ASSESSMENT OF THE EFFECTS OF LUBRICANTS DEGRADATION AFFECTING THE FRICTION

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Abstract: This present paper describes experimental findings regarding the evolution of friction processes for new lubricants and for various stages of lubricants degradation. Understanding the lubricant degradation process will provide a clear answer for two questions: what is the right time for changing the oil and what are the consequences of physical, chemical and tribological changes concerning the lubricant performance and also of the lubricated mechanical system. This article focuses on the elucidation of the second issue: we propose a relationship for calculating the friction coefficient based on experimental measurements dependent on load and speed for fresh and used hydraulic lubricant.

Key words: Degradation, Lubricant, Friction, Monitoring.

1. INTRODUCTION

This present paper describes experimental findings regarding the evolution of friction processes for new and degraded lubricants.

Among the factors that cause lubricant degradation, the most important one are the oxidation and the contamination of oil (Marshall, 1993).

Lubricant degradation requires its change; this moment is difficult to predict if technical, economic and environmental aspects of the issue are considered (Balan et al., 2000). However, this issue has a solution currently eligible (Sieber & Salmon, 1994).

During normal use of the lubricant, the physicochemical (viscosity) and tribological (friction coefficient) properties change due to contamination. The decrease of lubricant viscosity is a consequence of its degradation (A. Radulescu et al., 2008), affecting lubricant performance and also the lubricated mechanical system.

Experimental research findings presented in the paper show that the decrease of viscosity affects the friction process (variation of the friction coefficient). The study of friction processes in the presence of contaminated lubricants is necessary to understand.

The research conducted between 1988 and 1995 by Brian Armstrong-Helouvry led to the development of a new analytical model and a methodology that can be used for the study and experimental determination of the components of friction (static, dynamic and viscous).

The mathematical model (Helouvry, 1993) that describes the Stribeck friction and static friction effect is given by the equation:

$$F(t) = F_u \cdot \text{sign}\left(\frac{dy}{dt}\right) + F_v \frac{dy}{dt} + F_s(\tau, t') \frac{1}{1 + \left(\frac{y'}{y'_s}\right)} \cdot \text{sign}\left(\frac{dy}{dt}\right) \quad (1)$$

where: F_u - the amplitude of dry friction force [N]; F_v - the amplitude of viscous friction force [N]; F_s - the amplitude of Stribeck friction force [N]; τ - characteristic growth time of dry friction [s]; t' - period of stagnation [s]; y'_s - Stribeck friction characteristic speed [m/s].

The research described below refers to experimental analysis of viscous friction force (F_v) influenced by load, speed and characteristics of fresh and used hydraulic lubricant H46EP (***, 1993).

2. EXPERIMENTAL SET-UP

The experimental set-up used is the tribological pin-disk type equipment build up from the following structural elements as shown in Figure 1 and 2:

Fig. 1. Tribological pin-disk type equipment – generic view

- Drive motor;
- Reduction gear (transmission ratio - 15, maximum revolutions per minute - 5000 [r.p.m.]);
- Lubricating shell and friction joint disk;
- Pin-disk joint (the pin has a 4 mm diameter and is made of 38MoCrAl 09 steel, the disc has a 40 mm diameter and is made of hardened stainless steel - material for servovalve elements);
- System load (lever type);
- The friction force measurement system (strain gauge, with force transducer);
- Electronics control and measurement units (sets and display the wanted gear and measure the friction force).

Fig. 2. Tribological pin-disk type equipment - detail

3. RESULTS

Experimental investigations were performed at the ambient temperature of 20° C under the following conditions:

- Five loading level (from 10 to 50 [N]);
- For five speeds (0.15 - 0.35 m/s) ;

- H46EP lubricant – hydraulic oil for automatic control servo valves - fresh and used for 3200 hours;

For each type of lubricant (fresh and used) we performed three measurements of friction force (friction coefficient) depending on the speed and normal downforce. Measurement results are presented in Table 1 and the graph in Figure 3 and include the average values of the friction coefficient calculated depending on the measured friction force.

Sliding friction coefficient values (μ_f)						
Type of oil	revolutions per minute [r.p.m.] / speed [m/s]	Normal load (F_n) [N]				
		10	20	30	40	50
H46EP (fresh oil)	82/0,15	0,10	0,110	0,107	0,102	0,098
	109/0,20	0,10	0,100	0,097	0,087	0,084
	136/0,25	0,09	0,095	0,083	0,077	0,072
	163/0,30	0,09	0,085	0,077	0,065	0,064
	190/0,35	0,08	0,080	0,063	0,057	0,052
H46EP (used oil)	82/0,15	0,10	0,105	0,100	0,097	0,096
	109/0,20	0,12	0,120	0,110	0,107	0,104
	136/0,25	0,12	0,125	0,117	0,107	0,134
	163/0,30	0,13	0,130	0,123	0,120	0,132
	190/0,35	0,13	0,130	0,123	0,120	0,134

Tab. 1. Variation of the friction coefficient depending on sliding speed and friction force for fresh and used oil H46EP

Fig. 3. Variation of the friction coefficient for fresh and used oil - H46EP Lubricant

4. DISCUSSIONS

The experimental data were processed by regression analysis method, using SURFER software. In order to calculate the friction coefficient depending on load and speed we proposed a polynomial law variation of third degree:

$$\mu(F_n, V) = a + bV + cV^2 + dV^3 + eF_n + fF_nV + gF_nV^2 + hF_n^2 + iF_n^2V + jF_n^3 \quad (2)$$

The calculated regression coefficients are presented in Table 2.

Type of oil	Regression coefficient				
	a	b	c	d	e
Fresh	0.0797	-0.128	0.817	-1.466	0.00603
Used	0.0195	0.352	0.188	-1.2	0.00568
Type of oil	Regression coefficient				
	f	g	h	i	j
Fresh	-0.0161	0.0122	-0.000146	0.000112	$1.23 \cdot 10^{-6}$
Used	-0.00746	-0.00142	-0.000203	0.000158	$1.96 \cdot 10^{-6}$

Tab. 2. Third order polynomial regression coefficient for the coefficient of friction, for H46EP oil

5. CONCLUSION

The interpretation of experimental data supports the following conclusions on the evolution of friction coefficient:

- Variation curves of friction coefficient depending on sliding speed and normal force have the same aspect, for both fresh and used lubricant;
- For used H46EP oil the friction coefficient has higher values than corresponding values of fresh oil;
- For fresh H46EP oil, the trend of friction coefficient is to decrease with increasing of sliding speed and load force;
- Equation (2), applied to characteristic joints of automatic hydraulic systems with servo valves, describes the influence of friction force (friction coefficient) on the performance of automatic hydraulic systems (the precision and stability) and its development according to the degradation degree of the lubricant;
- Future work will consist of choosing other hydraulic lubricants and by extending the number of parameters influencing the lubricant degradation;
- A possible objective of the research could be the correlation of viscosity with the friction coefficient changed in the degradation process of the lubricant.

6. REFERENCES

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