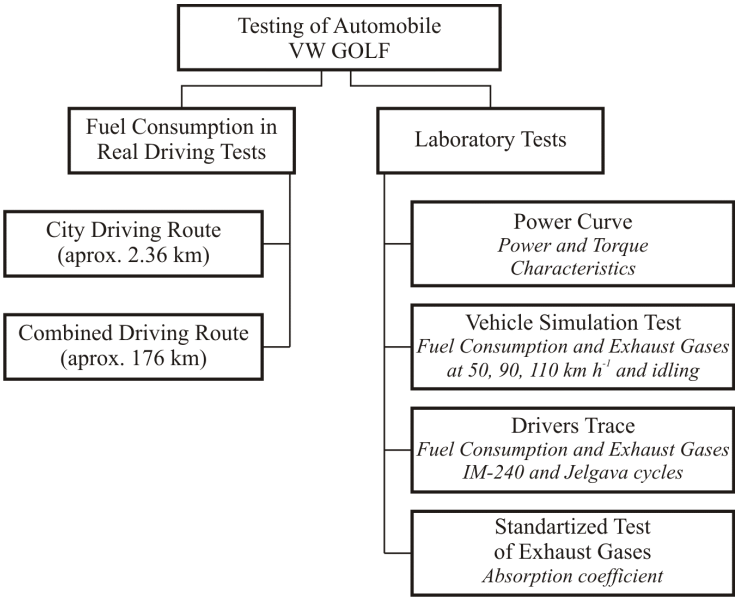

Fig. 2. **Flow chart of the procedure for automobile testing**

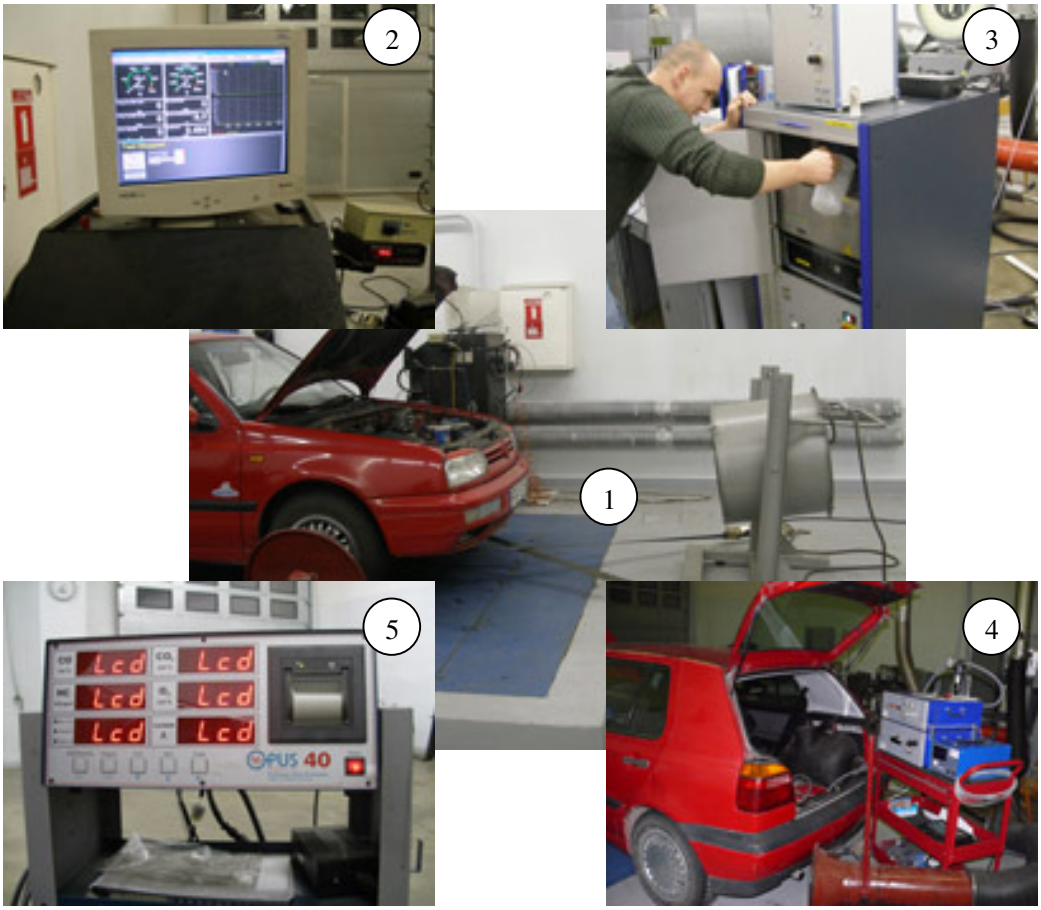

Fig. 3. **Laboratory equipment used in automobile testing**: 1 – Laboratory Chassis Dynamometer Mustang MD-1750; 2 – Control Platform MDSP-7000; 3 – AVL SESAM FTIR Multicomponent Exhaust Gas Measurement System; 4 – AVL KMA Mobile Fuel Consumption Meter; 5 – OPUS 40 Gas Analyzer

Results and discussion

Performing real driving tests the fuel consumption was estimated in two different routes – in intensive traffic conditions in Jelgava city and outside urban area. In the first selected route 15 drive repetitions using each fuel were made. Three trips with the highest speed curves correlations were selected for comparison. Driving tests were conducted during normal working days' peak hours (8:00 – 9:30 and 11:30 – 13:30). The second route included driving in the cities (Jelgava and Tukums), non-urban area, as well as driving through small villages. As the total route distance was large (approximately 176 km), it was covered three times with each fuel type. The comparison of the fuel consumption in these experiments is summarized in Figure 4.

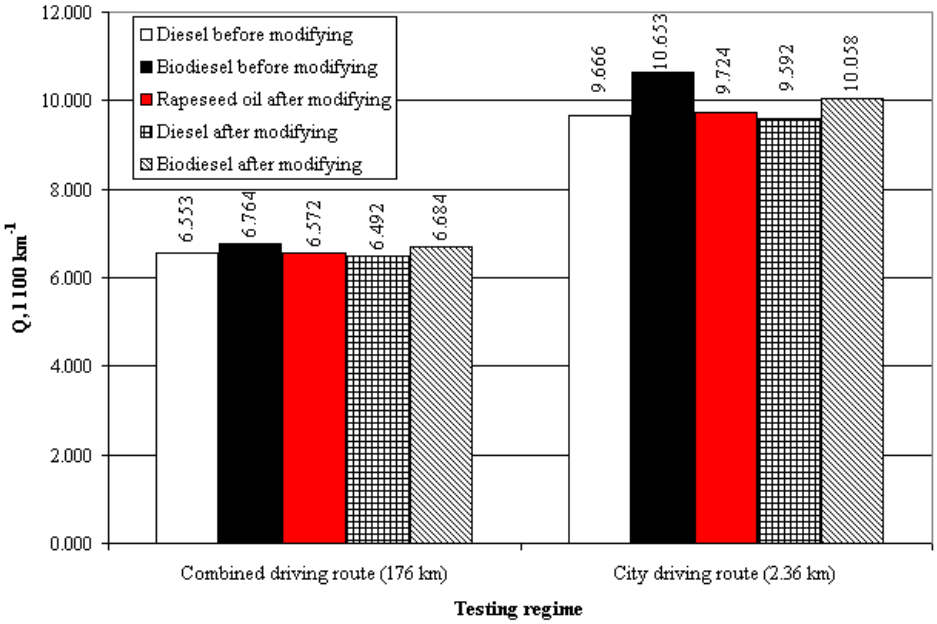

Fig. 4. **Fuel consumption comparison performing real driving tests**

The consumption of rapeseed oil is slightly above (less than 1 %) the fossil diesel consumption, but quite appreciably overtakes biodiesel (driving in the city, even at 8.7 %). Testing the car after conversion and with the two previously used fuel types, it appeared that the consumption was decreased (depending on the type of fuel and driving cycle from 1 to 5 %).

The tests show that the different incidental factors (for example, traffic intensity and traffic light setting changes, unexpected barriers in the streets, etc.) more often occur in the city driving that is why for more objective tests for urban areas driving cycles have to be developed. The investigations of such cycle development are realized also at the Scientific Laboratory of Biofuels [7]. The developed cycles are usually simulated on a laboratory chassis dynamometer.

The power and torque characteristics operating the automobile on three different fuels are shown correspondingly in Figure 5 and Figure 6.

Testing the car before the conversion with fossil diesel and biodiesel, there were not any surprises. Quite insignificant the power and torque decrease was observed for biodiesel. Testing the car after the conversion with rapeseed oil as a fuel, the power and torque characteristics were significantly lower. The torque and power decrease in certain ranges of speed reached up to 15 %. As the other researchers did not observe such decrease, then this fact can be explained by using new nozzles. However, if the use of a single tank system is planned, the use of these nozzles is very essential for engine starting in cold conditions as well for the normal operating for a long time period. Hence, such power and torque decrease has to be taken into account. An interesting feature was observed in torque characteristics – the peak torque compared with the other two types of fuels after conversion is shifted by about 400 rpm to a higher speed range. In turn, testing the car after the conversion with fossil diesel and biodiesel, the torque and power characteristics are about 10 to 12 % below pure rapeseed oil ones. Even here there is a shift in the maximum torque to the higher speed range.

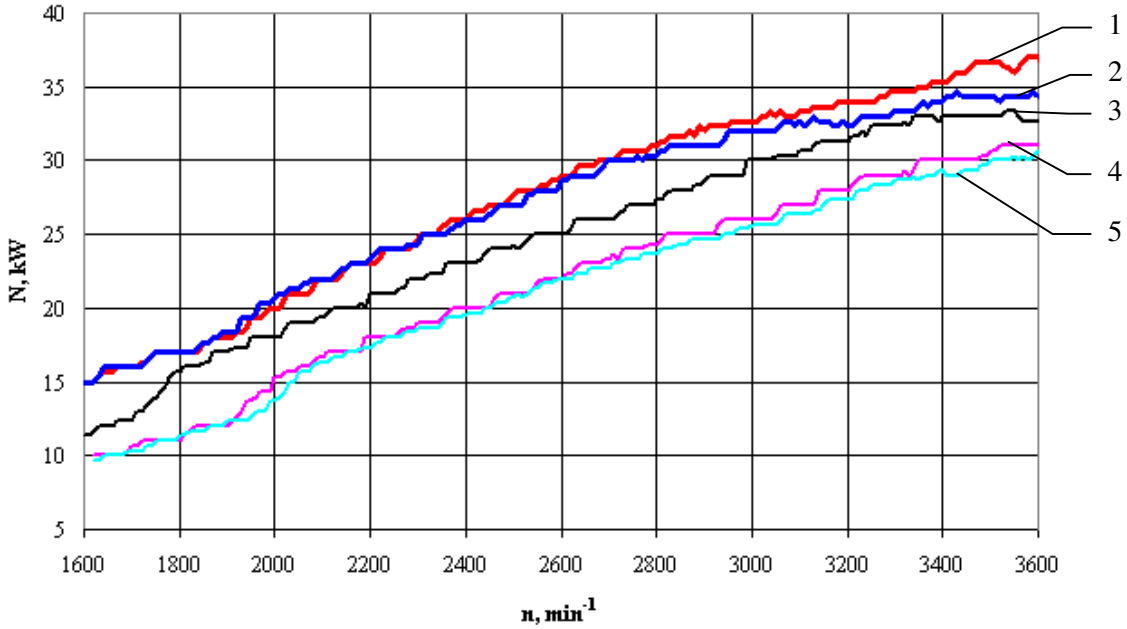

Fig. 5. **Power characteristics operating automobile on three different fuels**: 1 – diesel before modifying; 2 – biodiesel before modifying; 3 – rapeseed oil after modifying; 4 – diesel after modifying; 5 – biodiesel after modifying

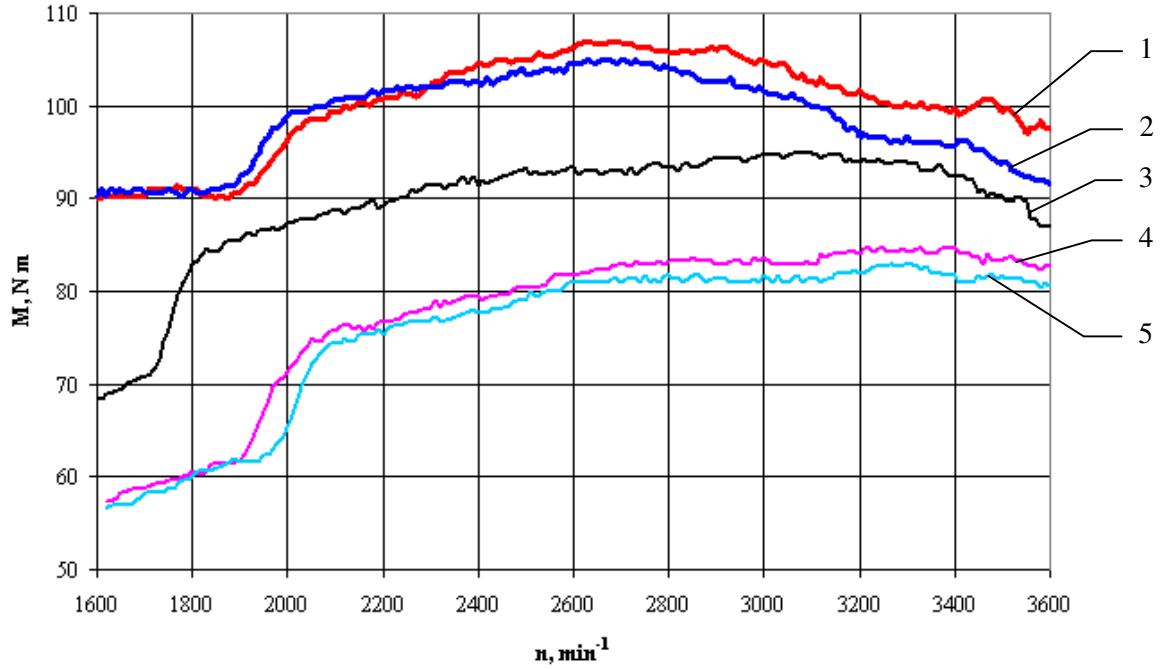

Fig. 6. **Torque characteristics operating automobile on three different fuels**: 1 – diesel before modifying; 2 – biodiesel before modifying; 3 – rapeseed oil after modifying; 4 – diesel after modifying; 5 – biodiesel after modifying

In the power and torque measurements the correlation between the average characteristics operating with each fuel type and measurement results of individual tests was calculated. In all cases it was above 99 %, that is why the measurement results qualify as high rating.

Performing laboratory vehicle simulation, the tests were conducted at speed of 50, 90 and 110 km h^{-1}. The first two of them correspond to the maximum allowed speed in Latvian urban areas and suburbs. The measurements at constant speed were performed for 120 seconds with the reading step of 1 second. Besides that two different driving cycles were used in drivers trace tests – the IM-240 cycle and own made Jelgava cycle [7]. The IM-240 belongs to the combined cycle type, which

takes 240 seconds. The first part of the cycle simulates urban driving conditions where the maximum speed does not exceed 50 km h^{-1}, but the second part of the cycle simulates driving in non-urban area. In turn, Jelgava cycle was created with the aim to simulate as close as possible the real driving in one of the cities of Latvia – Jelgava. The duration of this cycle is 360 seconds and the covered distance 2.36 km.

The comparison of fuel consumption in these experiments is summarized in Figure 7.

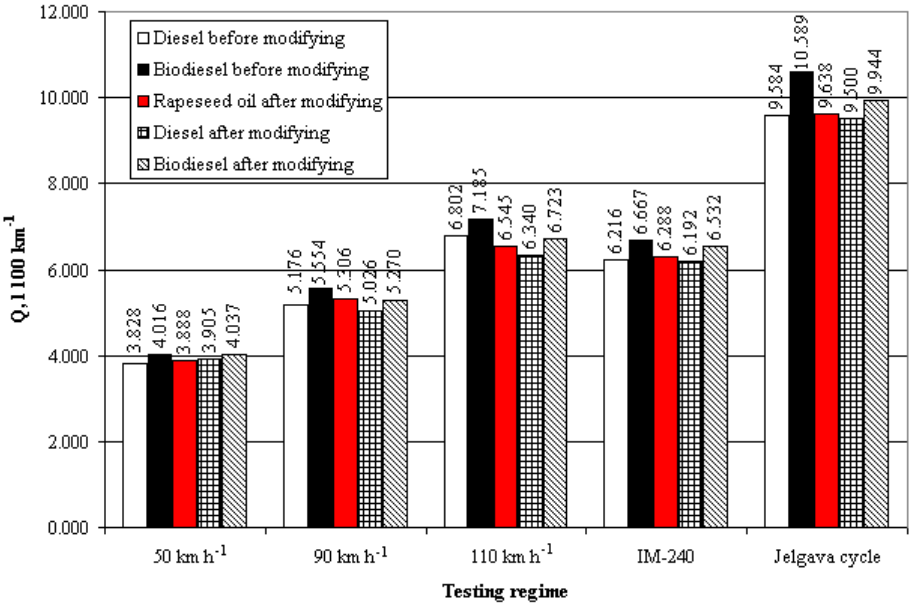

Fig. 7. **Fuel consumption comparison performing vehicle simulation test and drivers trace**

For each measurement repetition at constant speed the variation coefficient was calculated. As it was usually less than 0.3 %, the measurement accuracy is classified as very high. Analyzing the driving trace results for each cycle a strong correlation between the 3-trip velocity curves was observed. The minimal of them was 0.996. Consequently, the fuel consumption results seem to be objective. All tested modes are similar in trend – pure rapeseed oil fuel consumption is slightly behind fossil diesel, but quite significantly overtakes biodiesel.

Performing smoke analyses (Fig. 8), the best results are obtained using biodiesel fuel. Pure rapeseed oil is significantly behind, but at the same time, slightly ahead of the fossil diesel fuel.

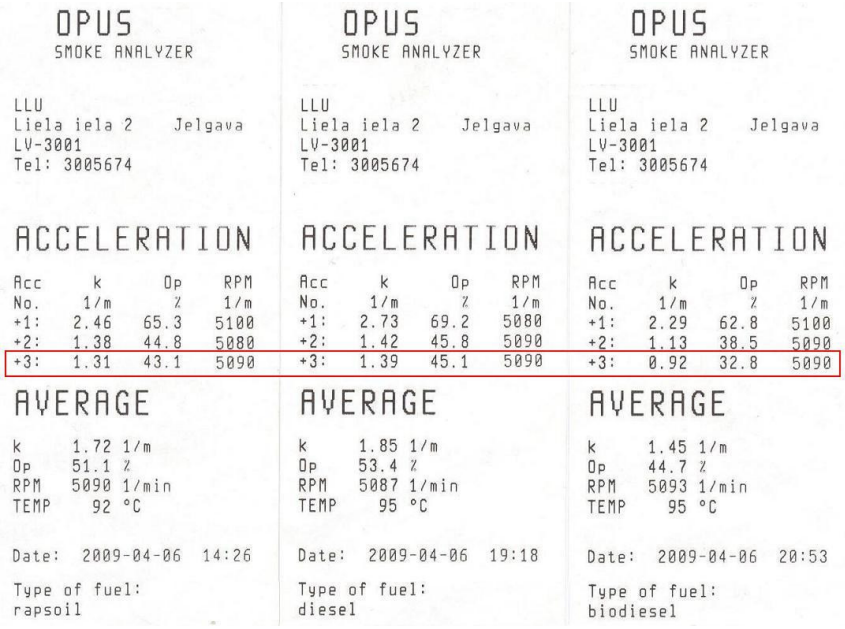

Fig. 8. **Absorption coefficient comparison performing smoke analyses**

It should be noted that before the conversion, using fossil diesel and biodiesel, the absorption coefficient was 1.48 and 0.98 correspondingly.

On a more detailed level the exhaust gases were analyzed using FTIR AVL SESAME Multi-component Measurement System. Figure 9 presents the amount of six different exhaust gas components.

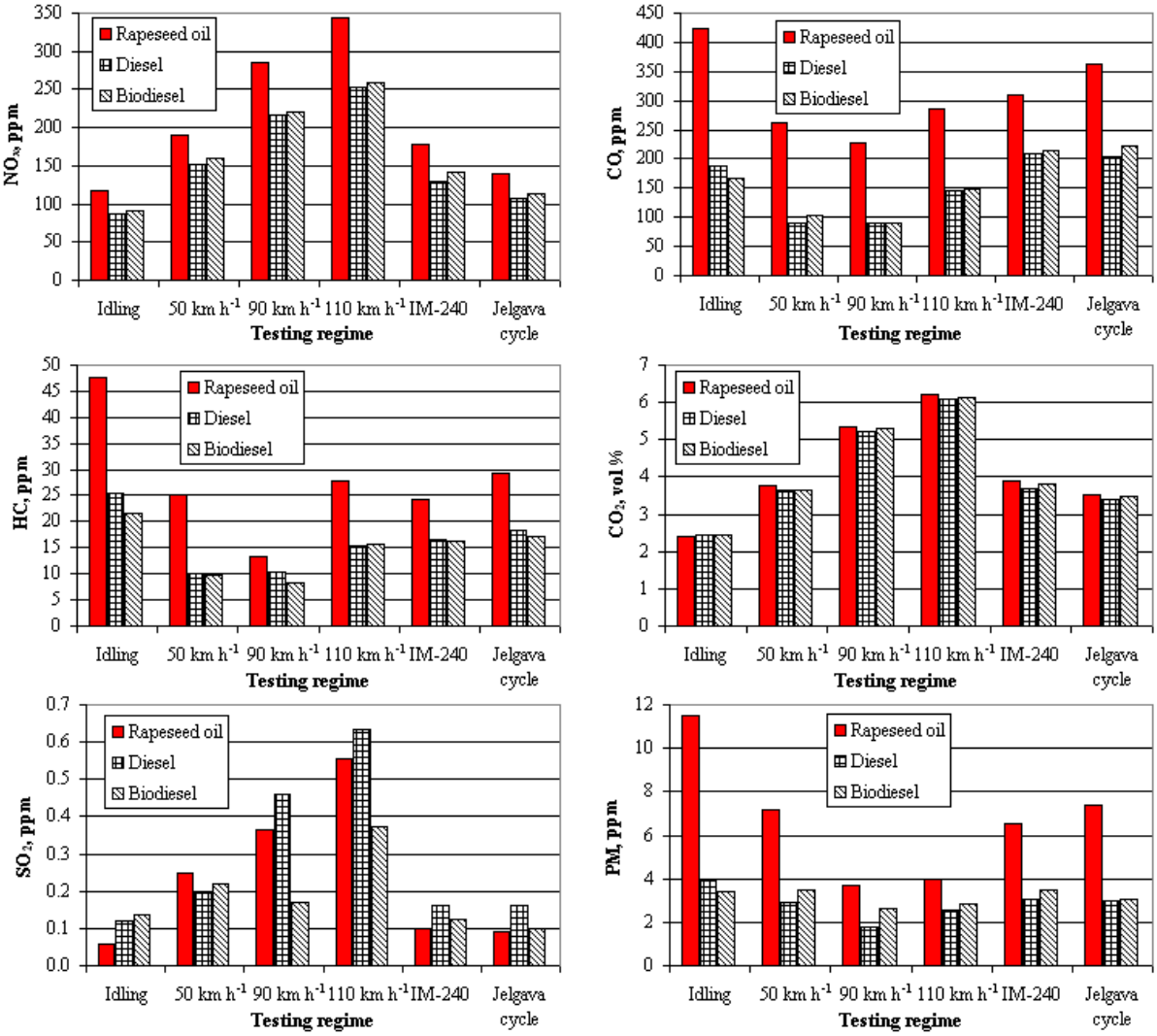

Fig. 9. **Exhaust gas measurement results**

The analyses confirm the results of other researchers that the content of NO_x in exhaust gases for biodiesel increases in comparison with fossil diesel. When using rapeseed oil, this increase is even greater, because of the oil slower combustion. Unfortunately, looking at the CO, HC, CO_2, SO_2 and mechanical particle (PM) quantity in exhaust gases, pure rapeseed oil results in these experiments unpleasantly surprise. Particularly, increase in CO and HC in comparison with the other two types of fuels was not expected.

As the most obvious explanation for the obtained results is the oil quality, as, for example, the total contamination of used oil in the experiments two times exceeded the norm. As established in previous studies [5], the quality assurance is one of the problems for oil producers in Latvia to realize oil as a fuel. It is problematic for them to provide a number of quality requirements, especially the phosphorus content.

Besides, an impact of the use of new nozzles on the combustion process has to be established in future studies.

Conclusions

1. Performing testing of the automobile VW GOLF operating on three different fuels, it was found that using rapeseed oil from the consumption point of view does not cause problems – pure rapeseed oil fuel consumption is slightly behind fossil diesel, but quite significantly overtakes biodiesel.
2. Testing the car after the conversion with rapeseed oil as a fuel, the power and torque characteristics were significantly lower. The torque and power decrease in certain ranges of speed reached up to 15 %.
3. Modified diesel engines can be operated not only with rapeseed oil, but also with fossil diesel and biodiesel. The fuel consumption in this case is slightly lower, but unfortunately the power and torque loss is very considerable. This means that after modifying using a single tank conversion kit, the car is more suited for the use of pure oil as a fuel.
4. After conversion the peak torque for all fuel types was shifted by about 400 rpm to a higher speed range. That is why the decrease of fuel consumption was more considerable driving at higher speed.
5. Performing smoke analyses, the best results were obtained using biodiesel fuel. Pure rapeseed oil was significantly behind, but at the same time, slightly ahead of fossil diesel fuel. Regardless of it, all of the used fuels satisfy the norms for the car to successfully pass the roadworthiness test.
6. Analyzing the exhaust gas measurement results it was ascertained that the content of NO_x, CO, HC, CO_2, and mechanical particles using rapeseed oil exceeded the analogue amounts using fossil diesel and biodiesel. Only in SO_2 content the decrease was observed. As the most obvious explanation for the obtained results is the oil quality, as, for example, the total contamination of used oil in the experiments two times exceeded the norm. That is why the researches on the impact of the use of new nozzles as well as different quality oils in the combustion process have to be continued.

References

1. Labeckas G., Slavinskas S. Performance of direct-injection off-road diesel engine on rapeseed oil. Renewable Energy 31, 2006, pp. 849. – 863.
2. Labeckas G., Slavinskas S. Performance and exhaust emissions of direct-injection diesel engine operating on rapeseed oil and its blends with diesel fuel. Transport – 2005, No. 5, pp. 186. – 194.
3. Altin R., Çetinkaya S., Serdar H.Y. The potential of using vegetable oil fuels as fuel for diesel engines. Energy Conversion and Management 42, 2001, pp. 529. – 538.
4. Thuneke K. Rapeseed Oil Fuel – Production, Quality Demands and Use Experience. Biomass for Energy – Challenges for Agriculture, September 25-26, 2006, Bruges, Belgium [online] [10.04.2009.]. Available at: http://www.northseabioenergy.org/files/17397/Klaus_Thuneke.pdf.
5. Dukulis I., Birkavs A., Birzietis G., Pirs V. Adapting of Automobile VW Golf for Using Pure Rapeseed Oil As a Fuel. Proceedings of the 8th International Scientific Conference „Engineering for Rural Development". Jelgava: LUA, 2009. (Article in press)
6. Dukulis I., Pirs V., Jesko Z., Birkavs A., Birzietis G. Development of Methodics for Testing Automobiles Operating on Biofuels. Proceedings of the 8th International Scientific Conference „Engineering for Rural Development". Jelgava: LUA, 2009. (Article in press)
7. Dukulis I., Pirs V. Development of Driving Cycles for Dynamometer Control Software Corresponding to Peculiarities of Latvia. Proceedings of the 15th International Scientific Conference „Research for Rural Development". Jelgava: LUA, 2009. (Article in press)