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Possibilities of using vegetable oil to power diesel engines as well as their impact on engine oil

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Abstract. The environmental advantages of biofuels cannot only evaluate the final production of pollutants resulting from the combustion of biofuels in the vehicle, but it is necessary to take into account the entire life cycle of fuels including the initial phase of production of raw materials through production to finally the fuel burning vehicle and how it affects the vehicle mechanisms. The Article describes the possibilities of powering diesel engines based on vegetable oils (RME, rapeseed oil) as an alternative to standard diesel fuel. It deals with the properties of biofuels and their potential use in the internal combustion engines by the structural adjustment of the fuel system or the combustion chamber. It also highlights the potential negative impacts of vegetable oils on the machine's operability and the possibility of reducing the negative effects. The article is based on laboratory analysis of tribotechnical diagnostics. They describe the current state of oil, its primary and secondary pollution and wear of the machine. The important method is ferrography to which the main emphasis is focused. The experimental section analyzes the impact of biofuels on the quality of oil used to fill diesel engines, and establishes an optimal oil change interval. For minimization the negative effects of biofuels is tribotechnical diagnosis necessary part of fuels quality evaluation.

Key words: rapeseed oil, RME, engine lubrication oil, construction change, tribotechnical diagnostic.

INTRODUCTION

The phenomenon of the 20th century, the automobile and oil, no other individual sectors of human activity to a degree not affect all our lives. The development of motorization had a major influence on the development and fuel consumption. During the last two decades, along with the impending exhaustion of fuel sources, greatly accelerated the development of automotive technology, particularly in relation to environmental requirements it is necessary to look for new energy sources environmentally friendly. In general, the consumption of energy is an exponential curve, while energy sources, especially fossil, rapidly diminishing, which largely relates to oil. It should also be borne in mind that the oil is not only fuel, but also an important raw material in the chemical industry. The situation in the sources is complicated because two-thirds of oil resources are concentrated in countries in the

Gulf region, which significantly affect world oil production (Hromádko et al., 2009; Hönig et al., 2009).

Currently, spending large sums on the search for alternative fuels for internal combustion engines. In order to alternative fuel to push must be resolved question of performance, range, durability and last but not least cost. Therefore, not biofuels seems like the easiest option in terms of production, engine characteristics, availability as well as the related financial difficulty (Šmidrkal et al., 2008). The main focus in this article is devoted to biofuel most promising for farmers rapeseed oil and its methyl ester (RME). It should be noted that the 'better and more modern vehicle, the more stringent the requirements on fuel quality'. Changes in the design and operation of modern engines prepared complex conditions for the various engine components. Vegetable oils can be used in two ways as a fuel for internal combustion engines. The first is connected minimizing fuel problems and it is a chemical transformation, the second is direct without the use of chemical treatments.

The use of purified rapeseed oil is primarily reduce dependence on petroleum fuel prices, reducing dependence on fossil fuels and means as well as the rise of lucrative farming. However, it is necessary to respect the diversity of parameters of fuel compared to diesel. Tables 1 and 2 provide a comparison of the individual fuel parameters.

Table 1. Dominant Parameters

Parameter		Diesel	RME	Rapeseed oil
Kinematic viscosity (mm^{-2} s^{-1})	-25°C	5–30		300
	0°C	3–14	10	180–220
	20°C	2–8	6.3–8,1	65–100
	100°C	0.7–2	1,7	6–8
Calorific value – weight (MJ kg^{-1})		42.5	37.1–40.7	37.4
Calorific value – volume (MJ l^{-1})		35.2	32.7	34.4
Heat of combustion (MJ kg^{-1})		45.3	39.1–42.9	39.6
Cetane number		45	54–55	35–50
Density (kg dm^{-3})		0.8–0.86	0.87–0.88	0.91–0.94
Flash point (°C)		min. 55	130	300–330
Freezing point (°C)		-12–0	-7	-18–0
Molecular weight		200	850–900	300

Table 2. Other Fuel Parameters

	Diesel	RME	Rapeseed oil
Difference in consumption compared to diesel	0	+10%	+/-2%
Quality of emissions (+/0/-) compared to diesel	0	+	+
Chemicals in the production	-	methanol, KaOH, NaOH	-
Aggression against components	-	aggressive	-
Threats to water resources	threat level 2	threat level 1	Only in high quantities

Comparison of the basic physical properties of rapeseed oil with diesel fuel, as specified in the Tables 1 a 2 reveals significant differences between these fuels. Calorific value of fuel decreases with the amount of added RME. The other parameters such as viscosity and flash point indicate, that the direct use of rapeseed oil in a normal diesel engine is not smooth.

The main advantages of using vegetable oils can be summarized as follows:

1) rapid degradation in the soil (within about 3 weeks);
2) renewable source of fuel in the European context;
3) positive energy balance;
4) increase lucrative agricultural activities and by-product formation;
5) reduction of harmful emissions;
6) absence of carcinogenic substances;
7) handling safety (Qi et al, 2013).

The disadvantage of vegetable oils that have a high viscosity. The viscosity can be reduced by heating the oil and appropriately adjusting flow rates of the injection nozzles (Pexa et al., 2013) The fundamental problem stems from the formation of relatively large droplets of oil and its low evaporation, resulting in the formation of carbon. The mean diameter of the droplets in the fuel injection is in a vegetable oil (even when heated to 90°C) by about 80% greater than diesel. This is also the surface tension, so it is necessary to use additives that can be reduced.

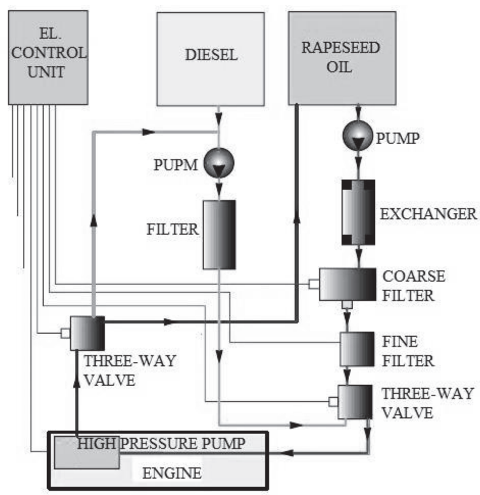

Figure 1. Drawing of Dual Fuel System.

In nowadays there are many companies that offer the possibility of conversion to vegetable oil. It is a dual fuel system with two tanks with a modified low-pressure branch (see Fig. 1). At the start of the oil is heated by an electrical heater, after reaching sufficient operating temperature, the driver can choose to switch the operation of the engine on rapeseed oil, which is preheated by heat exchanger (cooling liquid – vegetable oil). If the temperature is at least 60°C, the electronic unit switches and three-way valves in the high pressure pump is fed through the heat exchanger and at least two filters (coarse and fine) oil. The second three-way valve connects the overflow from the pump to the respective reservoirs. If the driver wants to end the ride must be at least a minute before stopping the engine switch to diesel operation to restart did not go to the oil, because if there 's cooled down, it is not pumped due to high viscosity. If they do, should not allow the control unit to stop the engine running, or at least should be the driver is alerted by an acoustic signal.

Also one possible solution is with one of the fuel tank based on an electrical preheating vegetable oil before the start and during engine operation. This system requires the use of other injectors. To overcome the higher pour point, depending on the outside temperature added to the tank minimal amount of diesel.

MATERIALS AND METHODS

Experimental analysis of the impact of biofuels on diesel oil charge is based on laboratory evaluation samples by tribotechnical diagnostics.

Tribotechnical diagnostic techniques applied to conditions follows three interconnected and inseparable objectives:

1. Determining the life of lubricant on the basis of the degree of wear and tear or depreciation of lubricant (oil) contamination secondly primary (arising from thermo-oxidative processes in the actual lubricant) as well as secondary dirt, getting to the operating lubricant from the outside (e.g. abrasion machine parts or in the form of intake silica dust).

2. The monitoring wear of moving and stationary parts. It is also important observations trend wear as monitoring increases wear metals (Fe, Al, Cr, Pb, Sn, etc.), which corresponds to the monitoring of secondary contamination.

3. Determining the optimal lubricant change interval (operating oil) is directly dependent on two previous findings mentioned in 1. and 2. Oil change interval is determined with respect to engine load, the working conditions and the condition of the engine.

The experiment is based on the assumption that it is impossible to seal the combustion chamber so as not to dilute the oil fill unburnt fuel. In the case of the impact of biofuels on oil filling is still a neglected issue, which however has a significant effect in terms of evaluating the use of non-standard fuels (Aleš, 2009).

The conditions for the realization of this experiment was the selection of a group of identical or similar cars (engines) operating under similar operating conditions. It is necessary to take into account cold starts, the proportion of short and long routes and the effect of STOP & GO motor mode typical of urban traffic.

Measured oil sample comes from three test vehicles Renault Mégane 1.5 dCi with a similar operation. The first vehicle that uses their power to FAME (B100), the latter with built-in dual-fuel system burning **rapeseed oil** + **diesel** and for comparison were analyzed oil samples from vehicles powered by conventional **diesel** fuel. In the experiment were successively sampled during motor oil change intervals of every three of the vehicles on which they were made these tribotechnical tests:

1. Determination of total impurities (% CN) using the apparatus TCM- U, whose principle is to evaluate the light transmittance of the oil filled in the microcuvette.

2. Determination of kinematic viscosity by Ford spout cup with a Ubbelohde viscometer hanging level. The test is based on the standard measurement of the time required to flow a certain amount of oil specified capillary at a given temperature. The results can be seen on Fig. 2.

3. Determination of flash point in open crucible by Cleveland. This is important not only for safety regulations (risk of fire), but also indicates contamination with fuel. The results can be seen on Fig. 3.

4. Particle analysis exploited oils with a final determination of the mode of wear and surface wear (WPC) on the unit PMA – 90 ferrographical method.

Ferrography is a technique that allows the size sorting, separating the particles of the metal nature (especially ferromagnetic) from operating lubricants and other accompanying substances generated primary pollution, such as carbon fiber and a number of so-called soft dirt when washing ferrographical tracks washed away (Ales et al., 2013).

The acquisition of ferrogram will then only assorted metal wear so that at the beginning of the track are particles with the largest volume (the largest magnetic susceptibility) and at the end of a track captures the volume smaller particles. This allows the divergent magnetic field of ferrograph.

1. Each friction pair, each node produces frictional wear particles of specific sizes and shapes, characteristic of the mode wear a pair of the materials.

2. With the increasing intensity of wear (or wear at elevated mode) grows and the shape and size of wear particles, but also by changing the ratio between the large and small particle abrasion.

3. When the machine wear monitors both the overall level of wear (WPC) the indication spectrographic analysis and, secondly, the intensity of wear.

Using PMA – 90 analyzer (capillary analyzer magnetic particles in fluids) is collected input data to compute the level of wear (WPC). The principle consists in the deposition of metal wear particles (especially ferrographic) in thin-walled glass capillary action of a divergent magnetic field. The particles are deposited in the capillary at certain distances depending on their magnetic susceptibility . Save particles in the capillary volume is done. Recorded fotodensity (infrared diode sends a beam through the capillary to the detector) is evaluated in an electronic device.

Used oil was refiled in engine each 15,000 km. Oil sample was taken after each 3,000 km. Samples were numbered according oil refilling and sampling procedure by to digits code. The analyzed oil samples were taken from vehicles to each of the replacement interval was measured successively five samples for three drain intervals. As an example, the pattern of change parameters of oil filling samples taken from the Renault Mégane 1.5 dCi with integrated bi-fuel system for a diesel drive + purified rapeseed oil.

RESULTS

The measured results of oil samples are plotted on nomogram wear trend (Fig. 4), the essence of which is the application of discriminant analysis. Discriminant analysis is a specific method for multivariate statistical analysis. Historically, the first comprehensive set of multivariate statistical methods in theory elaborated in the literature and applied in practice. All measured and calculated values of the level of wear WPC (metal wear particles) are plotted on the x-axis, they are assigned appropriate values determine the total impurities CN % on the y-axi, where it can be read at what stage of wear of engine oil sample analyzed located (Fig. 5).

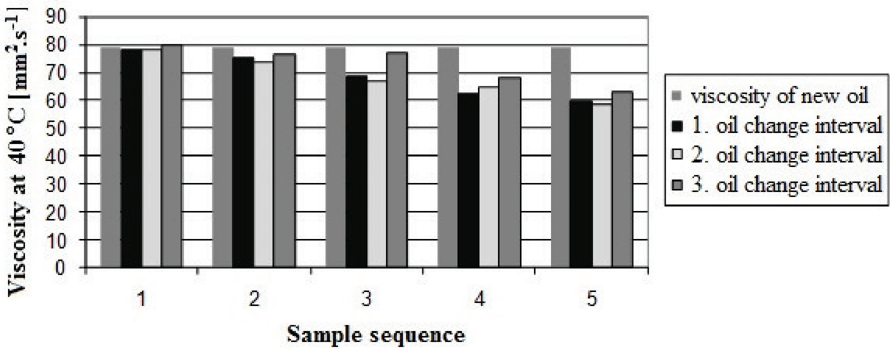

Figure 2. Comparison of kinematic viscosity changes with the new oil drain intervals for individual.

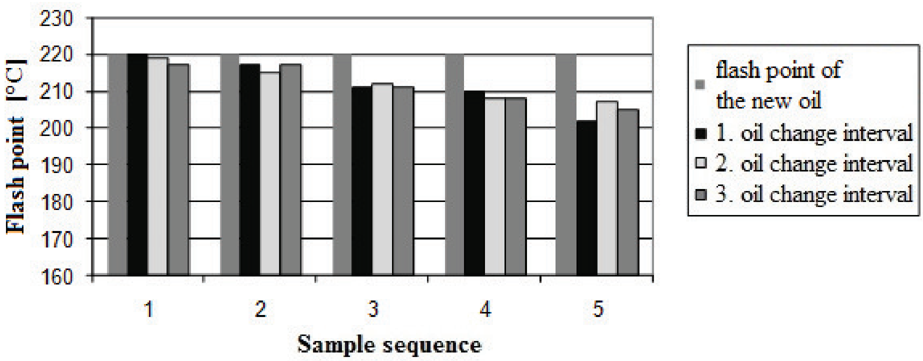

Figure 3. Comparison of changes in the flash point with the new oil.

Fig. 4 shows the correlation of wear oil filling individual drives. For example illustrates the progress of wear already mentioned, the Renault Mégane 1.5 dCi with integrated bi-fuel system, oil + rapeseed oil. The figure 4 shows also compared with samples from vehicles Renault Mégane powered by other fuels: diesel and RME.

To construct a nomogram the wear should be carried out to correct the WPC WPC_K, taking into account also the amount of new oil added for the full replacement interval.

$$WPC_K = WPC \cdot K_C \quad [\% \cdot ml^{-1}] \tag{1}$$

$$K_C = K_M \cdot K_{NM} \tag{2}$$

and the value of K_M, K_{NM} calculated according to equation

$$K_M = \frac{V_k + V_{tu}}{V_k} \tag{3}$$

$$K_{NM} = \frac{M_{ntu}}{M_{stu}} \tag{4}$$

where: V_k (l) – the volume of oil in the casing; V_{tu} (l) – the amount of oil added in the whole interval exchange; M_{ntu} (l) – standardized fuel consumption; M_{stu} (l) – actual fuel consumption.

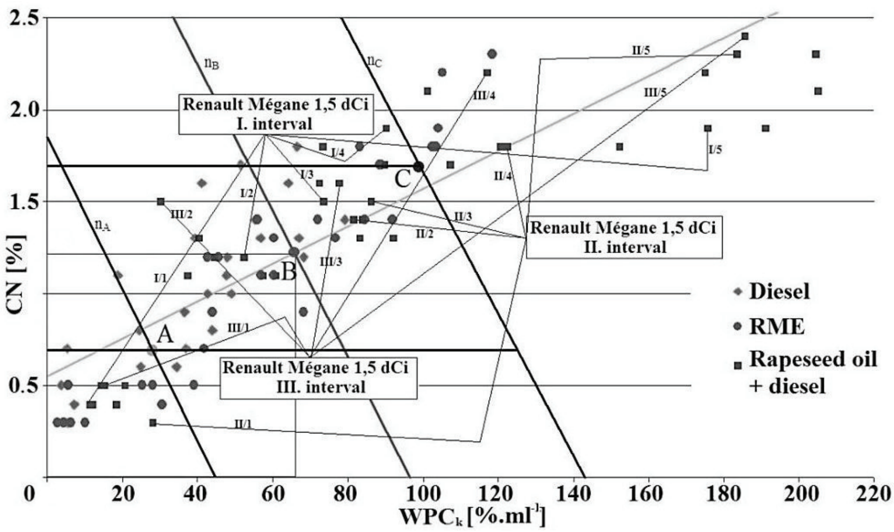

Figure 4. Construction of nomogram: *B* – average of all the values plotted in the graph; *A* – average of the poorer samples; *C* – average of the better specimens.

The results were compared with vehicles powered by conventional diesel fuel. In the case of type RME (B100) leads to higher levels of abrasion wear (WPC) and the overall pollution (% CN) exploited oils, although the decrease in viscosity is not as significant as for diesel. Effect of methyl engine oil, however, causes a greater increase of wear particles, faster degradation and the need to shorten the replacement interval oil.

Results of the effect of rapeseed oil to the oil filling systems from bi brings alarming findings. The first concerns again the values of total level of abrasion (WPC), in this case, the drive against the RME exaggerated, even though the system uses two tanks and propulsion diesel fuel. Surprisingly, however, with values up to extremely high compared with the change intervals of vehicles that run only on diesel.

In a surprising may also indicate relatively high values of total pollution (% CN) exploited oils, which reached more than two percent values. When a significant drop in viscosity leads to loss viscosity reserves and higher increase of wear particles.

Reducing the negative effects of biofuels on the one hand in a very careful adherence oil replacement interval from the start of operation of these vehicles, suitable oils, oil or dust filter and adapt to the structural characteristics of the motor vehicle.

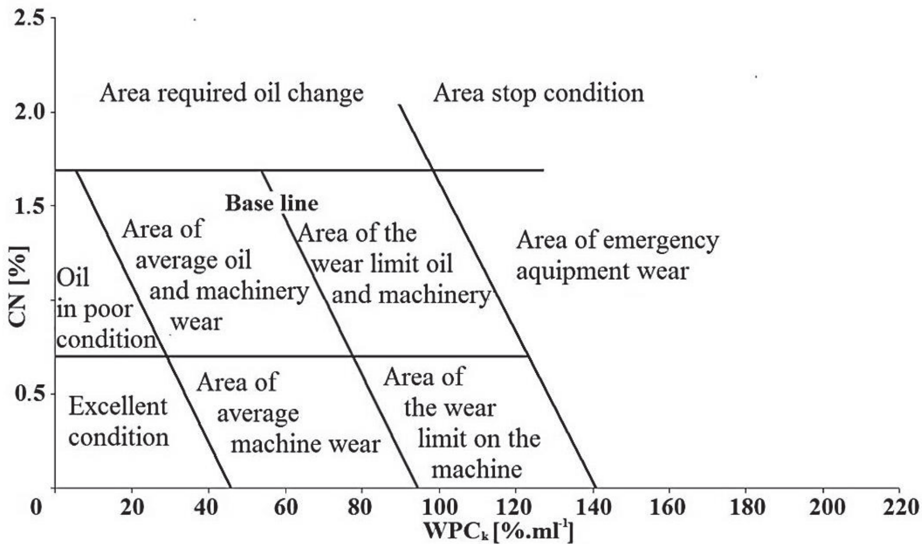

Figure 5. Nomogram the wear.

The degradation of the oil filling also affects the type of operation in which the vehicle is predominantly occurs . Vehicles in urban traffic compared to vehicles which prevails intercity traffic, the refill interval shorter, since an increase in urban wear contributes just STOP & GO mode (from the junction to the junction). The wear values (WPC) and total impurities (% CN), which should be given the most attention are also the dominant parameters for determining the replacement interval. Based on the analyzes of the experimental arises recommendations to shorten the interval exchange at rated vehicles in both cases biofuel. Compared with conventional drive diesel cars would drive by on pure RME should lead to exchanges of oil after about 13–15,000 km. As can be seen from Figs 4 and 5, the samples are largely found in the field of accidental wear, in the case of dual-fuel systems, diesel – rapeseed oil by this change intervals therefore not exceed about 9,000 km (considering mixed traffic – urban and interurban).

Preventive replacement of the oil filling may seem uneconomical, but subsequent negative effects have a decisive impact on uptime and the need for subsequent repair or replacement of parts, whether in the case of the oil, so if for example, injection pumps in the selection of inappropriate biofuels (FAME fats of animal recycling, used frying oils, etc.).

CONCLUSIONS

First, the purified rapeseed oil was in the case of production and use, for instance in the farm to cut fuel costs. From the point of view fuel running diesel engine with its high cetane index (CI around 50 units) finer, fuel is biodegradable, which may allow easier entry of agricultural machinery in times of extreme protected areas or places near water sources and burning produces minimally harmful emissions and substances contained therein are not carcinogenic.

The greatest enemy of smooth usage is motor temperature regime influenced by the nature of the power load. Viscosity rapeseed oil is significantly higher than for diesel fuel, which restricts the use of such dual fuel systems. The cold properties are worse than diesel or RME and fuel has a lower oxidation stability, causing the formation of sludge in storage.

In the case of the use of biofuels, it is necessary to define when and how they will be used. Since this is a non-standard fuel, should not be ignored chemical properties not only with regard to such oxidative stability and carbonization components, as well as characteristics of the vehicle, without which the fuel itself or not justified. As apparent from the above experiment, one can never provide the combustion chamber so as to prevent mixing of the oil filling unburnt fuel. This results in a change in viscosity and increase WPC (metal wear particles), which causes degradation of the oil and wear of the lubricated parts. It is therefore necessary to respond to the diversity of fuel and reduce replacement interval for oil.

With instituted mandatory admixture of bio-components and a gradual increase in the percentage of standard fuels are questions the impact of biofuels on the vehicle one of the most discussed issues of the problem. Despite a number of positive (environmental, economic, etc.), bringing biofuels as well as some negatives. As also evident from the evaluated experiment, so next elections alone fuel must take into account the impact on the oil, which should not be neglected in order to minimize risks and to secure the smooth operation of the vehicle.

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