THE RESEARCH OF OIL PROPERTIES AFTER DURABILITY TESTS OF POROUS BEARINGS

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Abstract

Self-lubricating bearings are characterized by silent–running work, long durability, and high load-carrying capacity at small sliding velocities. Durability of porous sliding bearings is one of the most important parameter determining future implementation. However, during operation loss of self-lubricating capability of the bearing can be caused by aging process of lubricant, what could lead also to decreasing of the durability. Oil aging process could be much deeper than in conventional sliding bearings with solid bushes, because of temperature, catalyst metal–porous structure and oxygen accelerating oxidation of oil. It was preliminary confirmed in the previous research that after durability tests of porous bearings high values of total acid number (TAN) of oils samples were achieved. Infrareds (IR) spectrums were also deeply changed. Thus the same investigation was performed for two other different oils (mineral gear oil and perfluorinated polyether - PFPE).

After the durability test oil samples were unsaturated from the bearings and IR spectrums and TAN were examined. As it appeared change of mineral gear oil properties were not very deep. On the other hand synthetic PFPE oil had high TAN values and significant differences in the IR spectrums were observed.

Keywords: *porous bearings, mineral oil, synthetic PFPE oil, aging process*

1. Introduction

One of the kinds of bearings are the self-lubricated bearings made of sinter metal of iron or bronze, impregnated with lubricating oils. The basic advantages of porous bearings are as fallows the non-service character of operation, possibility of runs without additional supply of, low cost of production, trouble-free technology and flexible to shape different machines elements. Porous sliding bearings have found application in conditions of low speed and high load, making up full complement of conventional sliding bearings. However during application of porous bearings it is necessary to mark their disadvantages: lower durability properties in comparison with the solid sliding bearings, difficult work with dynamic and edge load. The porous sliding bearings have been wildly implemented in all branches of technique.

The durability of porous sliding bearings is defined as time of work without seizure after single saturation of bush by lubricant or also as entire quantity of turns, which shaft can execute at definite load and speed, to the moment of bearing seizure. The durability of bearings depends from construction of tribological pair as well as the technology of porous bush production, conditions of bearing work, temperature of work and also properties of lubricant. Thus decrease of durability of the tribological couple with a porous sleeve can be caused in conditions over limits (temperature, velocity, load), decrease of lubricant amount (as the result of leakage and of evaporation), by ageing process of lubricant operating in contact with highly porous surface and by increased amount of impurities in porous structure and bearing gap. However, deterioration of oil in the porous bearing as the result of oil aging is believed to be one of the main reasons of limitation of the durability and self-lubrication capability. Many authors agree that among essential proprieties of oil used in the porous sliding bearings there is resistance on oxidation [1-5].

Firstly, during process of oxidation in oil occur active surface products, which can improve its lubricating properties, but can also easily create boundary layers inside the porous channels diminishing significantly their clearance and making difficult for oil to flow into the bearing gap. That process of obliteration of the porous channels is strictly connected with the chemical composition of oil and oxidation process of oil during bearing work. Olexa [5] clearly presented that permeability of the porous bearings, which parameter decides about oil circulation in the bearing gap, could be decreased by the active compounds comprised in oil.

Secondly, the porous bearings have worse exchange of heat than the bearings with solid bushes. Accumulated heat, catalyst metal–porous structure and oxygen accelerate oxidation of oil and change of its properties until total blockage of the porous channels. However, that effect was not confirmed in a laboratory research.

Analysis of professional literature showed that, there is a lack of complete investigation results of carrying capacity and service life of the porous bearings versus oxidation resistance. There are also no results presenting the change of oil properties during the durability tests.

The authors presented first results concerning the process of oil aging [6] and showed the investigative results of oils extracted from the bearings after durability tests in different conditions. Only IR spectrum and TAN of aged oils were examined because of small amount of oil collected from the bearings after the tests (about 0.8g for each work conditions). As it was discovered during stand tests the lubricant very deeply and intensively aged (high values of TAN) what was connected with high temperature of the bearing work, duration of the tests and a metal–porous structure strongly acting as catalyst. It was also noticed that rotational speed of the shaft influenced the value of TAN.

2. The research program

The first research object was mineral gear oil Hipol 15F. The second chosen oil was synthetic oil produced for applications in porous bearings. It was perfluorinated polyether (PFPE), having excellent antioxidation properties, appropriate for a temperature from -25oC up to 200oC, with the best performance at 150^{o}C.

During the research program the following stages of investigation were undertaken:

- investigation of basic parameters: density and viscosity at 20^{o}C, 40^{o}C and 100^{o}C, total acid number, infra-red spectrum (IR), antiseizure and antiwear properties (scuffing load Pt under linearly increasing normal load and limiting load of pressure G_{oz150} under 147.2 N) according to the four ball method (Table 1);
- 1000 hour durability test of porous bearings;
- investigation of basic parameters of chosen oils after durability test.

3. Investigation results

The density characteristic of chosen oils are presented in Figure 1. The synthetic oil had almost two times higher density then mineral oil.

Tab. 1. Investigation of lubricity properties of fresh oils

Oil	Pt [daN]	Goz [MPa]	Avg. wear scar diameter [mm]
Gear oil	2569.9	383.2	0.45
Synthetic oil	3691.2	132.6	0.76

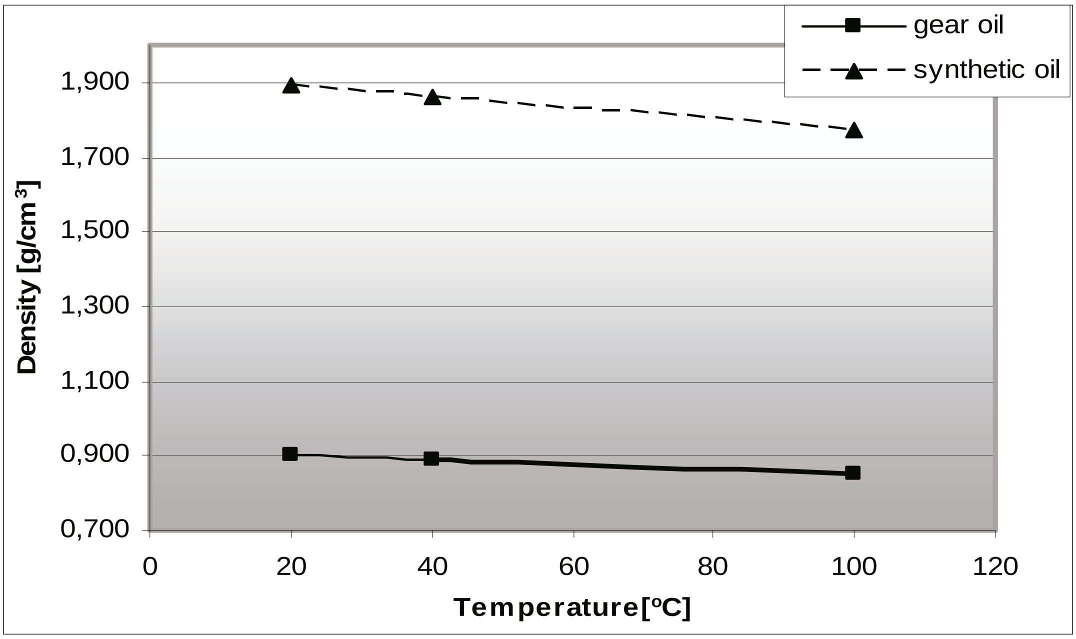

Fig. 1. Density of chosen oils

The synthetic oil had smaller kinematic viscosity than mineral gear oil (Fig. 2), but they had almost the same viscosity index (gear oil - 103, synthetic 110).

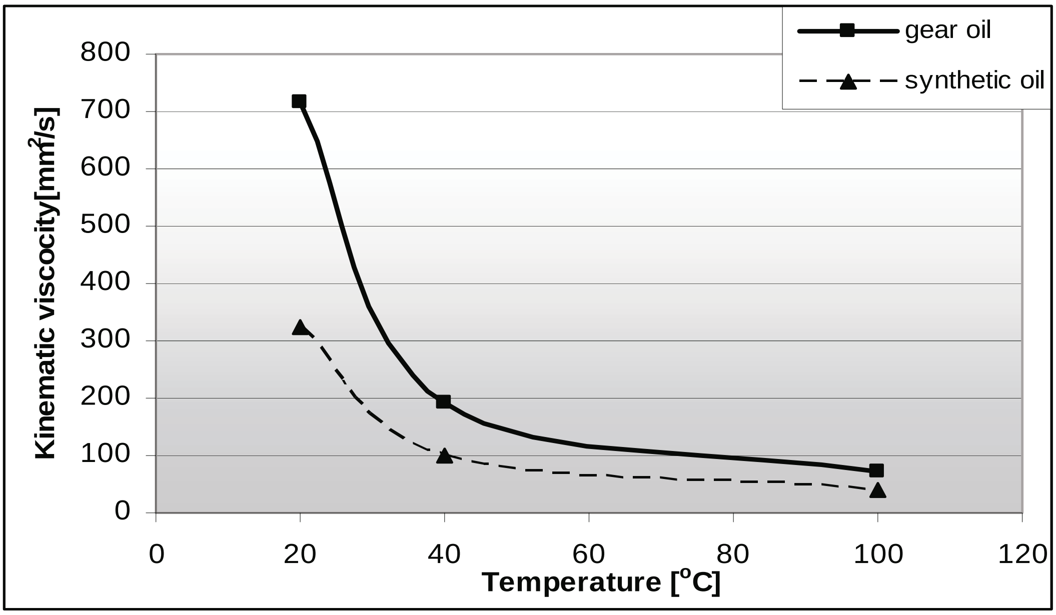

Fig. 2. Kinematic viscosity of chosen oils

As it appeared, higher values of density resulted in almost the same dynamic viscosity characteristics of two oils (Fig. 3).The dynamic viscosity characteristic presented in Fig.10. The synthetic oil has smaller kinematic viscosity than mineral gear oil and almost the same dynamic viscosity, because of its much higher density. That was especially important to observe the tribological characteristics of porous bearings impregnated with the oils.

Investigation of lubricity properties showed that synthetic PFPE oil showed higher Pt value, but had worse antiwear properties (smaller values of Goz).

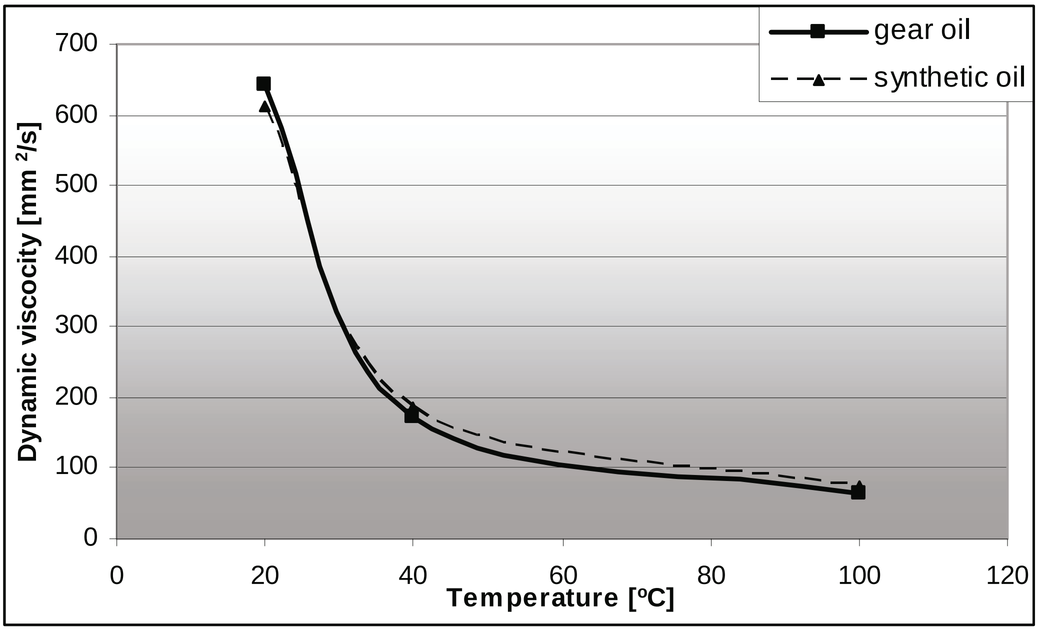

Fig. 3. Dynamic viscosity of chosen oils

In the second stage 1000 hour stand durability test were performed for the porous bearings impregnated with chosen oils. In the Fig.7-10 general view of the stand durability tester of porous sliding bearings is explained.

Fig. 4. View of the research module

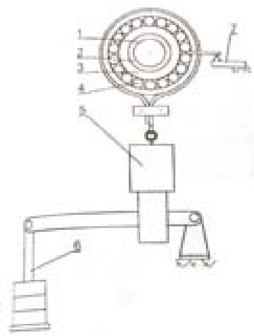

Fig. 5. The functional scheme of research module stand: 1-shaft Neck, 2-porous Bush, 3-bearing mounting, 4-needle bearing 5-load detector, 6-arm with weights, 7-resistance to motion detector

Fig. 6. View of the porous bearing

From the start, the test for both oils was performed under different rotational speed and load (Table 2).

Tab. 2. Work parameters in durability test

	Rotational speed [rpm]	Sliding speed [m/s]	Load [N]	pv factor [MPa*m/s]	Average temperature [^{o}C]
Mineral oil	600	0.78	1350	2.10	50
	1000	1.31	727	1.90	60
	1400	1.83	430	1.57	70
Synthetic oil	600	0.78	300	0.47	85
	1000	1.31	220	0.58	100
	1400	1.83	30	0.11	70

Analysis of registered characteristics showed that, the bearings impregnated with mineral gear oil had very good and stable characteristics of moment of friction and temperature (Fig. 7). It resulted in low temperature of the bearing work (avg. 60^{o}C). On the other hand, the bearings impregnated with synthetic oil had very unstable characteristics, showing that process of seizure occurred. The temperature of bearing (avg. 100^{o}C) was high even for small load at the end of the tests (Fig. 8). However, the bearings impregnated with synthetic oils were several times additionally fed with fresh oil to sustain and continue the 1000 hour durability test.

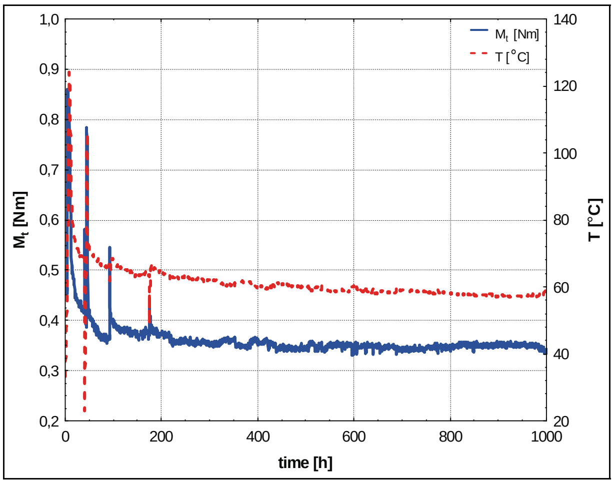

Fig. 7. Moment of friction and temperature during the 1000 rpm durability test – bearing with gear oil

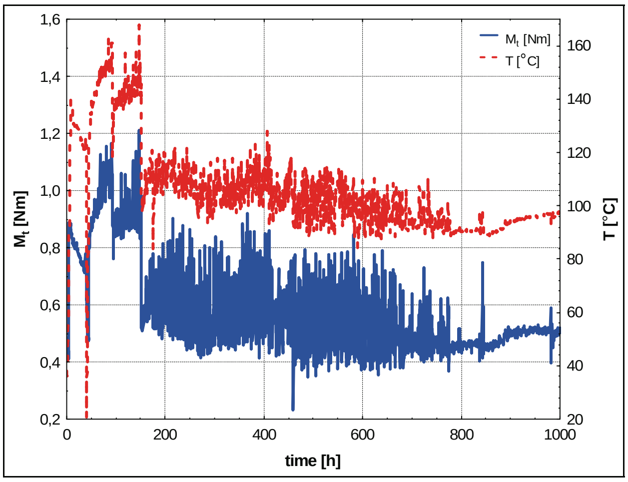

Fig. 8. Moment of friction and temperature during the 1000 rpm durability test – bearing with PFPE oil

Finally, after each durability test, oil samples were extracted from the bearings and some chosen properties were carried out (infra-red spectrums, total acid number).

The results of total acid number were compared with values achieved for fresh oil samples (Table 3).

Analysis of IR spectrums was also performed for the oil samples extracted from the bearings after the tests. However, it should be also pointed out that fresh synthetic oil was supplied into the porous bearings during the tests. Thus differences between IR spectrums at 600 rpm, 1000 rpm and 1400 rpm were not very deep (Fig. 9).

Tab. 3. Investigation after durability test (TAN)

Parameter	Rotational speed	Mineral gear oil	Synthetic PFPE oil
TAN [mgKOH/g]	0	1.01	0.00
	600	1.67	18.09
	1000	1.43	5.96(15.3*)
	1400	2.80	15.98

*TAN value measeured for greasy sediment taken from the bearings surface after the 1000 hour test (1000 rmp)

However during the 1000 hour test greasy sediment on the bearing surface and shaft was created. It enabled to measure IR spectrum (Fig. 9) and TAN (Table 3). The results showed deeper degradation and changes of chemical constitutions of synthetic oil than for samples collected from the bearings. IR spectrums of gear oils did not show meaningful differences (Fig. 10). Thus increase of TAN number of mineral oil was rather connected with increase of the bearing temperature.

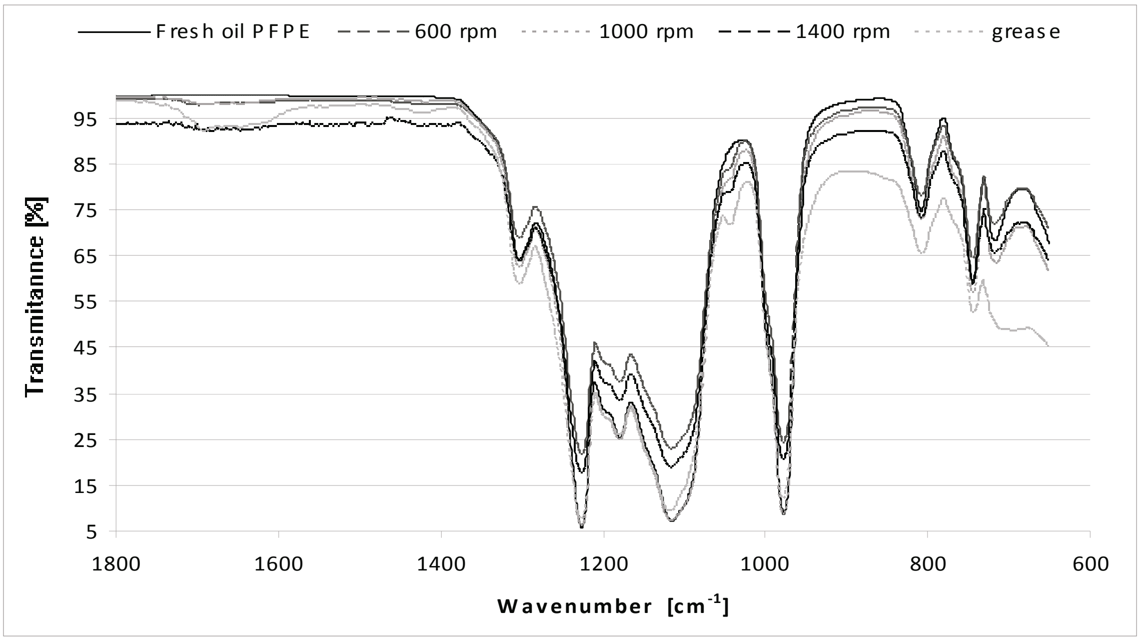

Fig. 9. IR spectrums of synthetic oil (fresh oil and after each durability test)

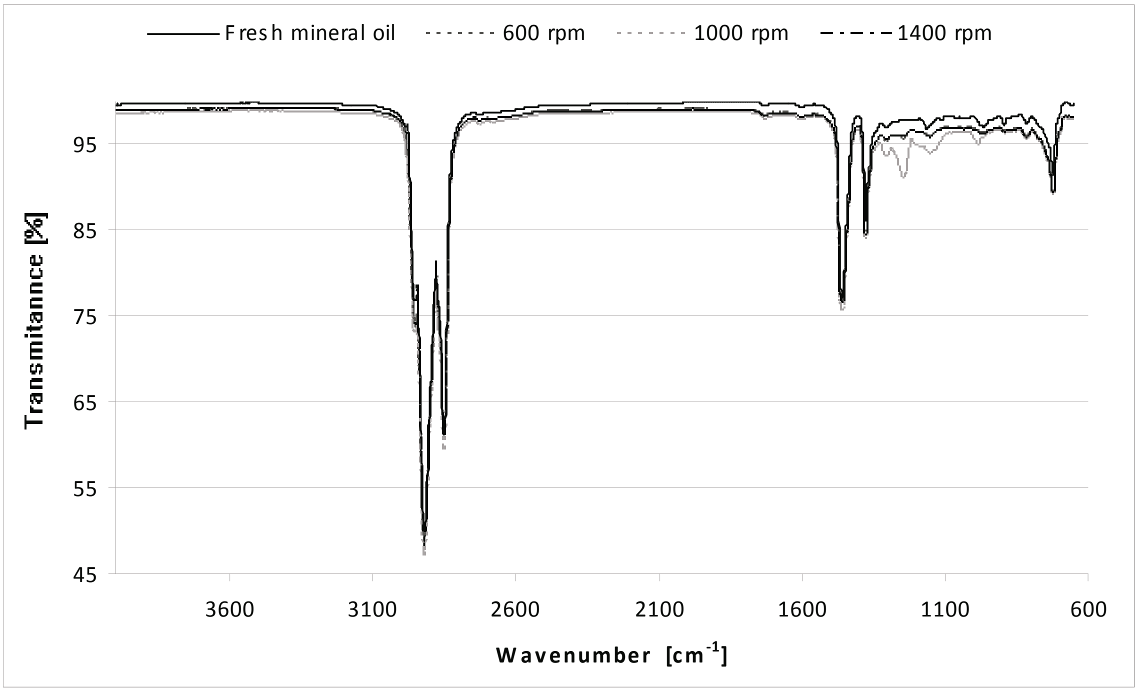

Fig. 10. IR spectrums of mineral gear oil (fresh oil and after each durability test)

4. Conclusions

Achieved results of the porous bearings investigations impregnated with mineral and synthetic oil showed that process of oil aging was strongly connected with work temperature of the bearing.

Synthetic oil having much higher anti aging resistance was deeper aged and decomposed.

The bearings impregnated with synthetic oils were several times additionally fed with fresh oil, what was probably caused by high density and rapid outflow of oil from the bearing.

Process of aging in the porous bearings could be very deep and destructive, even when bearings are impregnated with synthetic oil.

Acknowledgments

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