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Experimental research regarding the tribological properties of a hydraulic oil

S Haragâş[1], **D Pop**[1], **F Cristea**[1], **O Buiga**[1,2]

[1]Technical University of Cluj-Napoca, Romania

Abstract. This paper presents the results of the interesting experimental research regarding the influence of the additives over a hydraulic oil i.e. HFE46 (produced by ChemTrend [10]). In this vein, were used two types of additives (resulting two variants of oils denoted as sample C and D respectively) and was carried out a gravimetric determination (using the Timken test) analysing the hydraulic oils lubricating proprieties. Also, measurements regarding the vibrations in the tribotechnical system - TTS were conducted.

1. Introduction

Hydraulic oils are used in today's world in a wide range of domains, such as - *food and agriculture* - in various farming machinery; in *manufacturing engineering* - for all types of mechanical machines, presses etc.; in *constructions* - for all sorts of cranes and other pieces of equipment including here buckets, crawlers, etc. In all these applications the pressurized hydraulic oil - is carried out through the associated hydraulic circuit from the pump (driven by a power source, i.e. an electric motor) - pipes - valves - and finally to the end element - an actuator to convert the energy of the fluid into mechanical force or torque, in order to perform various tasks. The pump and the control valves create flow and pressure which are transmitted throughout the pipes to the entire system resulting vibrations and noises with harmful effects on the system's components. For example, in aircraft industry vibrations conduct to almost half of the failure of the hydraulic system [1]. Therefore, the performance of the hydraulic system is highly influenced by the hydraulic oils.

There are a series of studies regarding the influence of the hydraulic oils upon the hydraulic systems. Chai L. et al. in [1] developed a new versatile and compact hydraulic pulsation attenuator for hydraulic piston - pump systems. Chenxiao and Zhang [2] studied the vibration and noise sources into the hydraulic hoist systems. Cristea and Haragâş in [3] and [4] presented two studies regarding the oil the viscosity influence over the vibrations and noises in heavy industry machinery. Changbin and Zongxia in [5] describes an optimal design for a 3 DOF Helmholtz resonator used for a certain type of aviation piston - pump system in order to reduce the flow pulsation. Ye-qing et al. in [6] carried out a vibration analysis using the 3D model of a linear-motor-driven water piston pump. Harrison and Edge in [7] developed a novel mechanism in order to reduce the flow ripple in the case of an axial-piston-pump system. Bettig and Han in [8] described a hydro-generator rotor dynamic model for determining imbalances and shaft misalignments by running vibrations measurements.

Next the authors introduce the gravimetric determination of wear (section 2) for the case of a tribotechnical system - TTS [9] in presence of a hydraulic oil i.e. **HFE46** (produced by ChemTrend [10]) with two different types of additives (hereinafter refer as sample **C** and **D** respectively), after which the measurements carried out with a **SVAN 974 vibrometer** (section 3) are described. The fourth section contains discussions regarding the lubrication efficiency, about the variation of the friction coefficient with the speed (Stribeck curve). Finally, the authors conclude this discussion with some reflections and suggestions regarding the possible extensions of the present study.

2. Gravimetric analysis

The gravimetric analysis is the technique through which the amount of wear corresponding to a specific sample is appreciated by comparing the masses of the test specimen between and after the procedure. Obviously, the accuracy of this method depends on the precision of the measuring device (in here was used a digital analytical balance with 0.1 *mg* readability).

(a) **(b)**

Figure 1. The testing machines

(a) - the tribometer; **(b)** - the base body and counterbody analysed

In this paper the gravimetric wear analysis was carried out on a Timken universal wear and friction testing machine (figure 1,a).

Table 1. Experimental results.

Lubricant type	Initial mass, m_0 (g)	Mass after the test period, m_1 (g)	Wear mass loss, $m_0 - m_1$, (g)
Sample C	10.3023	9.9071	0.3952
Sample D	10.6226	10.5858	0.0368

The interfacial medium [9] i.e. the third element of the TTS as we already pointed out is represented by the **HFE46 hydraulic oil** in his two variants (i.e. sample C and D).

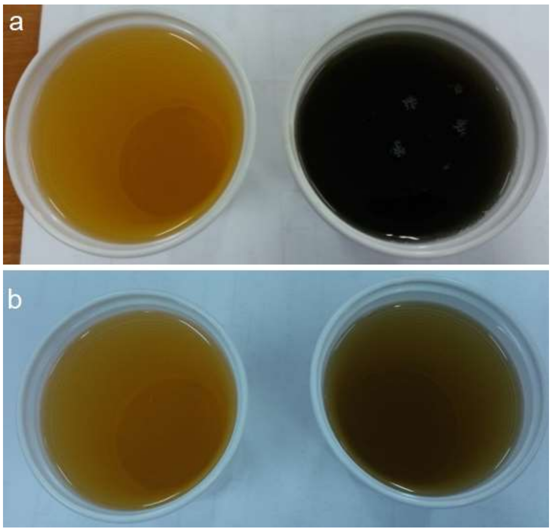

Figure 2. Initial and final colour of the samples. On the left the colour before and on the right – after the wear process

(a) - sample ***C***; **(b)** - sample ***D***

The other components of the TTS are the two cylindrical test specimens (with 16 *mm* diameter) which are in contact with a disc mounted on an electrical motor shaft having an input speed of ≈ 980 *rpm*. The rotary disc is made of 1C45 hardened carbon steel with 48 HRC. The tests are carried out for a total load of 227 *N* during 60 *min*. The experimental results are shown in Table 1.

As it can be observed from table 1 the quantity of material lost due to wear process in the case of sample **D (0,0368 g) is ten times lower than in the case of sample C (0,3952 g)**. This means that the wear rate is ten times higher for the sample C. It is obviously from this analysis that the hydraulic oil denoted as sample D has superior proprieties over the sample C.

Another important aspect represents the oxidation stability (the aging test [9]). During these experimental tests the oil temperature reached about 80^0C (in general the hydraulic oils are used up to 50 - 56^0C). As a result of this, a pronounced oxidation occurred. In figure 2 are illustrated the initial and final colours for both samples of oils. From here it can be observed that the sample D has the final colour close to the original one which indicate a lower oxidation rate.

3. Vibration determination

In this section is described the method used for measuring the vibration of the TTS. In this vein a **digital vibrometer** i.e. **SVAN 974** (figure 3,b) was used. It has a magnetic base which has been positioned on the tribometer according to figure 3,a (this position was used for both samples and was considered to be the most relevant in terms of transmission of vibrations to the tribometer's housing).

(a) **(b)**

Figure 3. Vibration determination

(a) - the vibrations measurement position; **(b)** - the SVAN 974 vibrometer

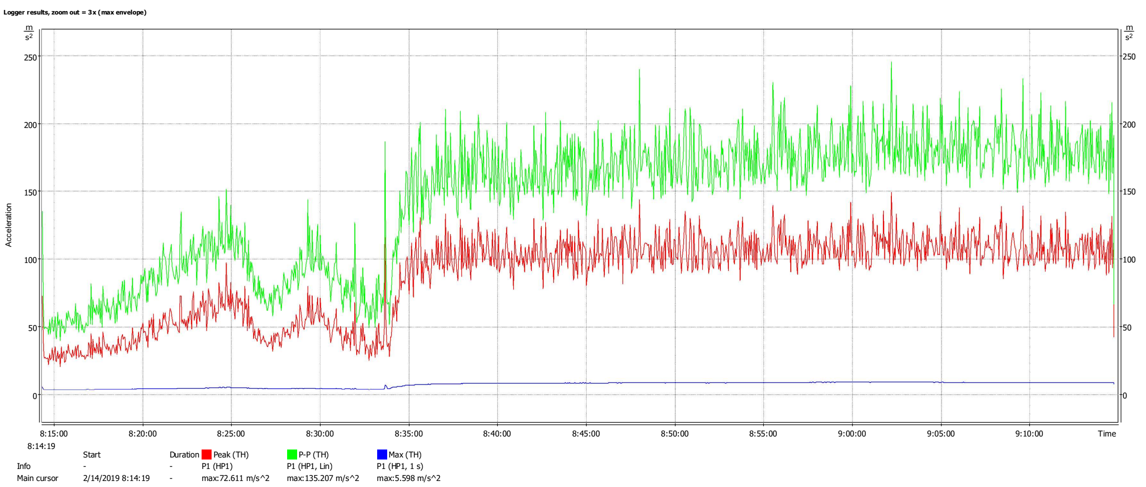

Figure 4. Peak-to-Peak (P-P) and Peak (P) acceleration for **sample *C***

In here were measured Peak-to-Peak (P-P) (which represents the distance from a negative peak to a positive one) and Peak (P) accelerations. The graphs resulted after the measurements for both samples are presented in figures 4 and 5.

It is observed from the above graphs that the P-P accelerations corresponding to ***sample C*** varies from **150-250** ***m/s*²** while for the ***sample D*** the P-P accelerations are in the range of **100-150** ***m/s*²**. Regarding the P accelerations, as it can be seen in figures 4 and 5, they vary between **100-150** ***m/s*²** for ***sample C*** and from **50** to **100** ***m/s*²** for ***sample D*** respectively.

Also, from these figures it can be seen that during 20 min of running the experiment the accelerations increase for both samples. After this interval of time for ***sample D*** the accelerations are dropping around the initial values while in the case of ***sample C*** the accelerations are continuously increasing (as a result of oil oxidation).

Regarding the vibration analysis it is clearly that in the case of the ***sample D*** they decrease considerably which means that this sample has superior lubricating proprieties over the other sample.

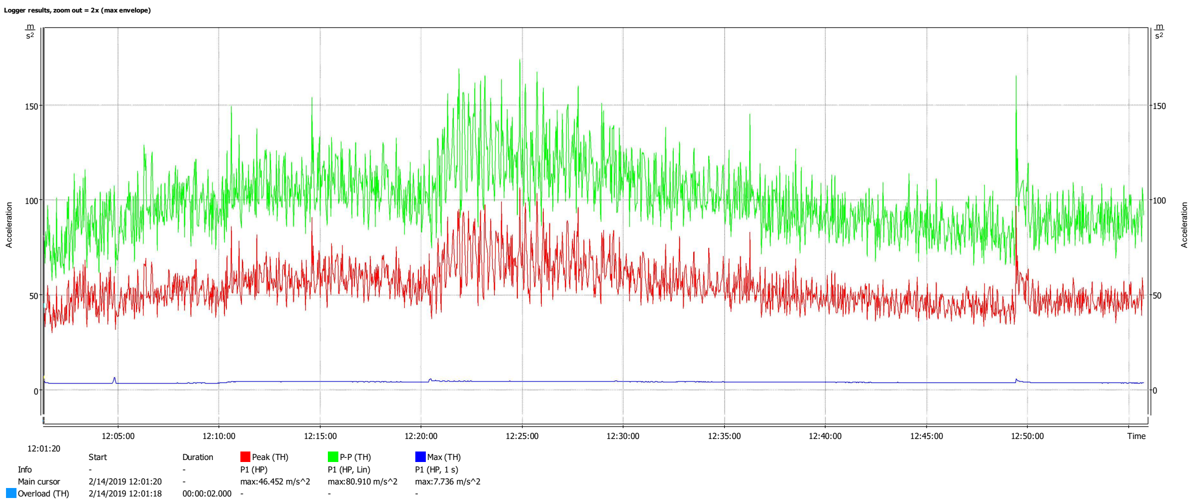

Figure 5. Peak-to-Peak (P-P) and Peak (P) acceleration for **sample *D***

4. Lubrications state simulation

In this section were carried out a set of experiments on an MCR 102 tribometer (figure 6) in order to study for both the hydraulic oil samples (C and D) the lubrication efficiency. Also, in here was analysed the variation of the friction coefficient with sliding velocity (Stribeck curve).

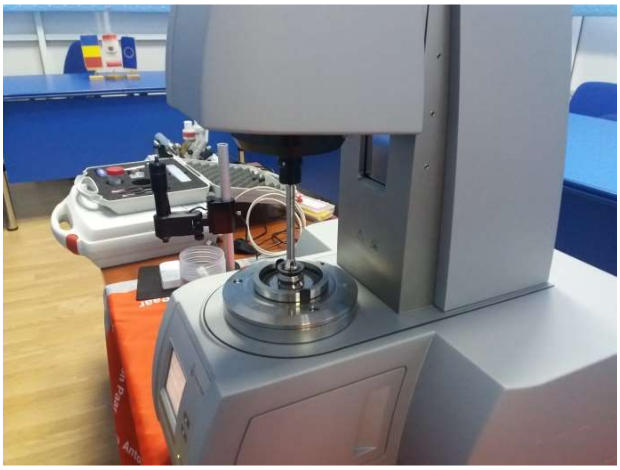

Figure 6. MCR 102 tribometer

In figure 7 the Stibeck curve is plotted. This curves in widely used [11] to describe the lubrication regimes, i.e. the boundary lubrication - *BL*, mixed lubrication - *ML* and hydrodynamic lubrication - *HL*.

It can be seen from these curves that initially; in the case of boundary and mixed lubrication the coefficient of friction is higher for the sample D (possible due to a higher kinematic viscosity of this oil). Upon passing to fluid lubrication regime, the coefficient of friction is lower for sample D than sample C.

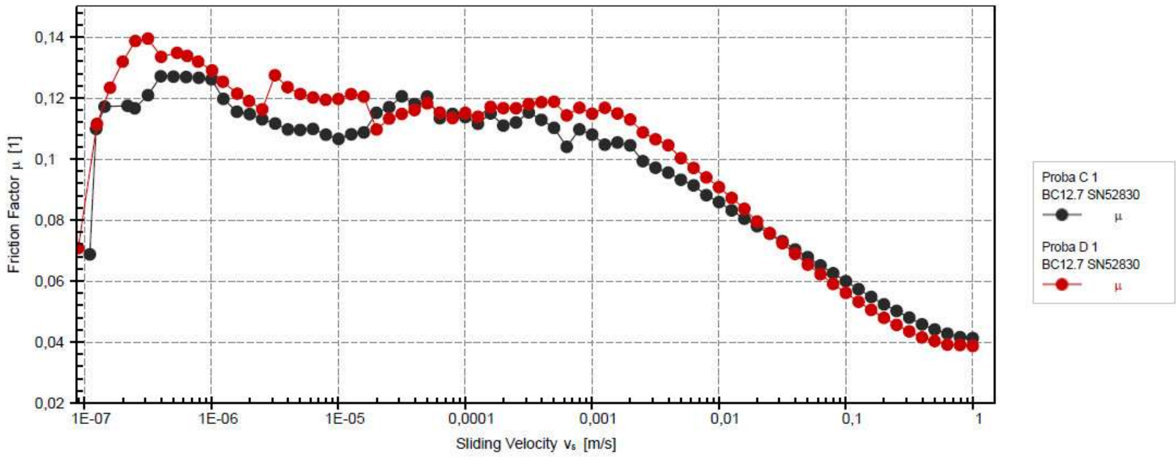

Figure 7. Stibeck curves for both samples

5. Conclusions

Experimental research carried out in this study for two hydraulic oil samples highlights the influence of additives used for hydraulic oils over theirs tribological properties. In this vein, in the case of gravimetric determination (using the Timken test) it was concluded that after the experiment the sample C was weighted **9.9071 *g*** (the initial value was **10.3023 *g***) while the mass of the sample D was **10.5838 *g*** (the initial mass was **10.6226 *g***). As compared with their initial masses it was observed that the wear rate in the case of sample C are ten time higher than for the sample D.

Regarding the vibration analysis, it is observed that the P-P accelerations corresponding to ***sample C*** varies from **150-250 m/s^2** while for the ***sample D*** the P-P accelerations are in the range of **100-150 m/s^2**. The P accelerations, vary between **100-150 m/s^2** for ***sample C*** and from **50** to **100 m/s^2** for ***sample D*** respectively.

Also, after an initial interval of functioning i.e. 20 *min* in the case of ***sample D*** the accelerations are dropping around the initial values while in the case of ***sample C*** the accelerations are continuously increasing (as a result of oil oxidation). From here we can conclude that the sample D has superior lubricating proprieties over the sample C.

From the Stribeck curve analyse it can be seen that in fluid lubrication regime the friction coefficient had lower values for the sample D over the sample C.

6. References

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