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RESEARCHES CONCERNING THE RHEOLOGY OF FRESH AND USED LUBRICANTS

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Abstract: *The present paper describes researches concerning the achievement of an informatics device for the lubricants wear behaviour. Methods and results obtained at national and international levels and, also, in the actual research project are presented. Several methods for rheological tests by comparing fresh and used oils in shear movement are presented also. The actual project develops a scientifically partnership for the idea of a fast diagnosis method for liquid lubricants (used for cars, air ships, sea ships, engines and different systems).*

Key words: *informatics device, lubricant, rheological test, fresh and used oils.*

1. INTRODUCTION

The researches accomplished in a project of PNCDI Program had as a leading objective the integrated modeling and simulation device for the study of lubricants wear behavior and sustainability, in terms of a fast and adaptive design for industry, by using modeling and simulation tools and integrated products.

The proposed information tool uses a rapid diagnostic apparatus for liquid lubricants, which is achieved with minimal investment; it has a high degree of accuracy and it is easy to use.

The architecture of this modeling and simulation tool is a centralized one, it is based on a general framework, which manages a complex and unitary system, which is composed of four modules: the theoretical one, the rheology experimental module, the viscosimeter validation module and the spectrometric analysis module.

Their high variety and complexity contributed to the multidisciplinary nature of researches.

The followings were analyzed, systematized and presented by the project partners:

- general description of the developed integrated device;
- experimental rheological module with the characteristic lubricants expulsion curves;
- viscosimeter validation module with the study of the rheology of fresh and used lubricants;
- tribological testing module, with the tribological behavior of industrial lubricants;
- spectrometric analysis module, with the electron microscopy of lubricants wear particles.

2. METHODS AND RESULTS AT INTERNATIONAL AND NATIONAL LEVELS

In different countries (Western Europe, SUA or Japan) the moment of oil changing is based on the instructions written on the oilcans, having a minimal recommended covered distance, in order to be sure that oil properties were not all vanished.

The degradation of "working" lubricant oil depends on many factors; the most important ones are the oxidation and the contamination. The stage of degradation and the oil changing moment is obtained by the periodically physical-chemical oil analyses. The damage of oil is pointed when its characteristics had touched some limit values, which are established for each type of engine. Studies show that the contamination level and the "lifetime" of used oil depend on the exploitation conditions, the oil quality, the construction and the technical state of engine.

Fig. 1. Preventive maintainability in a closed lubrication system [1].

At international level, the main directions and orientations are guided into the preventive maintainability domain and they can be applied in any closed lubrication system (Fig. 1) [1].

Some applicative researches for the determination of oil changing moment gave methods as:

- the method of the intersection curve of acidity with the curve of alkalinity, which is used for alkaline oil (especially when it is used a fuel with sulphur);
- the microscopic oil analysis;
- the method of oil spot.

A first industrial example is given by the determination of the oil lifetime for engines trucks (firm MAN from Germany), which uses the basicity analysis method, for Mobil class oils.

Also, the firm Mercedes from Germany uses insoluble impurity in oil, with microscopic tests for class Shell oils; the changing moment indicators are the number and the size of particles in suspension.

Surprisingly, the survey data shows that oil changes, when too frequent, can reduce the expected life of an automobile engine. The unexpected outcome is supported by lubrication technology literature. Changing engine oil at the proper mileage can improve engine reliability and has the potential to reduce nationwide waste and recycled oil by 325 million gallons annually [2, 4].

At national level there evaluations of the changing moment for the used oil were made, at the Roman firm, from Romania. For Romanian oils made at Lubrifin Braşov the oil spot method is applied, a good and efficient one, which is based on the aspect of the spot made on a filter paper.

Another method applied in Roman firm on Lubrifin oils is represented by the photoelectric method, which allows the establishment of used oil changing moment, according to the quantity of oil impurities.

At educational level, there are some Romanian institutions interested in the area: University "Politehnica" of Bucharest and "Gheorghe Asachi" Technical University from Iaşi, which realized researches for the determination of the rheological properties of the mixture of oil with polymers, that was emphasized their non-Newtonian tixotropic character.

Also, at "Transilvania" University from Braşov were obtained interesting results in management direction of solid residues from lubricants, by using the ferografic analysis of used oils.

Similar researches regarding lubricants durability, especially of consistent oils, were made in Romanian manufacturing bearing firms: Rulmentul Braşov, Timken Ploieşti or Koyo Alexandria. Industrial laboratories offered the opportunity to make physical-chemical standard tests and tribological ones (Timken stand, Amsler stand, etc).

By analyzing all these methods, a conclusion must be taken: the endowment with performing laboratories, at high technical level is absolutely necessary. An accurate application of these methods involves a special attention from the technical staff, a good practice experience and of course, high level practitioners [5].

3. METHODS AND RESULTS IN ACTUAL PROJECT

The main idea of this device is to use a small quantity of lubricant for a determination, to have low time of measurement and a flexible character; these features represent essential advantages of the researches.

New proposed method for rapid diagnosis of liquid lubricants may be used for automobiles, aircraft, ships, locomotives, various facilities, etc. It is based on the film lubricant extrusion phenomenon (squeeze-film and it is an original one, it is fast (5–10 minutes) and it may be used to diagnose a small quantity of lubricant (100 ml) [3].

In a short time it can be made an evaluation of the wear degree of the lubricant properties, considering the terms of a hydrodynamic flow. If the oil is more used than the normal, we may alert the owner on possible failures, and if the oil is less used than the normal – we may indicate how much time it can be used.

Fig. 2. Physica MCR 301 Rheometer [3].

The lubricants on which we had experimental determinations were:

- 5W30 Premium, fresh and used;
- M30 Super 2, fresh and used;
- H46, fresh and used;
- 10W40, fresh and used.

About the usage of lubricants there are known:

- the Premium 5W30 lubricant was used 10 000 km in an internal combustion engine, having a 36 000 km turnover;
- the lubricant M30 Super 2 worked 8 300 km in an engine with a 47,000 km turnover;
- the H46 lubricant was used around 6 500 hours in a hydraulic installation with high pressure cylinders;
- the 10W40 lubricant was used 7 900 km in an internal combustion engine which had a 17 000 km turnover.

Researches have focused on testing the comparative rheology of new and used oils, being in shearing motion. Tests were conducted in the UPB REOROM Laboratory using Physica 301 rheometer, which is one of the most powerful apparatus for rheological characterization of viscoelastic fluids (Fig. 2).

Fluid motion is made in rotational geometries: concentric cylinders or con and plate. It was used the dynamic test, in which the INPUT signal is a sinusoidal one, with constant amplitude, $\gamma = 0.1$ [-], and the frequency is variable in the domain: $\omega \in [0.1, 100]$ [1/s], which is applied to the fluid through the mobile surface (cylinder or con). On the same area is registered the OUTPUT -the friction moment, which is characterized by an amplitude and a phase difference, both having varying frequency. The separation response allows the calculation of elasticity modulus G' [Pa], of the viscosity modulus G'' [Pa] and of the complex viscosity η^* [Pas], in "phase" and "at 90^0 phase difference" accountable to the signal input. In the linear viscoelastic domain it is known that the variation of viscosity function, by the oscillation frequency, $\eta^*(\omega)$, is depending on the variation function viscosity $\eta = \eta(\dot{\gamma})$, in the shearing motion.

Dynamic tests for the characterization of viscoelastic fluids are used; the same test provides valuable rheological information on the viscous behavior and on the elastic behavior.

For the final study were chosen 4 oil samples; the measurements were made at 20°C temperature for previously configurations. Each oil was tested at various wear degrees: from the virgin sample ("new") to the maximum wear ("old" = 100%).

Unfortunately (except the 10W40 sample), there are not known all the terms of tested oil (the operation hours, the type of equipment, the load).

These results confirmed previous findings: the oil wear leads in general to the lowering of the viscosity and of the elasticity (if the oil has this property). This phenomenon is due to the molecular forces changes, which are due to the fluid wear; the presence of the solid particles in waste oils is not able to generate the increase of the viscosity (as in the case of virgin fluids).

It is interesting that an inadequate formulation of oils cause "deviations" from this rheological behavior type; it is obtained a lower viscosity, function of the wear degree. Such case is the 5W30 oil case, which is described in Fig. 3. It is detected that the used sample has higher values of viscosity and elasticity than the virgin sample, especially in low frequencies domain. Also there are quantitative differences between tests having different geometries.

Rheological measurements show remarkable structural changes between the tested samples, which shows that the fluid was affected by the mechanical wear, not only quantitatively, but also qualitatively. We can conclude that the tested oil has deficiencies of formulation or – it was not respected the technology for oil obtaining (considering a wearing process in normal operating conditions).

Figures 4 and 5 show the appropriate tests for H46 and M30 oils. Figure 6 shows the rheological measurements for 10W40 oil, in varying wear degrees (only con and plate geometry).

It is observed a normal rheological behavior of used fluids: the diminution of the viscosity is proportional to the wear degree.

It is also important to clarify that tests performed on cone and plate geometry highlight better the elasticity of investigated oils. Even if the measured values for elastic modulus G' are small (generally, $G' < 10^{-2}$ Pa), the measurements show that the oils have macromolecular additives. This is especially available in the low oscillation frequencies domain, where the elasticity modules have small frequency variations with (typical to the elastic materials).

The M30 and H46 samples show a weak pseudo plastic character ("shear thinning"); the viscosity is practically constant with the frequency. They have an approximately linear variation of the viscous mode with the frequency, which shows the low share of the elasticity concerning the rheology of these oils.

The 10W40 oil has a more pronounced pseudo plastic character, (Fig. 6), at low degrees of wear. The presence of elasticity modulus on the whole frequency area is an indication of the different formulation of this sample; there are additives in its composition, which give a greater elasticity share.

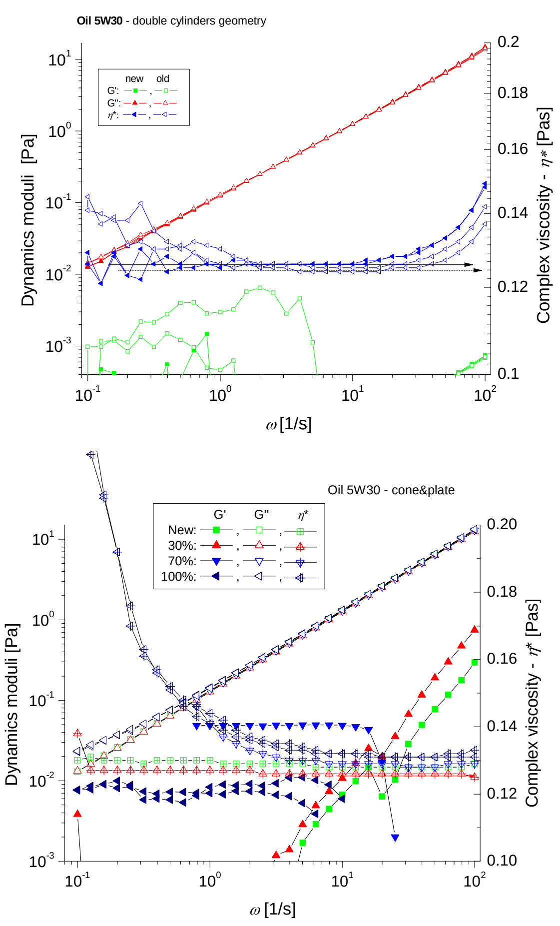

Fig. 3. Rheological properties of 5W30 oil, function wear (at 20°C).

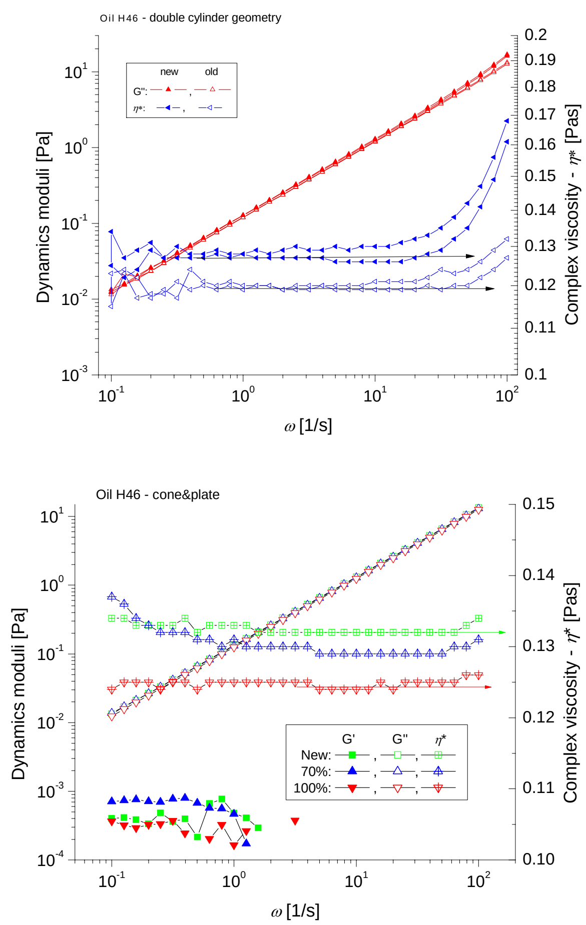

Fig. 4. Rheological properties of H46 oil, function wear (at 20°C).

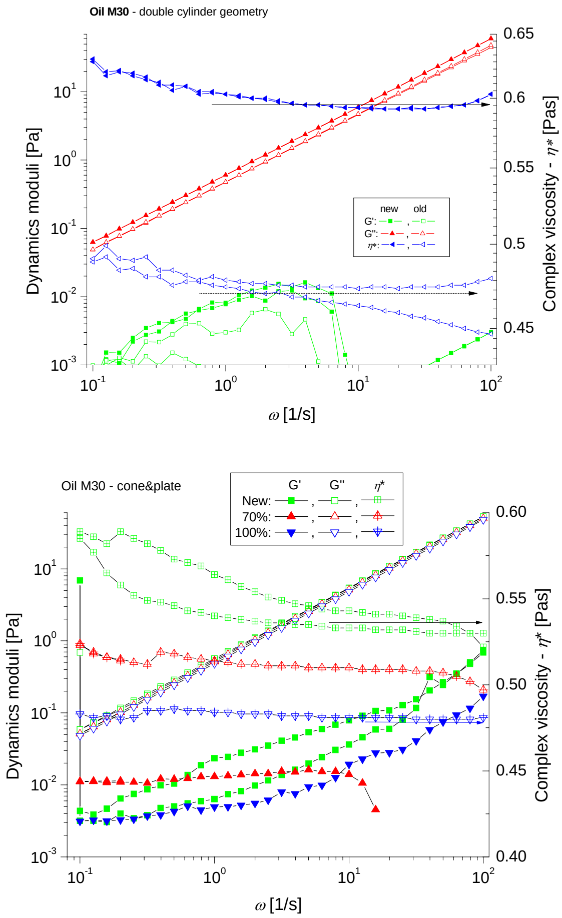

Fig. 5. Rheological properties of M30 oil, function wear (at 20^{o}C).

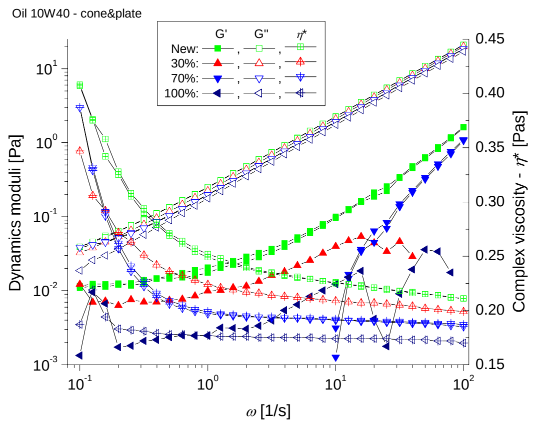

Fig. 6. Rheological properties of 10W40 oil, function wear (at 20^{o}C).

4. CONCLUSIONS

The rheological study compares virgin and used oils and accentuates quantitative and qualitative differences between the investigated samples, as: oil viscosity and oil elasticity, which decrease with the increase of wear degree.

Also, the rheological testing using precision equipment can highlight the differences between various forms of different oils and match the behavior type (viscous, viscoelastic, pseudo plastic) with the presence of additives into the fluids composition.

Researches indicated significant differences between fresh and used fluids properties, which are due to the changing of their physical – chemical properties; lubricants' aging is directly connected to lubricants viscosity decrease.

Practically application of tested method offers important data concerning wear process evolution. The designed device may be available for many users, in small product units and exploitation units, also in research and didactic domains.

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