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STUDY OF THE INFLUENCE OF THE TYPE OF FUEL USED IN INTERNAL COMBUSTION ENGINES OVER THE RHEOLOGICAL PROPERTIES OF LUBRICANTS

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Abstract: *This research intends to determine the rheological models suitable for Castrol 10W40 oil and to study the relationship between viscosity and temperature at different shear rates. Three different states of the lubricant have been investigated: fresh lubricant, lubricant degradated in a gasoline internal combustion engine and lubricant degradated in a LPG internal combustion engine. The main conclusion of the study is that, from rheological point of view, the level of degradation of the lubricant from a LPG internal combustion engine is very reduce by comparison with the same lubricant from a gasoline internal combustion engine.*

Key words: *Rheology, Combustion engine, Synthetic oil.*

1. Introduction

Generally, all lubricated mechanisms may be monitored during operation by analysis of the lubricant. The results can detect abnormalities such as: contamination by wear particles; type of wear; pollution by external agents causing deterioration of lubricant and/or abrasive wear [8], [9].

Concerning the choice of the methods of monitoring the degree of wear of the lubricants, there may be mentioned physico-chemical analyzes evaluating the lubricating quality of the oil, determination of the content of wear products, microscopic examination and counting particles suspended in the oil [6], [7]. From the perspective of the associated instrumentation that can analyze the sample, it should be noted the viscometer, the Aqua test, the gas chromatography, measuring the flash point, the photometric analyzer spot, the infrared absorption spectrometer, the wear particle counter etc. [4].

One of the most obvious factors that can affect the rheological behavior of a lubricant is the temperature. Some lubricants are very sensitive to temperature, and a relatively small change will result in a significant change in viscosity.

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The analysis of the effect of temperature on the viscosity is essential in evaluating lubricants that will be subject to temperature variations in service or processing, such as engine oils, greases, and hot melt adhesives [2], [3].

This research intends to determine the rheological models suitable for Castrol 10W40 oil and to study the relationship between viscosity and temperature at different shear rates. Three different states of the lubricant have been investigated: fresh lubricant, lubricant degradation in a gasoline internal combustion engine and lubricant degraded in a LPG internal combustion engine.

2. Methodology

The degradation process of the oil has been studied for two cars same type (Dacia Solenza), one equipped with a gasoline internal combustion engine and the other with a LPG internal combustion engine. Both cars had approximately 187000 km turnover, and the oil was collected and changed after a usage of 9000 km.

The physical and chemical properties of the investigated lubricant CASTROL Magnatec 10W40 in fresh state, according to the producer, are presented in Table 1 [10].

Table 1

Characteristic parameter	10W40
Density @ 15°C, g/ml	0.870
Kinematic viscosity at 100°C, mm²/s	14.2
Dynamic viscosity at -25°C, mPa.s	6900
Kinematic viscosity at 40°C, mm²/s	99
Viscosity index	148
Pour Point, °C	-36
Flash Point, °C	200
Ash Sulphated, % wt	1.1

This oil resists better to thickening, ageing and oxidation compared to conventional engine oils. The evaporation loss of the oil is very low and reduces fuel consumption.

The rheological tests were done on a cone and plate rotational viscometer ñBrookfield Cap 2000+ò, which has the possibility of data acquisition and numerical treatment of the results by using CAPCALC32 software [11]. The liquid is placed in between a cone and a disc, one turning point, the other stationary. The advantage of this device is that for large opening angles of the cone, the strain rate is constant across the gap.

All the rheological measurements were performed with two cone-and-plate geometries, which permit to investigate different ranges of shear rates:

- cone no. 3 (characterized by the diameter of 9.53 mm and the angle of 0.45^0), with shear rates of 667 ... 13333 s^{-1};
- cone no. 8 (characterized by the diameter of 15.11 mm and the angle of 3^0), with shear rates of 200 ... 2000 s^{-1}.

To determine the lubricant rheological model for the oil, in fresh and used state (on LPG and gasoline engine), it was used an ñimposed velocity gradientò test, at standard temperature of 20°C, with cones no. 3 and 8.:

There were tested the three samples of oil and there were calculated the lubricant viscosity assuming the Newtonian rheological model [5]:

$$\tau = \eta \frac{du}{dy}, \tag{1}$$

where:

τ - shear stress (Pa);

η - fluid viscosity (Pa.s);

$\frac{du}{dy}$ - shear rate (s^{-1}).

To determine the viscosity variation law versus temperature for analyzed oils, there were made tests for two imposed shear rates: 500 s^{-1} and 3333 s^{-1} and for a temperature range of 20 ... 75^{0}C. The law of variation which has been assumed was Reynolds law [1]:

$$\eta = \eta_{50} e^{m(t-50)}, \qquad (2)$$

where:

η – fluid viscosity (Pa.s);

η_{50} – viscosity at 50 ^{0}C (Pa.s);

m – temperature parameter ($^0C^{-1}$).

t – temperature (^{0}C).

3. Results and discussions

The rheograms for 10W40 oil, in fresh state, used on a LPG internal combustion engine and used on a gasoline internal combustion engine, are presented in Figure 1 for cone 3 and in Figure 2 for cone 8. Figure 3 shows the aspect (color) of the 10W40 oil in all three states.

Using the rheometer software (CAPCALC 32), it can be obtained the viscosity of the oil (Eq. 1), for all three states and both cones, and also the correlation coefficients of the measurements. Tables 2 and 3 show these results, for cone 3 and cone 8.

Table 2.

States of 10W40 oil	Viscosity (η), Pa·s	Corr. coeff.
Fresh	0.191	98.07%
Used on LPG engine	0.189	98.40%
Used on gasoline engine	0.123	97.24%

Table 3.

States of 10W40 oil	Viscosity (η), Pa·s	Corr. coeff.
Fresh	0.201	96.84%
Used on LPG engine	0.200	96.28%
Used on gasoline engine	0.122	82.62%

Analyzing the values of the viscosity, it can observe that the characteristic rheological model for all three states of 10W40 oil (fresh, used on gasoline engine, used on LPG engine) is the Newtonian model, with high values of the correlation coefficient.

Also, another important observation is the fact that the viscosity for the fresh oil and the oil used on a LPG internal combustion engine are approximately the same. That means that the oil from a LPG internal combustion engine is not submitted to any degradation process, from rheological point of view.

Regarding the oil from a gasoline internal combustion engine, its viscosity is reduced with more than 35% by comparison with the fresh oil, which represents an intensive degradation process.

The results concerning the variation of the viscosity with temperature, for both cones 3 and 8, are presented in Figures 4 and 5.

Once again, it can observe that between 10W40 fresh oil and the same oil, used in a LPG internal combustion engine, there is no difference regarding the degradation process.

In the case of the 10W40 oil, used in a gasoline internal combustion engine, the wear of the oil is very pronounced over the whole range of temperature variation.

The characteristic parameters for the Reynolds model corresponding to all three states of 10W40 oil (eq. 2) are presented in Table 4.

Analyzing Table 4, it can observe that the Reynolds model for the variation of the viscosity with temperature is valid for all states of the oil. The correlation coefficients for the regression curves are higher than 90%.

Table 4.

Parameter / Shear rate, s^{-1}	10W40 – fresh		
	η_{50}, Pa·s	m, $^0C^{-1}$	Corr. coeff.
500	0.0603	-0.0378	94.58%
3333	0.0599	-0.0363	95.5%
Parameter / Shear rate, s^{-1}	**10W40 – used on LPG engine**		
	η_{50}, Pa·s	m, $^0C^{-1}$	Corr. coeff.
500	0.0651	-0.0375	97.22%
3333	0.0539	-0.0387	95.71%
Parameter / Shear rate, s^{-1}	**10W40 – used on gasoline engine**		
	η_{50}, Pa·s	m, $^0C^{-1}$	Corr. coeff.
500	0.0452	-0.0314	92.27%
3333	0.0451	-0.0324	96.55%

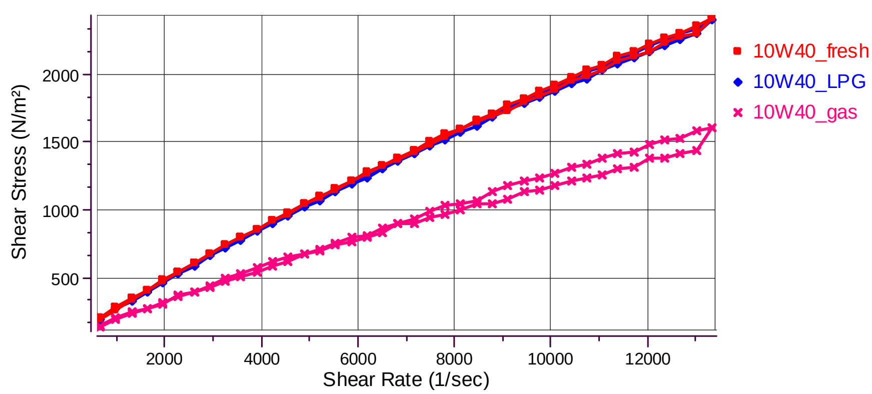

Fig. 1. *Rheogram for 10W40 oil, in fresh and used state, for cone no. 3*

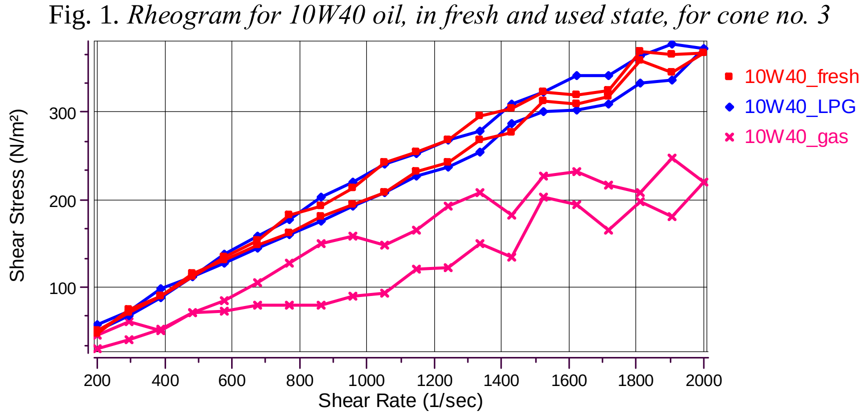

Fig. 2. *Rheogram for 10W40 oil, in fresh and used state, for cone no. 8*

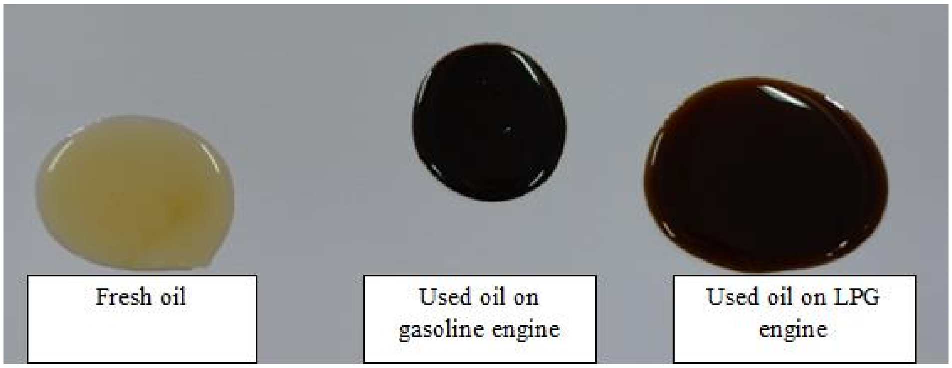

Fig. 3. *Aspect (color) of the 10W40 oil in all three states*

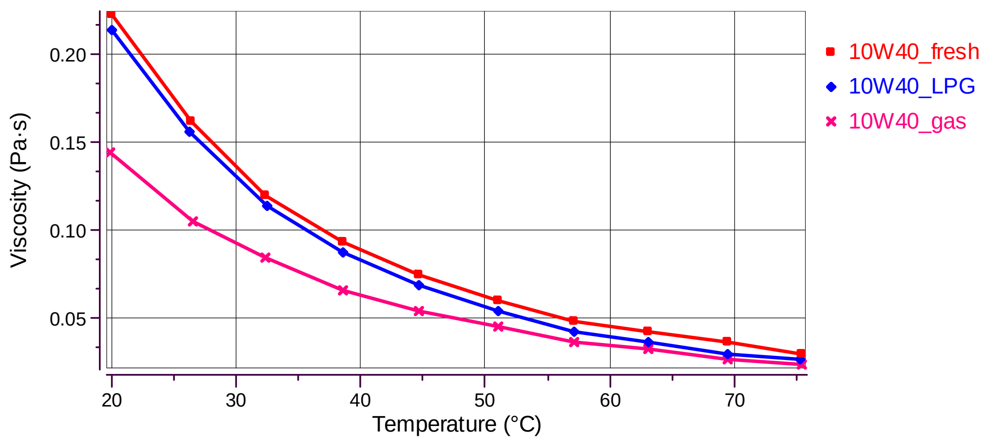

Fig. 4. *Variation of the viscosity with temperature for cone 3*

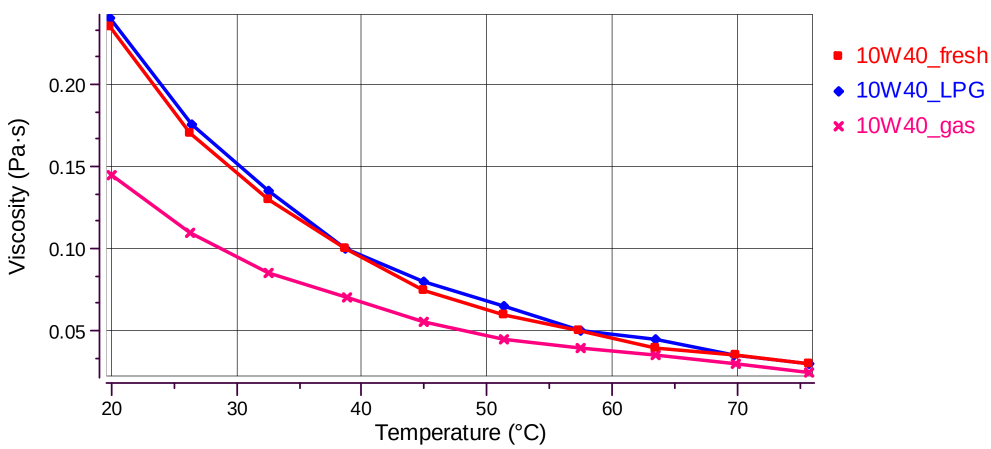

Fig. 5. *Variation of the viscosity with temperature for cone 8*

4. Conclusions

Information regarding the viscosity of the oils can be considered as a "window" to analyze other properties of fluids. The viscosity is even more relevant easier to measure than many other properties of lubricants, constituting a very important tool for characterizing fluids.

By analyzing experimental data presented in the paper, one can observe a significant decreasing trend of the values of the viscosity with the degree of wear of the oil used in a gasoline internal combustion engine. This phenomena appears for the whole range of values for temperature variation, between 20 … 75 ^{0}C.

Regarding the viscosity for the oil used in a LPG internal combustion engine, there is approximately no difference by comparison with the fresh oil, for any temperature. The only difference observed is the color of the oil, in the two states of degradation.

Finally, the main result of this research is a new methodology for the evaluation and quantification of wear and the durability of lubricants, taking into account the change in the viscosity of the lubricant relative to the temperature.

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