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The effect of biofuels on the quality and purity of engine oil

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Abstract. The European Union aims to promote the use of biofuels and thus set a commitment to the expansion of biofuels in transport. Biofuels replace fossil fuels mainly in part, the creation of biodiesel. For gasoline engines, the most widely used biofuel is E85, a fuel containing 85% ethanol and 15% gasoline. The more bio-components are contained in a fuel, the more oil filling the combustion engine suffers. Therefore, in this paper, a comparison of the properties of oil filling when using fossil fuels (currently contains a small amount of the fuel ethanol) and the E85 biofuel is provided. The cars Saab 95 and 93 are monitored, namely the motors B235 R, B207 L, and B205 L. For each car, the total of 10 samples of engine oil were taken. One part of the samples was collected during operation of the internal combustion engine on the biofuel E85 and the second during operation of the internal combustion engine on the fossil fuel BA95. Both vehicles used the same engine oil, Mobil 1 0W-40, for lubrication of the internal combustion engine. The analyses of the engine oil are focused on the evaluation of the kinematic viscosity and density at 40 and 100°C.

Key words: biofuel, oil, viscosity.

INTRODUCTION

In recent years, the European Union has devoted increasing attention to the possibility of using biofuels as a source of energy for transportation. The main requirements for bio include the requirement for similar chemical and physical properties to conventional fuel.

The E85 fuel is currently promoted as the most widely used substitute to fossil fuels, which cover most of the energy consumption in the transport sector, particularly in the automotive industry.

E85 is a fuel mixture, which contains 85% ethanol and 15% BA95. The composition of ethanol may vary depending on the season. The E85 fuel is exempted from excise duty in the Czech Republic (AUTO INZAT, 2014).

The standard ethanol component of E85 can be made of any crop which contains carbohydrates, i.e. grass over potatoes, cereals to beet. The raw material can be any lignocelluloses-containing biomass such as wood, sawdust or waste in the manufacture of pulp and paper (AUTO INZAT, 2014).

The aim of this paper is to compare the influence of fossil fuel and the biofuel E85 on the quality and cleanliness of engine oil. Measurements were carried out on the private car brand Saab 95 and 93, namely the motors B235 R, L and R B205, L. For each car, the total of 10 oil samples were taken. One part of the ethanol samples was from a driven vehicle and the other from a motor operated on fossil fuel.

The analysis of the motor oil is focused on the viscosity, which is a measure of the flow ability of liquids. Oils with lower viscosity are more fluid (less dense) and have a smaller internal flow resistance against the flow. Higher oil viscosity (thicker oil) turn means higher resistance and thus a slower rate, figuratively, and higher resistance to movement between two lubricated parts. The viscosity of motor oil is very important and is probably the best-known property of oil (Černý, 2006).

The viscosity (or the rate of internal friction) of lubricating oil is not a constant value, but depends on the environmental conditions. During engine operation, there are changes in temperature and pressure and it is desirable that the viscosity of the oil under these conditions changes as little as possible. The dependence of oil viscosity on temperature is expressed by the so-called viscosity index (VI). The higher the VI, the less the viscosity changes with temperature changes in the engine. The viscosity index is given in the catalogues of the manufacturers of automotive lubricants. For common designation, the viscosity properties of engine oil are used exclusively in the classification of the SAE (Society of Automotive Engineers, USA). This standard is used for classifying oils into 6 winter classes marked with a number and the letter ‘W’ (from the English word “Winter”) and 5 summer classes with designated numbers. The number is dimensionless and does not relate to any physical quantity. Nevertheless, it is an analogy to viscosity. Thus, if the value is higher, the oil is viscous at the designated temperature (Černý, 2006). The viscosity index is a value calculated from the kinematic viscosity, usually at 40°C and 100°C (Anton Paar, 2014). In Fig. 1, there is an example of viscosity and temperature.

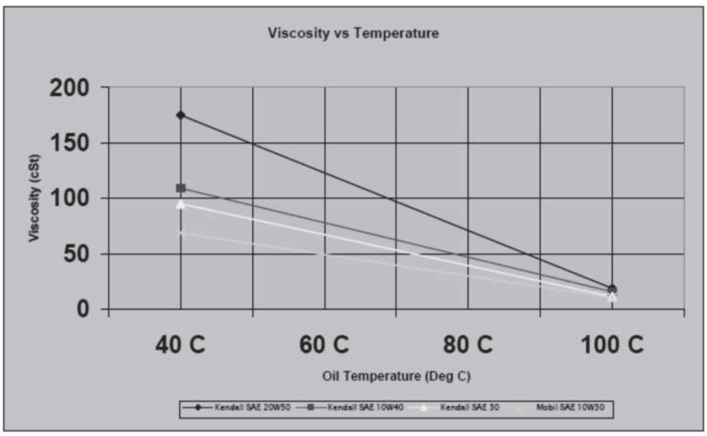

Figure 1. Dependence between viscosity and temperature (Toepfer, 2014).

The classification of the oils by the viscosity classes of the SAE and ISO-VG is performed by measuring the viscosity in new, unused oil. However, several tens of hours of operation may change the viscosity of oil. The viscosity of oil can reduce with intense mixing or increase by the force of oxidation. The change in the viscosity may be so significant that the oil classifies into a different viscosity class of the SAE or ISO-VG. This can have a very negative impact on the durability of the device, which is lubricated with the oil (Toepfer, 2014).

MATERIALS AND METHODS

The oils of the abovementioned combustion engines were analysed using a Stabinger viscometer. The viscometer SVM 3000 Stabinger is a modified rotary viscometer, which is used for measuring the viscosity and density of oils and liquid fuels in accordance with ASTM D7042. From the measured values of dynamic viscosity (mPa·s) and liquid density (kg m^{-3}), the unit automatically calculates the kinematic viscosity (mm^2 s^{-1}) and viscosity index according to ASTM D 2270/ISO 2909 (Sejkorová, 2013).

The principle for determining the dynamic viscosity is determination of the stable rotational speed for measuring of the rotor with an integral magnet that floats in the sample, which is a filled tube rotating at a constant speed. The stable measuring speed of the rotor is achieved when the braking effects of the eddy electric field and shear stress generated in the sample are balanced. The small volume of sample required for the analysis allows extremely rapid temperature changes and a very short time to reach the equilibrium (Sejkorová, 2013). An example of a Stabinger viscometer is provided in Fig. 2.

Figure 2. Stabinger viscometer (IRTEK, 2008).

Measurement of the viscosity is based on measurement of torsion and viscosity. The rotating magnet in 3000 SVM generates an eddy electric field with the exact dependence brake torsion. The swirl braking field is measured with high accuracy. In combination with an integrated thermoelectric thermostat, this provides extremely accurate results. The resolution when measuring the voltage is only 50 pico Nm. Therefore, it only requires a very compact measuring cell (Anton Paar, 2014).

The accuracy obtained by the SVM 3000 in the laboratory study of the ASTM subcommittee D02.07A has been shown to be equivalent to the accuracy achieved in the measurements made according to the ASTM D445. No significant bias can be found between the methods. The extremely high sensitivity of the eddy current torque measuring thermoelectric temperature control system provides unparalleled precision. The resolution moment is unmatched: 50 pico – Nm. This is comparable with the torque resulting from dust particles to 1 cm lever arm and allows minimization of the measuring cell (IRTEK, 2008).

In the observed passenger car brand Saab, engine oil with Mobil 1 0W-40 designation was used. Table 1 shows the specific parameters of the new engine oil from the safety data sheet of the indicated manufacturer.

Table 1. Parameters analysed for the new Mobil 1 0W-40

Oil – Mobil 1 0W40	40°C	100°C
Viscosity (mm^2 s^{-1})	71.0	13.5
Density (g cm^{-3})	0.865	Unknown

RESULTS

First, we analysed the viscosity and density of pure oil Mobil 1 0W40 to determine whether the data provided in the manufacturer's safety data sheet corresponded to reality. For the measured values, see Table 2. The measurements for statistical control were performed 10 times and Table 2 shows the average of these values.

Table 2. Average of net oil Mobil 1 0W-40

Oil – Mobil 1 0W40	40°C	100°C
Viscosity (mm^2 s^{-1})	75.127	13.516
Density (g cm^{-3})	0.833	0.795

The viscosity of pure oil at 40°C was measured 4.127 mm^2 s^{-1} higher than the value given in the safety data sheet of the manufacturer. The density at 40°C of the pure sample was 0.032 g cm^{-3} lower. These differences between the safety data sheet and the analysis of pure oils are negligible and it can be said that the analysed pure oil at 40°C corresponds to reality. When measuring the viscosity at the temperature of 100°C, the values were almost equal, the difference was about 0.016 higher for pure oil; again, the values correspond to the reality.

Furthermore, for measuring the viscosity of the engine oil of the first automobile 95 with an engine Saab Turbo 2.3, with performance 184 kW, engine identification B235 R and vintage 2004, the samples were taken after 7,000 km. The data of the viscosity and density at measured temperatures 40 to 100°C are presented in Table 3.

Table 3. Viscosity and density at 40 and 100°C in the car Saab 95

	Saab 95	
	Fuel E85	Fuel BA95
Viscosity at 40°C	69.379 mm^2 s^{-1}	70.993 mm^2 s^{-1}
Viscosity at 100°C	unmeasurable	13.010 mm^2 s^{-1}
Density at 40°C	0.698 g cm^{-3}	0.853 g cm^{-3}
Density at 100°C	unmeasurable	0.814 g cm^{-3}

The measured values show that the viscosity and density of the engine oil when using E85 decreased by up to 20%. The measured kinematic viscosity at 40°C was about 5.748 mm^2 s^{-1} lower than that of pure oil. The density was about 0.135 g cm^{-3} lower compared to pure oil. It was not possible to measure the viscosity and density at 100°C, since the device's value could not be recorded.

Regarding the use of the fossil fuel BA95, the viscosity and density at both the engine oil temperature of 40°C and for the temperature of 100°C deviate within the maximum of percent units, i.e. it can be stated that it corresponds to pure oil.

The second type of car was the Saab 93 with the engine volume 2.0 Turbo, performance 129 kW, engine identification B207 L, and vintage 2003, where the samples were taken after 7,000 km. The data of the viscosity and density measured at the temperatures 40 to 100°C are given in Table 4 below.

Table 4. Viscosity and density at 40 and 100°C in the car Saab 93

	Saab 93	
	Fuel E85	Fuel BA95
Viscosity at 40°C	69.263 $mm^2\ s^{-1}$	70.561 $mm^2\ s^{-1}$
Viscosity at 100°C	unmeasurable	12.986 $mm^2\ s^{-1}$
Density at 40°C	0.648 $g\ cm^{-3}$	0.842 $g\ cm^{-3}$
Density at 100°C	unmeasurable	0.786 $g\ cm^{-3}$

From the measured values, it again appears that the viscosity and density of the engine oil decreased by more than 20% when using E85. The viscosity measured at 40°C was about 5.864 $mm^2\ s^{-1}$ lower than that of pure oil. The density was 0.185 $g\ cm^{-3}$ lower than that of pure oil. It was again not possible to measure the viscosity and density at 100° C.

Regarding the use of the fossil fuel BA95, the viscosity and density at both the engine oil temperature of 40°C and for the temperature of 100°C deviate within the maximum of percent units, i.e., again, it can be noted that the values correspond to clear oil.

The third type of car was the Saab 95 with the volume of engine 2.0 Turbo, performance 110 kW, engine identification B205 L and vintage 2002, where the samples were taken after 7,000 km. The data of the viscosity and density of the vehicle were measured at measured the temperatures 40 to 100°C and are shown in Table 5.

Table 5. Viscosity and density at 40 and 100°C in the car Saab 95

	Saab 95	
	Fuel E85	Fuel BA95
Viscosity at 40°C	68.873 $mm^2\ s^{-1}$	70.243 $mm^2\ s^{-1}$
Viscosity at 100°C	unmeasurable	12.763 $mm^2\ s^{-1}$
Density at 40°C	0.624 $g\ cm^{-3}$	0.824 $g\ cm^{-3}$
Density at 100°C	unmeasurable	0.782 $g\ cm^{-3}$

From the measured values, it again appears that the viscosity and density of the engine oil decreased by more than 20% when using E85. The viscosity at 40°C was about 6.254 $mm^2\ s^{-1}$ lower than that of pure oil. The density was about 0.209 $g\ cm^{-3}$ lower compared to pure oil. It was again not possible to measure the viscosity and density at 100°C.

The engine oil when using fossil fuel BA95 has the viscosity and density at both the temperature of 40°C and the temperature of 100°C with the deviation of an acceptable percentage, thus, again, it can be noted that the values correspond to clear oil.

CONCLUSIONS

We used the Viscometer SVM 3000 Stabinger with which the kinematic viscosity and density of the engine oil were measured. These two values were measured at temperatures from 40 to 100°C. The measured values were compared with those of clean engine oil Mobil 1 0W-40, which had the same characteristics with the manufacturer's safety data sheet for that type of motor oil.

The analysis of engine oil was carried out on three types of cars of the brands Saab, which ran on two different fuels. The sampling interval of the oils was about 7,000 km. The measured results are shown in Tables 2, 3, 4 and 5.

From the measured values, it is clear that using E85 decreases the viscosity and density of the engine oil at 40 and at 100°C for all three cars and by more than 20%. When using a fuel with 95 octane values, the difference in the viscosity and density compared to pure engine oil in hundredths of a percent can be considered satisfactory. However, a change of more than 20% is regarded as critical in order to change the engine oil.

The lower viscosity and density when running on the E85 fuel reduce the lubricity of the engine oil and cause the risk of damage to engine components. To prevent or at least limit this, it is necessary to operate the engine running on E85 with a significantly shorter replacement interval, and it must also be halved.

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