CONTRIBUTIONS CONCERNING RHEOLOGICAL METHODS FOR EVALUATING THE DURABILITY OF INDUSTRIAL LUBRICANTS

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ABSTRACT

The paper propose a method for diagnosing the wear degrees of lubricants based on determination of the rheological properties, more precisely the reducing of the viscosity values during the time. An exponential relation is proposed for the variation of the viscosity versus the equivalent distance covered by the motor vehicle. The two parameters characteristics are the initial viscosity for the fresh oil and the wear intensity coefficient. These values are determined using the regression analysis method.

1. INTRODUCTION

At this moment of time, an important problem of the world economy is the continuous grow of waste and residue as result of the human's activities and with a devastator ecological impact to the environment. From this point of view, it is important to develop a new method of fast diagnosis of industrial lubricants, starting from the idea that the deadline for changing the oil is imposed to be made when it is complete used and not based on the theoretical recommendations of the products.

In some case, at motor vehicles, the oil is changed more frequently that is necessary, in order to be sure that its properties were not all vanished. This type of procedure is not dangerous, from theoretical point of view, but it is expensive. The degradation of lubricant oil, collected directly from „working" conditions depends on many factors, the most important being the oxidation and impurity. The level of impurity and the period of used oil depend on the exploitation conditions, the quality of oil, the construction and the technical state of engine, [1], [2].

This paper propose a method for diagnosing the wear degrees of lubricants based on determination of the rheological properties, more precisely the reducing of the viscosity values during the time. The rheological model proposed for the industrial lubricant is the Newtonian behaviour, expressed as:

$$\tau = \eta \frac{du}{dy} \qquad (1)$$

This relation shows the direct proportionality between the shear stress and the velocity gradient, and the proportional coefficient is the viscosity. The experimental stand used for measuring the rheological parameters of the lubricants is a cone and plate viscometer, which offers absolute viscosity determination with precise shear rate and shear stress information.

In order to estimate the wear degree of the used oils, a theoretical relation is proposed [3], which established the variation of the viscosity versus the equivalent distance covered by the motor vehicle:

$$\eta = \eta_0 e^{-Kd} \qquad (2)$$

The two parameter characteristics for Eq. 2 are the initial viscosity $_0$ for the fresh oil and the wear intensity coefficient *K*. These values are determined using the regression analysis method, [4].

2. EXPERIMENTAL PROCEDURES

Experimental investigations were undertaken with the aim to check the assumed theoretical method. They were carried out at the ambient temperature of 20 ^{0}C using a cone and plate Brookfield viscometer, presented in Figure 1.

In the same figure, the spindle geometry of the viscometer and its characteristic parameters are presented. They offer absolute viscosity determinations with precise shear rate and shear stress information readily available. The sample volumes required are extremely small and temperature control is easily accomplished.

CAP Spindles

SPINDLE	SHEAR RATE	SAMPLE VOLUME	CONE ANGLE	CONE RADIUS
CAP-01	13.3N sec^{-1}	67 µL	0.45	1.511cm
CAP-02	13.3N sec^{-1}	38 µL	0.45	1.200cm
CAP-03	13.3N sec^{-1}	24 µL	0.45	0.953cm
CAP-04	3.3N sec^{-1}	134 µL	1.8	1.200cm
CAP-05	3.3N sec^{-1}	67 µL	1.8	0.953cm
CAP-06	3.3N sec^{-1}	30 µL	1.8	0.702cm
CAP-07	2.0N sec^{-1}	1700 µL	3.0	2.399cm
CAP-08	2.0N sec^{-1}	400 µL	3.0	1.511cm
CAP-09	2.0N sec^{-1}	100 µL	3.0	0.953cm
CAP-10	5.0N sec^{-1}	170 µL	1.2	1.511cm

Figure 1: *Brookfield cone and plate viscometer, [5]*

In order to obtain practical informations concerning the durability of the lubricants, three types of oils have been tested, comming from motor vehicles with different wear degrees:

– ELF EXCELLIUM LDX 5W-40 from a Diesel motor vehicle with 130000 km way;
– ELF PERFORMANCE EXPERTY 10W-40 from an essence motor vehicle with 38000 km way;
– ELF COMPETITION ST 10W-40 from an essence motor vehicle with 80000 km way.

For each type of oil, the mean life time recommended by the producers is 10000 km. During this period, a few samples of lubricants have been collected, corresponding at different wear degrees: for fresh oil (at 0 km) and for used oil (approx. at 3000 km, 7000 km and 10000 km).

The physical and chemical properties of the fresh tested lubricants are presented in Table 1.

Characteristical parameter	**ELF EXCELLIUM LDX 5W-40**	**ELF PERFORMANCE EXPERTY 10W-40**	**ELF COMPETITION ST 10W-40**
Density at 15°C	849 kg/m^3	871 kg/m^3	883 kg/m^3
Viscosity at 40°C	86.5 cSt	96 cSt	98.5 cSt
Viscosity at 100°C	14.2 cSt	14.4 cSt	14.6 cSt
Viscosity Index	170	139	170
Viscosity CCS at 30°C	6500 cP	6700 cP	6900 cP
Pour point	-41° C	- 33° C	-35° C
Flash point COC	226° C	230° C	235° C
TBN	10.4 mg KOH/g	12 mg KOH/g	10.4 mg KOH/g
Volatile factions	11 %	10.5 %	12 %
Viscosity HTHS (150°C)	3.8 cP	3.9 cP	3.7 cP
Colour (ASTM)	L 3.5	L 3.0	L 3.5

Table 1: *Physical and chemical properties of lubricants, [6]*

3. RESULTS

The characteristic rheograms obtained with the Brookfield cone and plate viscometer, for all the tested oils. are presented in Figures 2, 3 and 4. In each figure, four curves are presented, corresponding for different wear degrees for the tested oils. It can observed that the viscosity decrease once with equivalent distance of the motor vehicle, and cleary depends of the oil type.

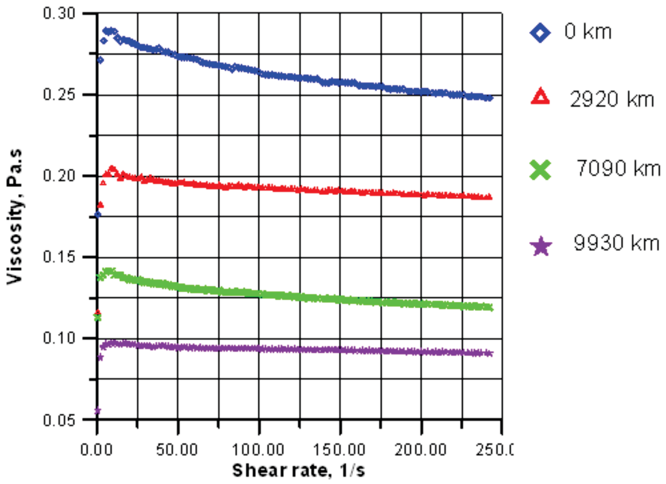

Figure 2: *Experimental rheogram for ELF EXCELLIUM LDX 5W-40 oil*

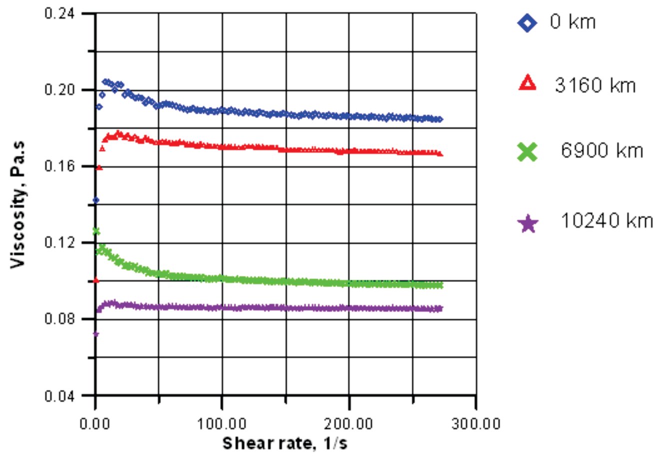

Figure 3: *Experimental rheogram for ELF PERFORMANCE EXPERTY 10W-40 oil*

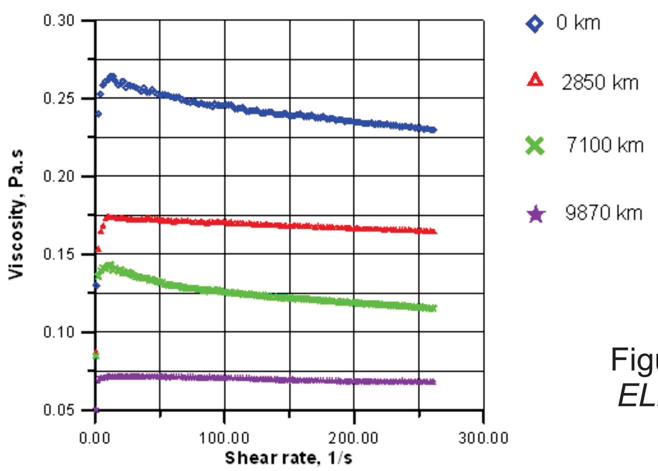

Figure 4: *Experimental rheogram for ELF COMPETITION ST 10W-40 oil*

The experimental data have been numerical analized with the regression analysis method, in order to obtain the mean values of the viscosity, for fresh and used oils (see Table 2).

The same table presents the values of the correlation coefficient, which is an indicator of the correlation level between the theoretical Newtonian model and the experimental data.

Type of oil	Wear degree	Equivalent distance, km	Viscosity, Pa.s	Correlation coefficient
ELF EXCELLIUM LDX 5W-40	Fresh oil	0	0.186	0.963
	Used oil	2920	0.167	0.982
		7090	0.086	0.991
		9930	0.099	0.994
ELF PERFORMANCE EXPERTY 10W-40	Fresh oil	0	0.253	0.957
	Used oil	3160	0.189	0.978
		6900	0.122	0.989
		10240	0.092	0.995
ELF COMPETITION ST 10W-40	Fresh oil	0	0.229	0.968
	Used oil	2850	0.164	0.975
		7100	0.118	0.988
		9870	0.068	0.990

Table 2: *Regression parameters for tested oils*

In order to obtain the main values of the initial viscosity $_0$ for the fresh oil and the wear intensity coefficient *K* (see Eq. 2), the data from Table 2 are numerically treated and the results are presented in Table 3.

The wear characteristics of the tested oils, which include the experimental data and the theoretical fitted curves, are plotted in Figure 5.

Type of oil	Initial viscosity, Pa.s	Wear intensity coefficient, km^{-1}	Correlation coefficient
ELF EXCELLIUM LDX 5W-40	0.188	$7.793 \cdot 10^{-5}$	0.811
ELF PERFORMANCE EXPERTY 10W-40	0.254	$10.092 \cdot 10^{-5}$	0.996
ELF COMPETITION ST 10W-40	0.234	$11.582 \cdot 10^{-5}$	0.964

Table 3: *Main values of the initial viscosity and wear intensity coefficient*

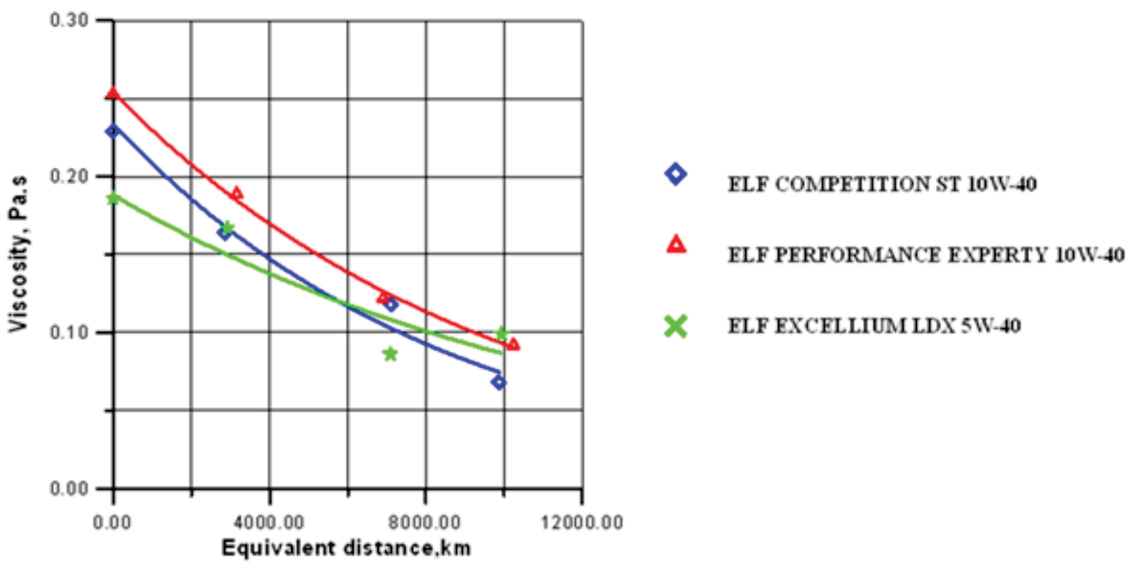

Figure 5: *Wear curves for the tested lubricants*

4. CONCLUSIONS

As a scientific theoretic research in technical science domain, these ideas are very important, by the thematic approach and by the novelty degree brought. Also, the possibility of changing the oil when it is really used, and not after the theoretical recommendation of the producer, gives a good economical and ecological impact, considering the practical character of the method.

On the international plan, two main directions and orientations are guided in the preventive mentenability domain and they can be applied in any closed system of lubrication:

- the management of wear products (residue) to determine the quantitative volume of wear particles;
- the management of the stage of lubricants based on physical, chemical and rheological test.

Analyzing the experimental results obtained with this rheological method, it can be observed an important tendency of viscosity decreasing during the working time. Using the determination of the two characteristic parameters, the initial viscosity $_0$ for the fresh oil and the wear intensity coefficient *K*, a new criteria for the wear degree of the oils is obtained.

Finally, the principal result of this research is a new methodology, efficient, performed and ecological for the evaluation and quantification of the wear degree and lubricants durability. In addition, it is important that a new complex device can be performed for the diagnosis of “life reserve” for industrial lubricants.

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