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Crude rapeseed oil as a fuel for vehicle propulsion

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Abstract. The paper presents results of operating testing of passenger car Ford Fiesta 1.8D, furnished with an additional installation for fuelling the engine by crude rapeseed oil. Testing was carried out of load characteristics, compression pressure, level of external noise during stoppage of the vehicle and the temperature distribution on particular elements of the engine. To allow an ecological analysis of the engine presented were results of testing of exhaust gas smoke logging. The studies indicate that the use of rapeseed oil does not cause the lowering of power or torque, and has no adverse impact on the operation of the injection pump. Pressure, noise level and smoke logging value did not differ (within error limits) from results obtained for diesel oil.

1. Introduction

Nowadays, while the motorisation industry is developing quicker than ever, air pollution is the object of international debates, and standards concerning the emission of exhaust gases are being systematically tightened, a topic that is gaining particular importance in such a situation is the search for alternative possibilities of fuelling engines of vehicles, mainly passenger cars, by vegetable fuels [1, 2].

Given the familiarity with parameters of rapeseed oil, its properties and the impact on engine structure [3-6], a decision was made to modify a diesel engine to obtain dual fuel engine [7-9]. Diesel oil was used in this case to initiate the combustion process, and the main fuel was crude rapeseed oil, heated up in a specially designed heat exchanger [10, 11]. Such a solution has a lot of advantages and is considered to be forward looking [12, 13].

The concept of the research was to verify the legitimacy of using crude rapeseed oil in a passenger car with a dual fuel system. A study was conducted of basic characteristics pertaining to the performance of a vehicle fuelled by rapeseed oil and the exhaust gas opacity level.

2. Methodology

The tests were carried out using a passenger car (Ford Fiesta 1.8D equipped with a diesel engine, with indirect injection into the swirl chamber), which was additionally furnished with an installation for fuelling the engine with crude rapeseed oil. Technical parameters of the engine have been presented in table 1, and a sample diagram of a system adapting the standard fuelling system for needs of rapeseed oil fuelling (dual fuel system) is illustrated by figure 2. The rapeseed oil flow heater used the heat of the refrigerant fluid. The mechanical thermostat kept the temperature of rapeseed oil at approximately 55°C. In the research use was made of winter diesel oil IZ-35 (produced by PKN S.A.) and pure rapeseed oil.

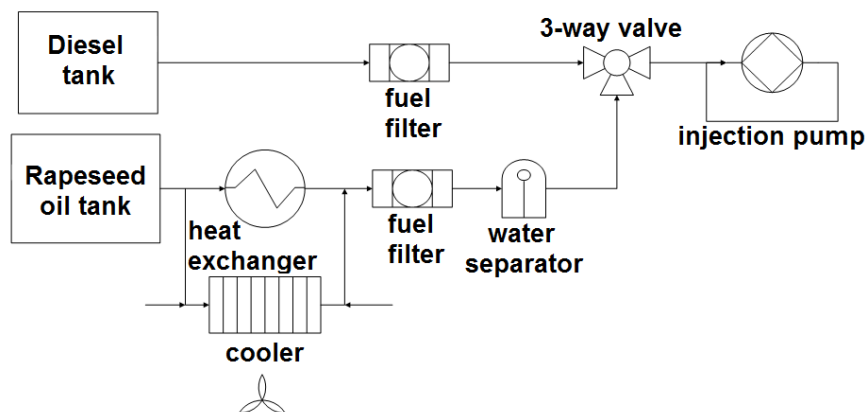


Table 1. Physiochemical parameters of analyzed oils.

Parameter	Diesel oil IZ-35	Rapeseed oil
Sulphur content [mg/kg]	10	6,9
Flash-point [°C]	56	272
Carbon residue in 10% distillation residue [% (m/m)]	0.3	0.5
Ash content [% (m/m)]	0.010	< 0.001
Kinematic viscosity in 40 °C [mm ² /s]	1.5-4.0	35.40
Cloud point [°C]	-22	-19

Table 2. Technical parameters of engine (Ford Fiesta 1.8D).

Engine capacity [cm ³]	1753
Engine type	diesel
Engine power at 4800 [r/min] [kW], [KM]	44. 60
Maximum moment 2500 [r/min] [Nm]	110
Method of engine mounting	in a transverse way at the front
Camshaft type	SOHC(OHC)
Number of cylinders	4
Arrangement of cylinders	in rows
Compression level	21.5
Number of valves per cylinder	2

**Figure 1.** Layout scheme of dual fuel retrofit system.

To allow an accurate determination of external characteristics of the engine (power, torque, capacity losses), the vehicle was tested on a chassis dynamometer. The dynamometer was furnished with an air fan assuring air exchange during tests of capacity and simulation of driving conditions, to maintain the appropriate measurement conditions. For needs of the testing selected was the method of free acceleration. It consists in forceful maximum pressing down the acceleration pedal. A full fuel dose is supplied to the cylinders, until the engine has achieved the admissible rotational speed and fuel dosage is then being decreased as an effect of activation of the injecting pump regulator [14]. In this case the assessment criterion is the highest smoking value which is the counterpart of maximum smoking of the loaded engine. Opacity was measured using a ISC OLIVER D60 opacimeter, and the external noise level was measured with the use of the AS120 noise level meter. The measurement consisted in making a read out of the noise level value (dB) during the short period of engine operation

at the rotational speed conforming to 75% of rotational speed for maximum power. An analysis was executed of values that have been obtained from three consecutive measurements, which differed from each other by more than 2 dB. The distribution and level of temperatures on selected engine components were measured in the facility of the Technical Inspection Centre situated on the premises of the Department of Production Engineering of the Warsaw University of Life Sciences with the use of the Vigocam V50 thermal vision camera.

3. Execution of analyses and results

An analysis of measurements of power, torque and capacity losses in the function of the engine rotational speed (figure 2 and figure 3) allows the presumption that the usage of rapeseed oil for fuelling of a diesel engine with direct injection does not cause a decrease in power and torque as compared to fuelling by diesel oil. Power curves on the graphs have an identical shape; only once engine rotations achieve the level of ca. 5250^{-1} , the power of an engine fuelled by rapeseed oil decreases. The similar happens for example for torque. In both cases power losses are identical.

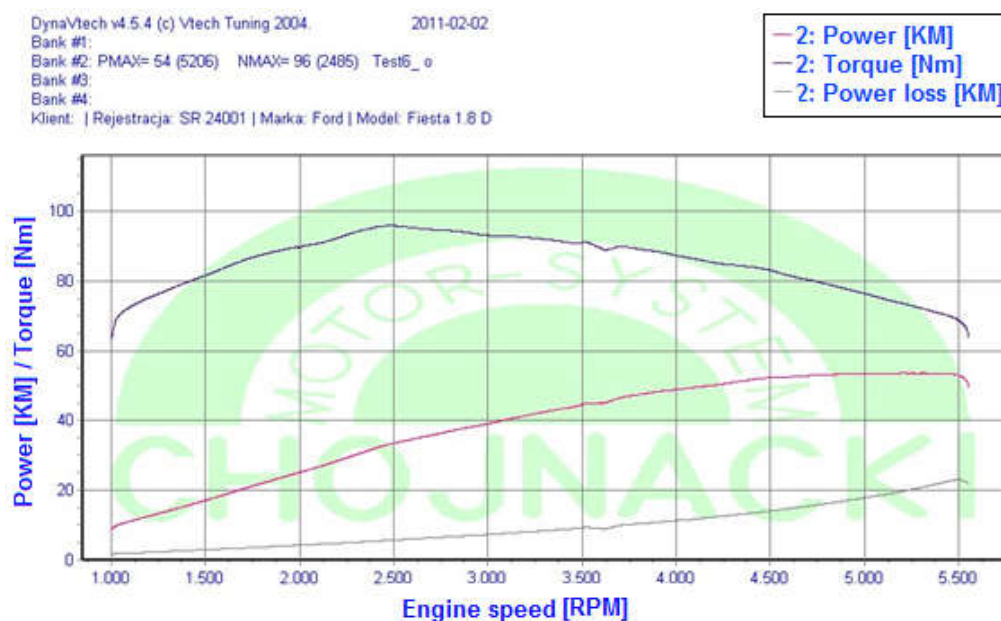


Figure 2. Graphs of power, torque and power loss as a function of engine speed test of passenger car engine fed with diesel.

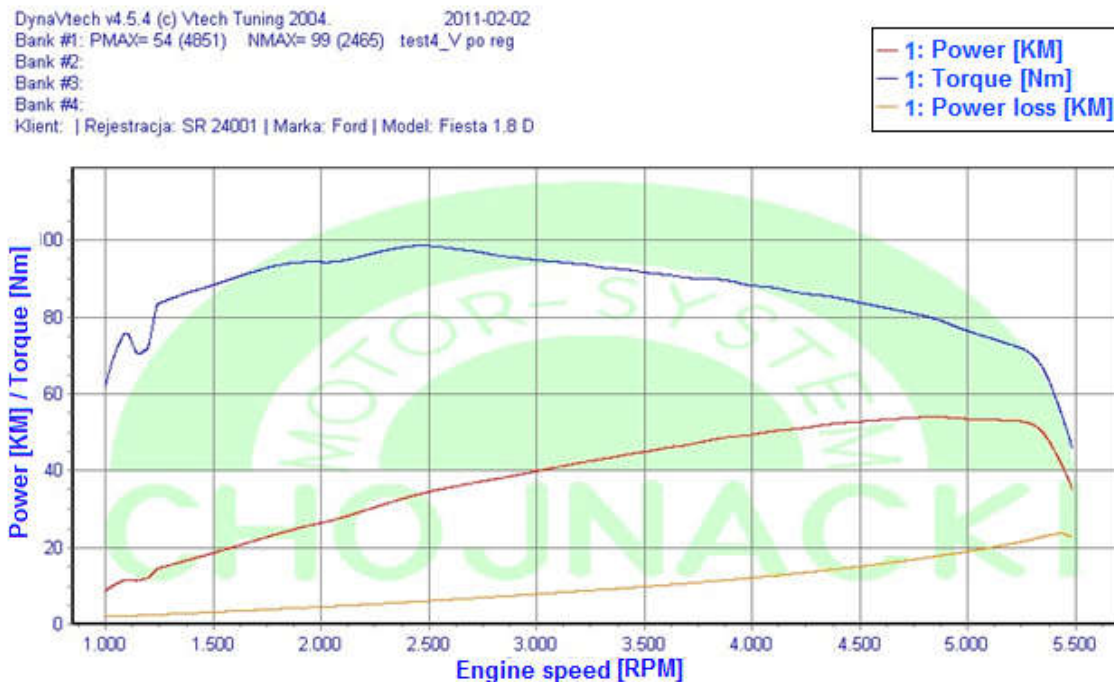


Figure 3. Graphs of power, torque and power loss as a function of engine speed test of passenger car engine fed with crude rapeseed oil.

Two measurements were carried out of the compression pressure. The first test was performed on a cold engine for diagnostic needs. The second test was performed for a warmed engine. Results of the experiment have been presented in table 2. The value of compression pressure in the first cylinder in an unheated engine is lower by 7% than the pressure on the remaining cylinders. This indicates a slightly impaired engine start-up at lower temperatures. The pressure measurement carried out on a heated engine showed that during operation of the engine the compression pressure in all cylinders became equalised and ranged from 3.0 to 3.1 MPa.

Table 3. The compression pressure of cold and hot engine.

Cylinder number	1	2	3	4
Compression pressure of cold engine [MPa]	2.8	3.0	3.0	3.0
Compression pressure of warmed engine [MPa]	3.0	3.0	3.1	3.1

In addition during the testing two series of smoking parameters have been carried out (table 3). Those analyses were performed due to ecological requirements (contents of toxic compounds in soot) and safety needs (visual screen impairing driving of the car). Average values of exhaust gas smoking in both series of measurements of an engine fuelled by rapeseed oil did not differ (within error limits) from those obtained for an engine fuelled by diesel oil. Final measurement values of exhaust gas smoking did not exceed the maximum value determined in §9 par. 1 item 3 and in §45 par. 2 of the regulation on technical criteria ($K = 2.50 \text{ m}^{-1}$).

Table 4. The results of the measurements of smoke opacity of engine fuelled with diesel and crude rapeseed oil.

Measurements for engine fuelled by diesel fuel - series 1		Measurements for engine fuelled by rapeseed oil - series 1	
Exhaust gas smoke value K [m ⁻¹]	Average smoke value of exhaust gas K [m ⁻¹]	Exhaust gas smoke value K [m ⁻¹]	Average smoke value of exhaust gas K [m ⁻¹]
2.43	2.24	2.47	2,27
2.25		3.15	
1.96		2.48	
2.33		2.25	
-		2.27	
-		2.07	
Measurements for engine fuelled by diesel fuel - series 2		Measurements for engine fuelled by rapeseed oil - series 2	
Exhaust gas smoke value K [m ⁻¹]	Average smoke value of exhaust gas K [m ⁻¹]	Exhaust gas smoke value K [m ⁻¹]	Average smoke value of exhaust gas K [m ⁻¹]
2.47	2.04	2.76	2.05
1.87		2.10	
2.00		2.08	
2.08		1.88	
2.19		2.16	

The consequent studies were related to noise level. The background level (disturbances) outside the vehicle equalled to 54.2 dB, while the value of noise level at the defined rotational speed conforming to 75% rotational speed of maximum power for an engine fuelled by diesel oil, as well as for engine fuelled by rapeseed oil, was identical and amounted to 86 dB. Hence the final value of measurement of the external noise level of the vehicle did not exceed the maximum value specified in §9 par. 1 item 1, §45 par.1 item 2 and in §53 par. 5 of the regulation on technical criteria (96 dB).

In order to compare the heating of the engine supplied with different fuels, the temperature distribution components of engine fuelled with diesel and rapeseed oil was determined. Thermographic images were recorded by the camera in sequential mode at intervals of 5 seconds from the moment of starting until the engine reaches the set operating temperature.

Figure 4 presents sample thermograms obtained during heating up the diesel engine fuelled with diesel oil after 15, 130, 325 and 985 seconds from the moment the engine was started. The first thermogram (after 15 s) shows that the temperature distribution is also influenced by the glow plugs preheating the pre-combustion chamber in the head. The analysis of the other thermograms shows that the highest external engine surface temperatures occur on the surface of the head around the injectors.

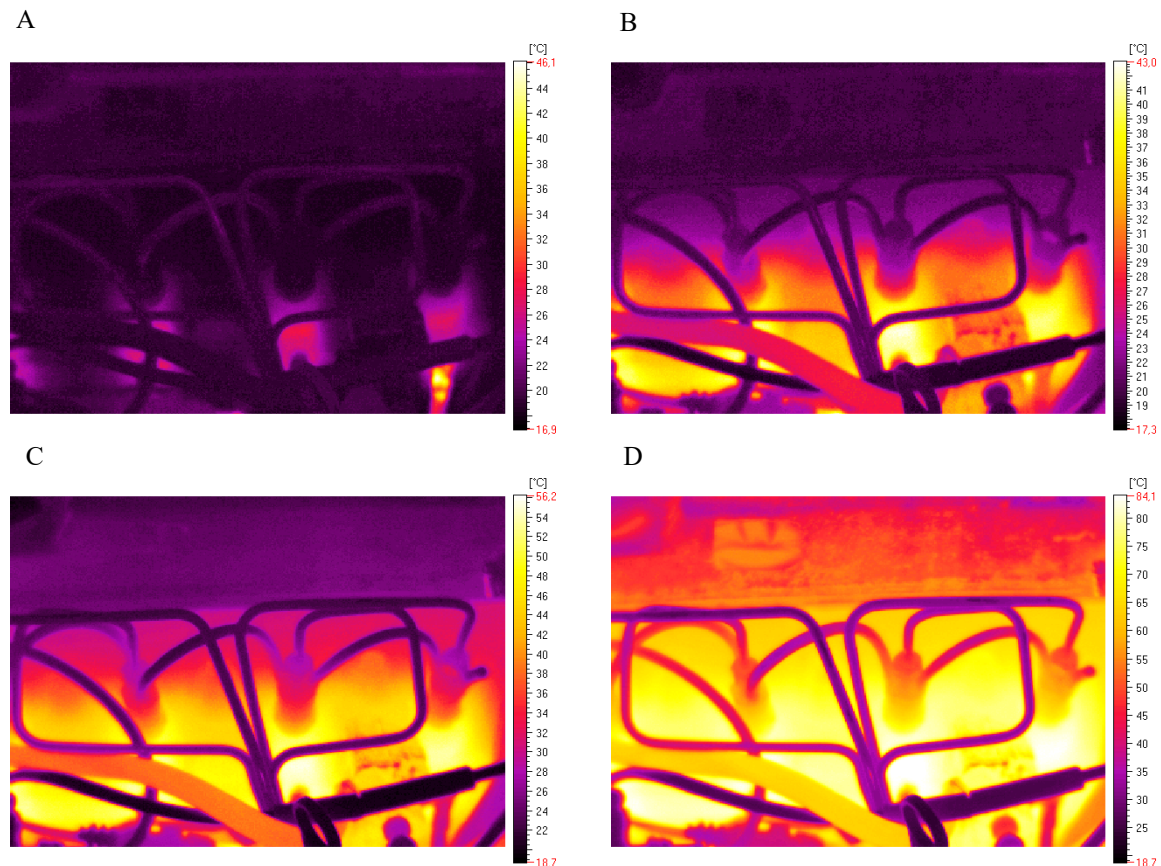


Figure 4. Temperature distribution on individual elements of engine fuelled by oil after: 15 sec (A), 130 sec (B), 325 sec (C), 985 sec since the start (D).

In the same way, thermograms were made for various components during the heating of the engine fuelled with rapeseed oil (Figure 5). The course of the heating process and the temperature distribution on different engine components was very similar to the previous experiment, however, for longer times since the engine was started, higher temperatures of individual engine components were achieved when supplied with rapeseed oil.

High temperature of high pressure pipes supplying fuel to the injectors and the injectors themselves indicates that the fuel supplied is heating up and therefore the viscosity is reduced, which facilitates the spraying process during its injection into the swirl chamber.

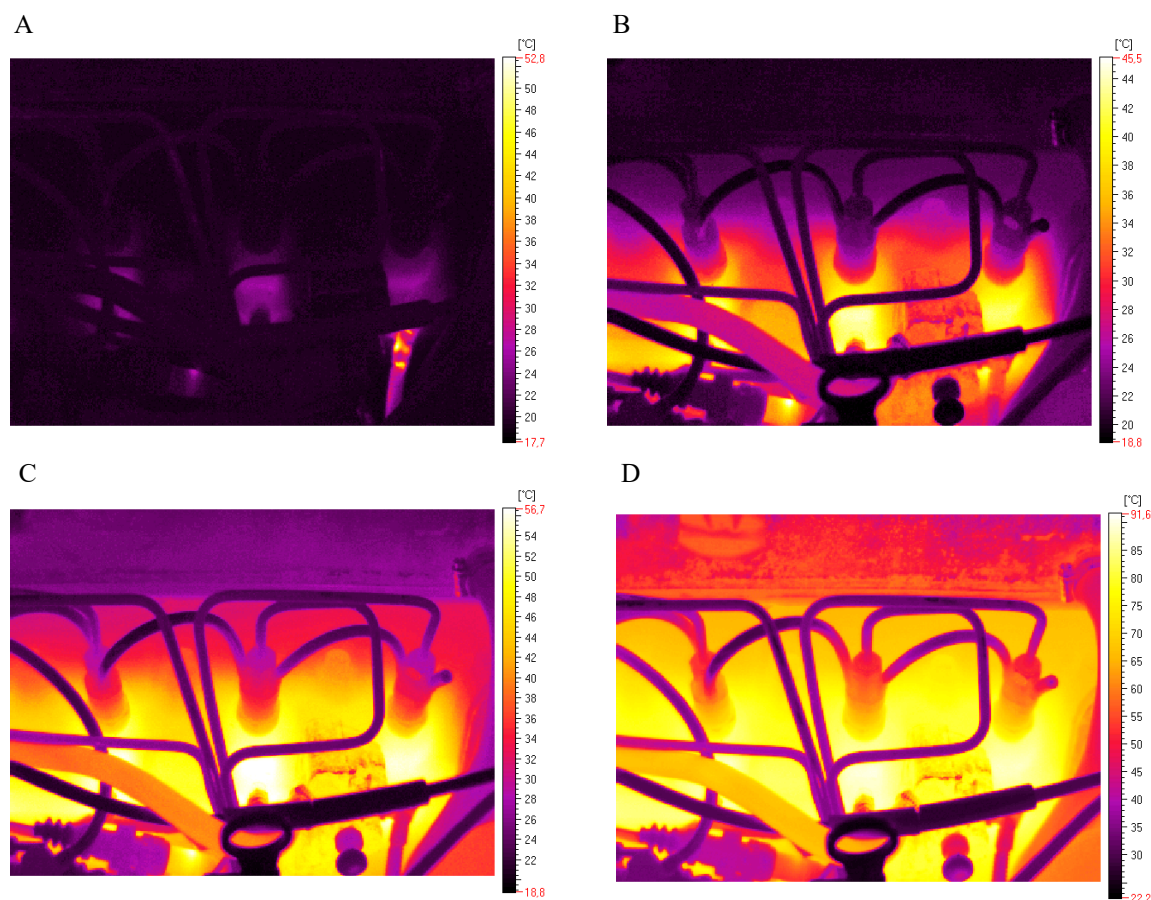


Figure 5. Temperature distribution on individual elements of engine fuelled by crude rapeseed oil after: 15 sec (A), 130 sec (B), 325 sec (C), 985 sec (D).

Figure 6 presents a comparison of the average surface temperature of the observed elements during the heating of the engine running on the two tested fuels. The conducted tests indicate that the temperature level of particular engine elements to the time until achievement of nominal operating depends on the type of fuel used in the engine.

Higher temperatures of particular components of the engine are achieved in fuelling by rapeseed oil. Analyses of thermograms have also shown that as of engine ignition until achievement of nominal operating state, as well as during its operation, particular parts of injectors and head of engine achieve various temperatures. This phenomenon occurs in two cases: then the engine is fuelled by diesel oil, and also by rapeseed oil. Temperature of cylinder block in the analysed fragments is identical and does not depend on the type of engine fuelling.

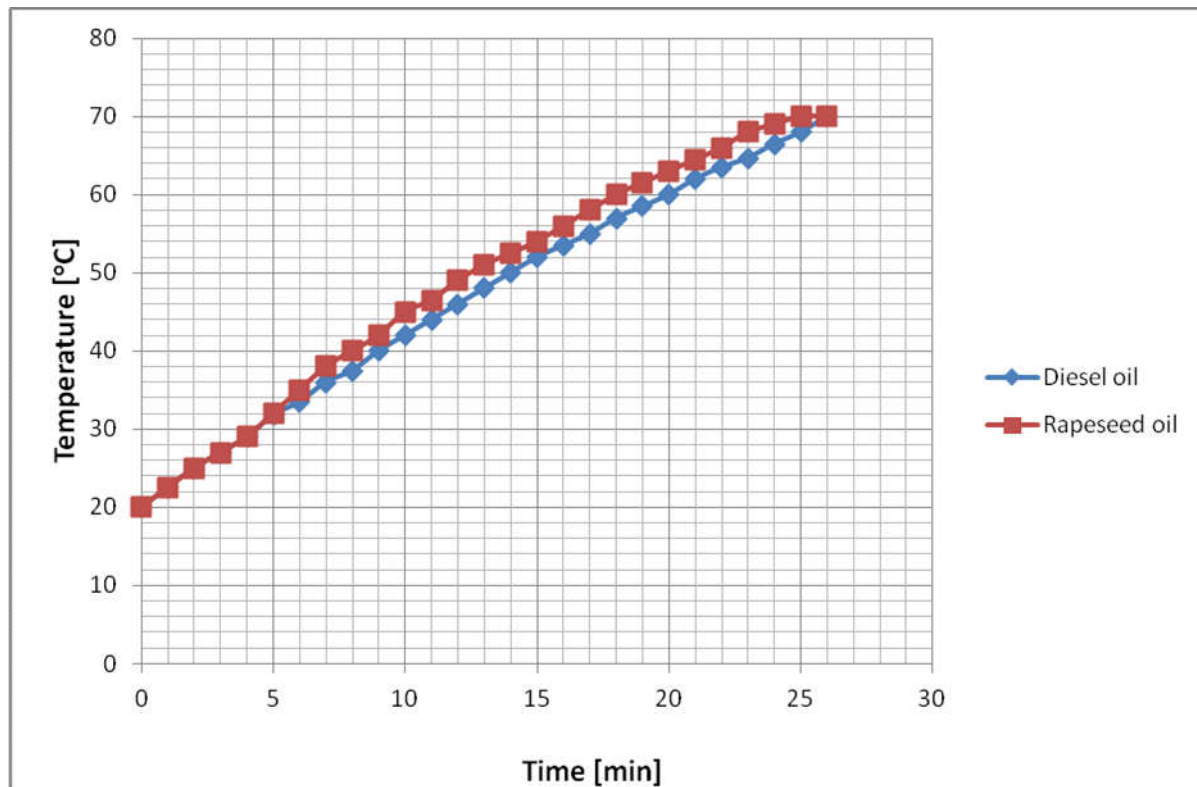


Figure 6. Comparison of the average surface temperature of the observed elements during the heating of the engine running on the two tested fuels.

4. Conclusions

Control of a part of the engine fuelled by rapeseed oil showed that the combustion process after operation throughout 80 000 km progressed correctly and did not have an adverse impact on the durability of the injection pump. Based on measurements of power and torque a presumption may be made that the use of rapeseed oil for fuelling of a diesel engine with indirect injection does not cause a decrease in power or torque as compared to its fuelling by diesel oil. Measurements of pressure, exhaust gas smoking value and noise level did not point to a harmful impact of fuelling of this type of engine by rapeseed oil. A disquieting fact is the increased amount of carbon deposits on the surface of piston bottoms, surface of heads and valves, outfall gas ducts and injector tips. This is an adverse phenomenon, which may nevertheless be limited to a considerable extent by using additions to rapeseed oil, to enhance its combustion.

Conducted thermovision tests of surface temperatures of engine components during its heating indicate that higher temperatures occurred when the engine was fuelled with rapeseed oil than diesel oil.

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