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RHEOLOGICAL METHODS FOR EVALUATION OF THE BASE OILS OBTAINED BY CONDITIONING OF HYDRAULIC USED OILS

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Abstract: *The purpose of the experimental research presented in this paper is to study the possibilities of evaluation, by rheological methods, of the base oils obtained by conditioning of hydraulic used oils. The method proposed for the hydraulic used oil (H46) regeneration, was a simple, efficient and low cost one. That consists in removing of water and solid particles of contaminants by centrifugal separation, followed by distillation, for realising of volatile contaminant (solvents) and remaining small quantities of water. In this way, a good quality of ISO-VG 46 base oil was obtained. Comparing the specific values obtained for the fresh and regenerated H46 oil, it can be observed that the conditioned H46 oil accomplish the requirements specific for fresh base oil ISO-VG class.*

Keywords: *rheology, lubricant, regeneration, conditioning, experiment.*

1. INTRODUCTION

Rheology refers to a set of standard techniques that are used to experimentally determine rheological properties of materials (fluid or solid), involved in lubrication calculus of a large class of bearings [1-3]. The idea underpinning rheology is to realize flows, where the stress and/or strain fields are known in advance, which make it possible to deduce rheological properties from measurements of flow properties [4,5].

A rheometer is usually an experimental stand, which can exert a torque/force on a material and accurately measures its response with time (or conversely, it can impose a strain and measures the resulting torque). All the measurements can be done normally in a field of temperature between 15 °C and 75 °C [6,7].

The main purpose of the experimental research presented in this paper is to study the possibilities of evaluation, by rheological methods, of the base oils obtained by conditioning of hydraulic used oils [8,9]. The majority of the processes applied for regeneration of used oils are based on a succession of purification stages consisting in: separation of water and gasoline by distillation at atmospheric pressure, refining by sulfuric acid and potassium hydroxide and finishing by clay contacting, or other procedures like hydrotrating, that presume high cost, high energy consumption and expensive additional materials [10-12].

In the present study, the method proposed for the hydraulic used oil (H46) regeneration, was a simple, efficient and low cost one. That consists in removing of water and solid particles of contaminants by centrifugal separation, followed by distillation, for realising of volatile contaminant (solvents) and remaining small quantities of water. In this way, a good quality of ISO-VG 46 base oil was obtained.

2. EXPERIMENTAL STAND AND METHODOLOGY

The experimental test stand was a Brookfield cone-plate viscometer (Fig. 1) [2]. The liquid is placed between a cone and a disc; one is slewing, the other is stationary. For large opening angles of the cone, the rate of strain is constant across the gap; this is the advantage of this device. The viscometer is suitable for data digital acquisition and it offers the possibility to determine the variation of viscosity by the temperature.

Figure 1. Brookfield cone-plate viscometer

To determine the lubricant rheological model in fresh and regenerated state, it was used an “imposed velocity gradient” test, with the variation limits 100 ... 2000 s^{-1} and 20 °C reference temperature. The tests were carried out with a load up to 2000 s^{-1} and unloading up to 0 s^{-1}, in order to highlight the effects of lubricant thixotropy.

The physical and chemical properties of H46 oil, in fresh and regenerated state, are presented in Table 1.

There were tested the two fluids and there were calculated the lubricant rheological parameters, by using the rheometer software, beyond the non-Newtonian fluids model, for the power law:

$$\tau = m\left(\frac{du}{dy}\right)^n , \qquad (1)$$

where: m is consistency index (which is equivalent to the Newtonian fluid viscosity); n is flow index (equal to 1 if the fluid is Newtonian).

Table 1. The physical and chemical properties of H46 oil, in fresh and regenerated state

Characteristic parameter	H46 fresh	H46 regenerated
Viscosity at 40 °C [cSt]	46.13	46.02
Viscosity at 100 °C [cSt]	6.71	6.64
Viscosity Index	98	95
Flash point [°C]	224	206
Copper corrosion	1b	1b
Rust prevention	No rust	No rust
Colour		

To determine the viscosity variation law versus temperature for analyzed lubricant there were made tests for fresh and regenerated lubricant, for four imposed velocity gradients: 500 s^{-1}, 1000 s^{-1}, 1500 s^{-1} and 2000 s^{-1} and for a temperature range of 5 ... 75 °C. The law of variation which has been assumed was Reynolds law:

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

where: η is viscosity; η_{50} is viscosity at 50 °C; m is temperature parameter; t is temperature.

The parameters values of the variation laws were determined using the regression analysis method, by using MathCAD software.

3. RESULTS AND DISCUSSION

Lubricant rheograms for fresh and regenerated state are presented in Figures 2 and 3. The results for lubricant rheological parameters for both states are directly obtained by using the rheometer software

(Capcalc V3.0), (Figs. 4 and 5). Results are centralized in Table 2.

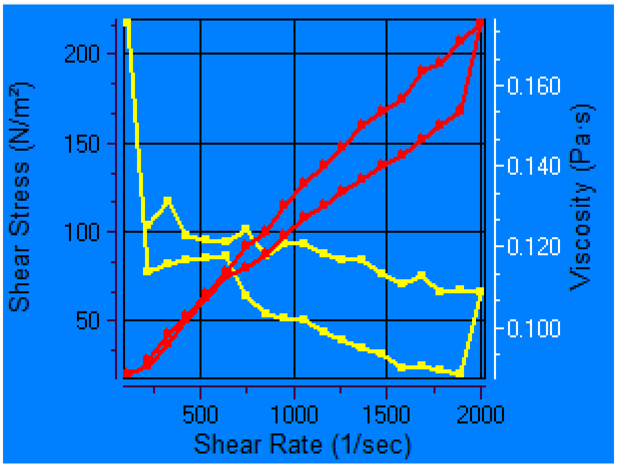

Figure 2. Lubricant rheogram in fresh state (shear stress: red curve; viscosity: yellow curve)

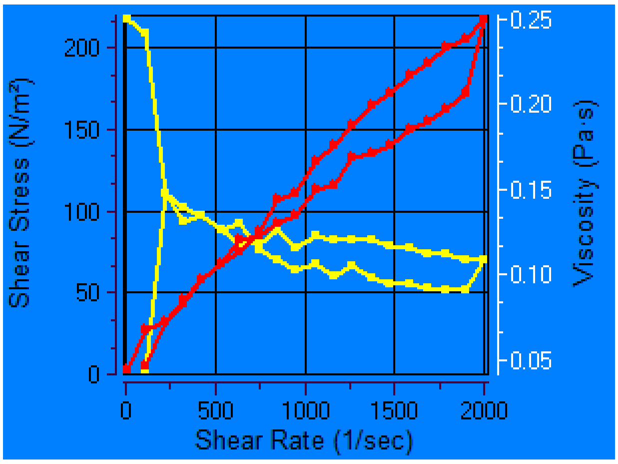

Figure 3. Lubricant rheogram in regenerated state (shear stress: red curve; viscosity: yellow curve)

Table 2. The lubricant rheological parameters in fresh and regenerated state

Lubricant type	Consistency index (*m*) [$Pa\cdot s^n$]	Flow index (*n*)	Correlation coefficient
H46 fresh	0.277	0.865	91.6 %
H46 regenerated	0.273	0.871	85.4 %

For both types of lubricant, in fresh and regenerated state, the results concerning the variation of viscosity versus temperature are presented in Figures 6 and 7.

The characteristic parameters for the viscosity variation law with the temperature are presented in Table 3.

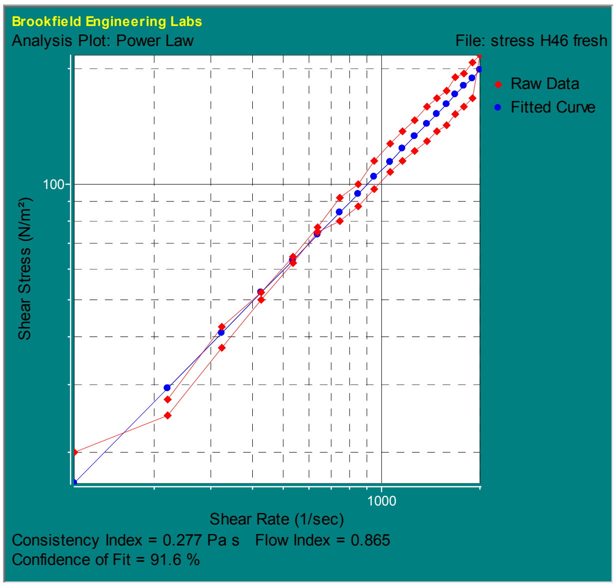

Figure 4. Numerical regression for the results of fresh lubricant

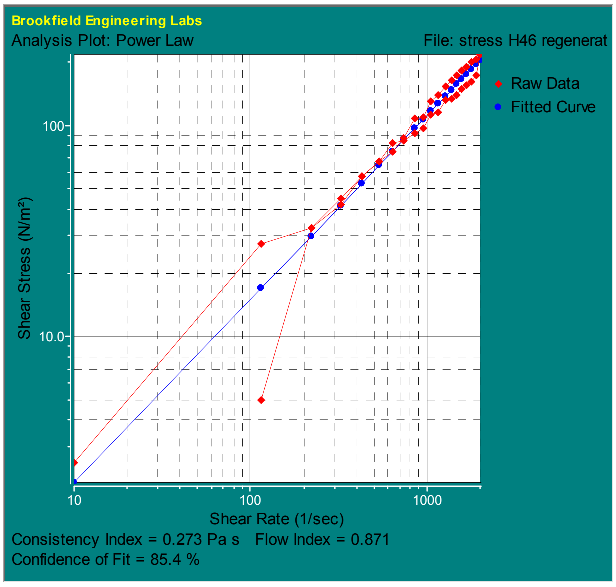

Figure 5. Numerical regression for the results of regenerated lubricant

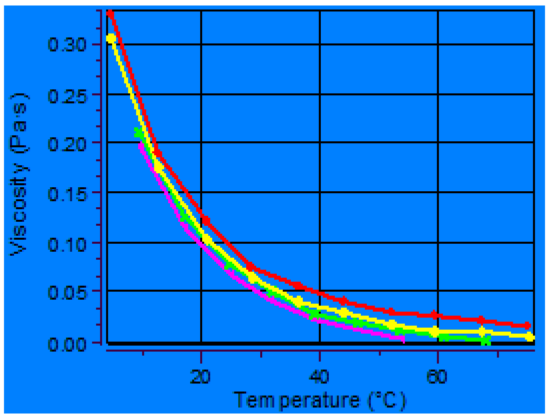

Figure 6. Variation of viscosity versus temperature for fresh lubricant (500 s^{-1}: red curve; 1000 s^{-1}: yellow curve; 1500 s^{-1}: green curve; 2000 s^{-1}: magenta curve)

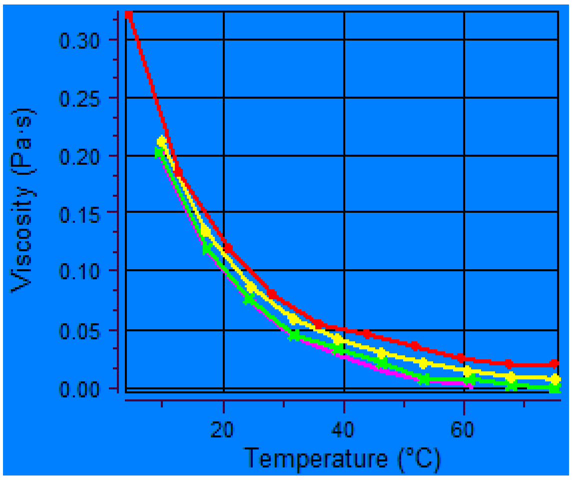

Figure 7. Variation of viscosity versus temperature for regenerated lubricant (500 s^{-1}: red curve; 1000 s^{-1}: yellow curve; 1500 s^{-1}: green curve; 2000 s^{-1}: magenta curve)

Table 3. Characteristic parameters for the variation of the viscosity versus temperature, according to Reynolds model, for H46 oil, in fresh and regenerated state

Parameter / Velocity gradient [s^{-1}]	H46 in fresh state		
	η_{50} [Pa·s]	m [°C^{-1}]	Correlation coefficient
500	0.02333	-0.05794	0.99712
1000	0.01612	-0.06484	0.99947
1500	0.01253	-0.07162	0.99910
2000	0.01078	-0.07389	0.99916
Parameter / Velocity gradient [s^{-1}]	H46 in regenerated state		
	η_{50} [Pa·s]	m [°C^{-1}]	Correlation coefficient
500	0.02635	-0.05427	0.99644
1000	0.02214	-0.05595	0.99903
1500	0.01473	-0.06468	0.99939
2000	0.01269	-0.06835	0.99964

4. CONCLUSION

This study proposes an efficient method for conditioning of used hydraulic oils, with relatively low cost. For this kind of lubricant, the content of the contaminants and the chemical structure modifications are relatively low and that allow the application of less expensive but efficient method for conditioning of used oils.

The solutions proposed by experimental study lead to adequate results, the quality of the obtained conditioned oils were in conformity with the requirements for base oils.

The rheological properties of the regenerated oils are almost similar with those for fresh oils, from the point of view from the rheological model and regarding the variation of the viscosity with temperature.

Finding of suitable solutions for used oils revaluation will increase the lubricant's life cycle. More than that, the waste oils will be not more treated like residuals, with negative impact on environment, they will become a viable raw material resource.

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