APPLICATION OF ACOUSTIC EMISSION IN MONITORING OF FAILURE IN SLIDE BEARINGS

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Abstract

The article describes the laboratory tests, which make the first stage of the study concerning the use of the AE method to determine the technical state of the slide bearings in engines with self-ignition. The aim of the present tests was to compare the recorded signals in relation to the technical state of the material of the bearing bush and to check the possibility of using the AE method in determining the transition moment from the fluid friction into the semi-dry friction in the bearing and signaling the first micro-defects of the material of the bearing bush. The experiment has not solved the problem, but they are of a development character and will be continued in the nearest future.

Keywords: Frequency analysis, slide bearing, friction factor, bearing bush

Introduction

Ship combustion engines with self-ignition have fundamental influence on the profitability of ships and their safety at sea. Therefore, it is important to ensure the failure-free operation of these engines. In ship engines, the maintenance of the sliding abilities of the main bearings and connecting-rod bearings is of special importance because the failures of these bearings constitute almost 30% of the total number of failures in all parts of engines. Since the costs of failures of combustion engines caused by the failures of slide bearings are high, intensive theoretical and experimental tests of the slide bearings properties have been undertaken [1, 2].

The currently used methods of monitoring of the technical state of slide bearings indicate the state of failure only when a considerable degradation of the slide bearing material appears. In many cases, this is unsatisfactory in avoiding severe defects or failures. Testing by means of the AE method occurs in real time, and this method can be used as a system of the early warning to avoid damage in structural parts of combustion engines [3, 4].

The presented tests were carried out on the fully computer-controlled laboratory stand (PG-2 1L type) for the examination of slide bearings, as shown in Fig. 1. This stand enables one to simulate the real performance conditions of a bearing and to record all the essential parameters, such as: moment of friction, rotational speed, temperature of the bearing and of the lubricating oil. Technical data of PG-2 1L laboratory stand:
- Power of engine: 11 kW,
- Range of rotation of shaft: 1-4000 RPM,
- Maximum transversal load: 150 kN,
- Diameter of shaft: 76.18 or 80.25 mm,
- Length of bush: 36.75 or 40.00 mm.
The tested bearing bush of MB10-type (Fig 2) is used in C-330-type diesel engine. This engine is generally used for drive auxiliary assembly on ships.

Fig. 1. The laboratory stand PG-2 1L for examination of slide bearing.

Technical data of MB10-type bush:
- Catalogue No.: 1006020010 and 100602010,
- Length: 40.00 mm,
- Outside diameter: 86.00 mm,
- Thickness of wall: 2.905 mm,
- Thickness of steel part: 2.600 mm,
- Diameter of seating of frame: 86 mm.

Tests were made under different conditions of slide bearings:
- Constant transversal load and constant rotation:
  1 or 2 kN, 1700 RPM,
- Constant transversal load and cyclic variable rotation:
  1 or 2 kN, 1-1700 RPM,
- Step changing transversal load and cyclic variable rotation:
  1, 2, 4 and 8 kN, 1-1700 RPM.

The trials by the AE method were carried out with the use of the Vallen AMSY5 system with different types of sensors (VS150RIC-Vallen, WD-PAC and others) in order to cover the widest band of frequency measurements. At the same time, the AE system enabled us to record the test parameters (moment of friction, rotational speed, loading force, temperature) in order to correlate them later with the recorded AE.

Fig. 2. The bearing bush MB10-type after several cycles.
Measurements of the acoustic background

The first stage of the tests concerned both the measurement of the acoustic background and the noise generated by the operation of the installations on the testing stand. That is why the first tests were carried out on a new bearing in different loading variants and rotational speeds with the recording of signals in a widest band of frequency. The frequency analysis of the recorded signals allowed us to determine the main band of noise and the selection of frequency high-pass and low-pass filters for subsequent measurements in order to minimize noise coming from the operation of the testing stand.

An example of the recorded bands of frequency on two wide-band PAC-WD sensors with constant transversal load and constant rotation is presented in Fig. 3. Two examples are given for narrow-band filtered signals (a) and wide-band signals with strong low-frequency activity (b).

Fig. 3. The arrangement of the frequency bands of the signals recorded by 2 wide-band sensors. (a) narrow band, 100-300 kHz segment of 95-850 kHz filter output; (b) Wide band, 20-850 kHz.

Measurements of bearings in different technical state

The first stage of the tests using frequency filters was the measurement of a new bearing with the accepted conditions (loading and rotational speed) similar to the preliminary tests. We used the constant rotational speed of the shaft of 1700 RPM and two values of the bearing loadings, 1 and 2 kN. The AE parameters for these operating conditions for a new bearing established the basis of comparison in the remaining tests.

In order to compare the AE signals recorded during the testing of the new bearing with the signals coming from defected bearing, the measurements were taken of three sliding bearings made of the same material (simulated different bearing capability):

- The new bearing bush without defect – full bearing capability,
- The bearing bush with an opening, simulating a local defect in the material of the bush, which caused disturbances in the flow of lubricating oil – a small but apparent loss of bearing capability,
- The bearing bush with longitudinal and circumferential scratches simulating considerable wear of the bush material – large loss of bearing capability.
High activity of AE was recorded but clearly different for each kind of tested bearing bushes. General AE parameters such as: Hits, Counts, Duration, Energy and RMS showed differences between bushes. However, Amplitude of signals contained similar ranges for all the tested bearing bushes. To evaluate different activities of AE, uses of different threshold levels made comparison difficult with these parameters. At this time, the best parameters for comparison are RMS and frequency distribution of signals. Recorded RMS for the new bearing and the bearing simulating the local loss in the bearing bush material are presented in Figs. 4, 5 and 6. There are data of RMS from different channels with different frequency ranges. Two types each of low- and high-frequency data (with or without *) and medium frequency data are shown. Note RMS for High Frequency (red line) is off-scale because overloading occurred on this channel.

Fig. 4. RMS for different ranges of frequency filters – new bush with no defect.

Fig. 5. RMS for different ranges of frequency filters – bush with an opening defect.
The observed data shows general increase of AE RMS levels (except Low* and High* channels between Figs. 4 and 5). Medium and High channels respond to bush damage states sensitively. The relative changes in the 5-channel data provide clear indication of the bush damage states.

The initial dimensions of the bearing and the bearing’s fit are of vital importance on the parameters of the recorded AE. For the bearings of the same dimensional group, different level of the AE activity was recorded. It is especially visible in the first stage of the bearing operation, when the initial wear of bearing bush surfaces to the shaft neck takes place. Therefore, it is vital to enlarge the data library by taking a larger number of measurements for each of the accepted variant of the bearing states.

Considering the serious differences in the intensity of emission for the particular kinds of the state of bearings during the measurements, changes were being made in the arrangements of the acquisition parameters in order to record the measuring data, which could enable the subsequent analysis with the use of the waveform [5].

**The measurement of the bearing with changeable parameters**

During the testing of the new bearing, a measurement was also taken under the conditions of variable rotational speed and step changing of transverse load, which were to lead to a quicker wear of the bearing bush material. After the cyclic changes in rotational speed, the AE was recorded during the operation of the bearing under the established conditions. The recorded AE was to detect the appearance of the first damage in the material of the bearing. The sum of distribution of hits in frequency bands is presented in Fig. 7. The visible change in the activity of hits indicated a change in the operation of the bearing. The reason of the sudden increase in the AE activity was the wear of the surface layer of the bearing. These changes were invisible in the conventional bearing parameters (moment of friction, temperature, ...) recorded on the testing stand PG-2 1L. It was indicated that significantly changing inside slide bearing is detectable by AE. The example of one of the half bush after these tests is shown on Fig. 2, where surface wear
can be seen. It should be noted that this research requires a larger number of the trial tests in order to record AE in different states of wear of the bearing material.

Fig. 7. The arrangement of the frequency bands of the signals during long-time tests with variable rotation and step changing of transverse load.

The measurement under the conditions of intermittent fluid friction

One of the essential aspects of the tests was the measurement of AE during the disappearance of the fluid friction and transition into the semi-dry friction; i.e., at the moment of the first contact of the pin with the bearing bush. To this end, the test methodology was modified and caused to decrease the friction factor till the start of the contact of the metal pin with the bearing bush. The AE recorded at this time signaled the decrease of the friction factor due to the disappearance of the activity of the AE signals. This was followed by the increase in the friction factor during the contact of the pin surface and the shaft, then a sudden increase in the activity of AE was observed. Figure 8 shows the changes of the bearing parameters, the moment of friction (left) and RPM (right) in the new bearing test. The changes in the AE hit activities in various frequency bands are also presented in Fig. 8. Here, actual RPM reached zero when the friction was high. No AE was emitted in this period and until ~700 RPM was reached.

In this connection one should suppose that carrying out of a larger number of tests will allow the unequivocal identification of the moment of transition from the fluid friction into the semi-dry friction. The presented tests were carried out on the testing stand under the laboratory conditions. In the future, measurements of the bearings installed in combustion engines are planned.

Conclusions

The application of the frequency filters allowed the reduction of the majority of noise for the testing stand, but in the future it will be necessary to determine noise on real engines. The presented examples illustrate that it is possible to apply the AE method in order to define the state of the bearing material. The sensitivity of the AE method allows one to record the signals,
which indicate the transition from the fluid friction into the mixed friction. In the future, it will be advisable to use a pattern-recognition analysis software to identify the recorded signals.

![Graph showing changes in friction and RPM parameters](image)

**Fig. 8.** The changes of the moment of friction (left) and RPM (right) parameters and the AE hit activities in the new bearing test.

**References**


