Monitoring of Acoustic Emission Signal of Loaded Axial Bearings

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Abstract

The disclosure of initial stadium of contact fatigue of rotating machines is very difficult. At present, some methods which are suitable for diagnosis exist, such as vibration method, shock pulse method, acoustic emission and others. The article describes laboratory tests with axial bearings which are monitored by acoustic emission method.

In the article, experimental stands, measuring devices and chosen types of axial bearings are presented. The exploitation of acoustic emission signal for the lifetime evaluation of selected bearings is shown with the characteristics as number of counts, rise time, maximal amplitude or duration of event. The bearing lifetime is separated to three stages and a representative sample in its time and frequency domain for each of them is chosen. Final failures of the bearings are shown too. The paper is focused also on examples of results obtained with continuous AE signal sensing

Introduction

In this 21st century, saving of money is very important for almost all companies in the world. The maintenance costs are one of the few items which could be reduced by modern sophisticated systems. The choice of a suitable diagnostic method is very important for describing and estimating of true lifetime state of machinery parts. The machinery with rotating systems have mostly slide or ball bearings and the faults of these bearings are the frequent cause of breakdowns.

Vibration methods, Shock pulse method, Stator current and Acoustic emission (AE) belong to the suitable methods of diagnostic of machinery with rotating systems. TANDON et al. presented an experiment with comparing of these four methods for testing of radial ball bearing in the course of variable loading and exact size of defects. The acoustic emission was the best of these methods as a response on the size of defect [1]. ELFORJANI et al. published a paper focused on the axial bearings and monitoring of natural degradation processes with mainly acoustic emission method. The first case confirmed that the acoustic emission is more sensitive for detection of the first stages of failure than others, for example the vibration methods [2].

Root mean square (RMS) is a parameter which is mostly used for evaluation of the total damage construction under monitoring. Next to RMS, other parameters are important in the time domain named as Counts, Events or Distress ® parameter [3]. Some authors present the time characteristics of events as for example Rise time, Duration of Event or Maximal Amplitude [2]. The signal outgoing form flat surface is evaluated in the time domain and in the frequency domain. The frequency analysis of the acquired events can have a different character according to lifetime of bearing. The combination of these methods with finding correlations between samples in the frequency domain and the characters in the time domain (Rise time, Duration or Maximal Amplitude) could be important for finding initial stadium of contact fatigue.
Aim of measurement

The aim of this measurement was to find some correlations between acquired data of acoustic emission from the tests of contact fatigue of axial bearings. The laboratories at Faculty of Mechanical Engineering of BUT are equipped by the experimental stands for measuring of bearing specimens of axial and radial bearings. These stations have own vibration sensors which are bewaring an initial stadium of contact fatigue but these stations could be also monitored by the acoustic emission. Thereby the identification of initial stadium of contact fatigue is done earlier. The specimens and the bearings were measured under heavy loading to reduce their lifetime, in some cases the lubricant in bearings was reduced too.

The research was aimed to measuring of bearings under the specific conditions by the acoustic emission for whole lifetime of the bearings. The main goal was to find changes in the acquired signal as changes at global view, which means counts, RMS and the changes of events in time domain as rise time, length of event duration or maximal amplitude. The new technique of full sampling of signal means gain of a huge number of samples in short time. These data could be painting to 3D maps [4].

Experimental equipment

The research was provided on experimental Axmat stands which are situated at laboratory of contact fatigue of Faculty of Mechanical engineering (FME) in BUT Brno. These stations are created mainly for testing of circle specimens. Currently it is also possible to test some kinds of axial bearings. The Axmat stands are shown in figure 1 and main parts of stand are described in figure 2. The main parts are a frame, a three-phase electromotor, a rotary base, a load member, a silon and a beam with set defined load. Specified elements are situated between the rotary base and the load member. These components are created especially for each type of tested bearing. The first element is called Segment and its position is between one bearing ring and the load member. In the middle of these components there is a rising frictional force in the contact area and this is why the bearing ring is not rotating. The second element is called Bush for bearing and the position of the second bearing ring is fixed by three screws. For monitoring, an analyser XEDO with 4 channels and 4 magnetic sensors of AE from DAKEL Company was used. We tested four bearings 51102 with lubricant and especially coupling between sensor and surface was used too.
Experiment

This experiment was created as a part of internal postgraduate project of FME BUT Brno. The main purpose of this project was to create new elements for clamping some types of bearings to Axmat stands. The results obtained in this paper describe the contact fatigue of the axial bearing with number 51102. Four same types of bearings in total were tested in similar conditions. The results in the following graphs show a characteristic example of monitoring of contact fatigue by acoustic emission method.

The first graph in figure 4 shows AE Counts during test of lifetime bearing. The measurement could record up to 16 levels (Counts) of AE signal. This tested bearing was loaded by 2 kN and lubricant was used too. Up to 0.1 day it seems like initial start-up then rise of intensity of the signal to the 0.4 day. The first three levels show very often peak in signal from 0.4 day till 1.2 day then the signal from these levels is steady. The count 5 and count 10 are progressively rising during bearing lifetime that indicates of incipient contact fatigue.
Figure 5 shows the Duration of AE events during test of lifetime bearing. These events are separated to the three sections A, B and C according to their length. This graph is not too significant because the set of measurement of thresholds is very sensitive to obtained final results. This graph shows an actual value in any point for section A and then section B although in fact most of evaluated events are only in section A. After 0.4 day there are some narrow bands with high peaks up to 1 day and next there are wider areas with higher and lower intensity of signal.

![Figure 6. Rise time of AE events during test of lifetime bearing](image)

Rise time of AE event is shown at figure 6 and it is divided into three sections as in the previous graph. These sections were chosen with requirement to a good resolution and for mutual comparison. The Rise time is described as the time from the first exceed of set threshold to maximal amplitude of event. The lay-out of acquired signal in this graph is similar to the previous graph. The first area of graph is from start to 0.4 day, it could be named as a running state. Time domain from 0.4 day approximately up to 1 day has strong narrow peaks in signal and these peaks could reflect the first stadium of contact fatigue. By comparing the same areas of these two graphs it can be noticed that the events have quite a large duration but very short Rise time. Next areas could be characterized the chipping upper particles from surface of ring and sleeking repeatedly.

The fourth of this group of similar graphs is the record of maximal amplitude of lifetime bearing. There is a similar course of AE signal as in the previous records and the signal is separated to tree sections for good resolution too. The main difference compared to the previous records is a distribution of section C. The first occurrence of it was in the beginning of measurement, immediately after that it disappeared and a new occurrence appeared about 0.6 day. The higher areas are for 1.2 day and 1.9 day; this could characterize a gradual fatigue called pitting or next spalling.

![Figure 7. Distribution of amplitude during test of lifetime bearing](image)

Evaluation in frequency domain could provide another view to estimate of initial stadium of contact fatigue. But this method includes several complications as: a good setting of measurement parameters (gain, thresholds of events, sampling rate and others), selection of representative events for interesting areas in time domain, choice of the time length (window) for transformation.
to frequency domain and the hardest thing is to find something what can distinguish the initial stadium of fatigue or failure of mechanism. The bearings are quite complicated parts and evaluating them is hard.

Figure 8 shows the samples of AE event in time and frequency domain. The first of them is taken from beginning state of bearing lifetime. The left graph includes window with chosen area in time domain that is converted to the frequency domain. Power spectral density (PSD) in logarithmic units is on y-axis in the right graph. The frequency domain has maximum value of PSD in 43 kHz the next are 62 kHz and 85 kHz. Logarithmic units are sensitive to detect small valuables of PSD so the next interesting areas are around 230 kHz and 320 kHz. The second graph, at the time 23:49 it is mean 0.5 day, is selected as a characteristic sample with low amplitude but quite a lot of length of event and this is corresponding with previous graphs. In the frequency domain there is one maximal peak in 85 kHz.

Figure 9 shows the next samples from interesting areas of lifetime of bearing. The first is taken at the time 11:12 (0.9 day) where events are with higher amplitude and the frequency have
three peaks (around 62 kHz, 84 kHz and 120 kHz). The last sample shows the point at 09:15 (1.9 day) where the events have high amplitudes with long duration and in frequency domain there are many of peaks between 45 kHz up to 120 kHz. The area between 125 kHz to 320 kHz has frequent peaks and in this time the pitting appears on one ring of bearing.

![Image of bearing damage](image1.jpg)

**Fig. 10. Example of contact damage on surface of axial bearing ring**

The final failure of the bearing is on one of the rings. This damage is situated in race of the ring and has one bigger and two smaller sections. Figure 10 contains two photos of the surface of damage area which were taken with the aid of electron microscope. The left of them shows both damage in magnitude 75x with the scale 200 μm. In the right photo greater damage with magnitude 200x is shown.

New techniques and devices are being developed and our Faculty is cooperating with some subjects in this research field. One of the new devices is IPL from Dakel Company which can records the signal with high density (full record). This measurement is suitable for using once in while during bearing lifetime to estimate the right condition of the watched mechanism. The typical example is shown in figure 11 where measurement has only 300 s. In this graph the intensity of signal is characterized by colour scheme with the highest peak of PSD marked by the darkest colour. After it we can have a lot of information about sensed bearing or another mechanism [4]. This record requires high speed of transfer path and a large hard disk space.

This record from IPL device is shown practically immediately after measurement. This factual record is not from tested bearing as shows previous graphs but a circle specimen was measured on the Axmat stand. This graph includes the date and the time of measurement and next RMS and frequency with maximal of PSD.

![Image of AE signal](image2.jpg)

**Fig. 11. Full record of AE signal from IPL device**
Figure 12 shows a longitudinal cut in frequency axis. There could be seen layout of signal in frequency domain in any time of measurement. The IPL device can carry out also the cuts in time domain where changes of individual frequency in the measurement of mechanism lifetime could be seen.

Conclusion

The measurement of conditions of complicated machine parts, for example bearings, is not simple at all. Acoustic emission is a method which is capable to detect small changes outgoing from inside of materials or propagation of micro cracks in surface. In this experiment the bearing was stopped by vibration sensor of Axmat stand although the sensitivity of vibration is possible to be set. The AE detected sensed the signal much earlier than vibration. This experiment with axial bearing shows that parameters in time domain could draw maintenances attention to main changes in sensing part. From these previous graphs it is possible to consider that the amplitude of events can be one of the better characteristics to estimate the initial failures and becoming of pitting.

A combination of these results from time domain and frequency domain could better display which section of mechanism are damaged. The selection of representative events is time-consuming and it requires needed experiences. For this bearing and this damage the characteristics frequencies were between 43 kHz and 85 kHz with different density during the bearing lifetime. The pitting was described mainly by arising of counts and high amplitudes of events in time domain.

The full record of IPL device is the step to further future, but at this moment this application is appropriate for trends and measurement only once in a while. Especially the cuts from 3D maps at the time and the frequency domain are very interesting for analysis of acquired signal.
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References


