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ROLLING BEARING FATIGUE TESTS USING STATISTICAL PARAMETERS

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Abstract: The condition monitoring of roller bearings is particularly an important topic nowadays. These machine elements can cause great damages in the most of rotating machineries, therefore perpetual failure detection is necessary. The following paper presents rolling element bearing fatigue tests.

Keywords: *fatigue test, vibration analysis, rolling element bearing*

1. INTRODUCTION

Rolling element bearings are one of the most widely used machine elements. Their usage means risk for almost all forms of rotating equipment, such as pumps, machine tools, electric motors, generators, starters etc. Their operating properties impact the function of the whole machine [1].

An accidental bearing failure can cause serious damages. In order to hinder abrupt losses, rolling element bearing failures should be detected as early as feasible. Owing to the early detection, availability of machines can be increased. Perpetual condition monitoring facilitates to determine the location of the fault. Thus corrective activity can be taken and maintenance work can be planned properly.

2. CONDITION MONITORING METHODS

Condition monitoring is one possibility of prognostic maintenance programmes. The gathered information can be used to define machinery problems and corrective actions can be implemented. Several techniques are used for detection of bearing failures. These techniques can be classified as temperature monitoring, noise analysis, vibration analysis, wear debris detection etc. Vibration signals collected from rolling element bearings carry detailed information on machine health conditions. Different vibration analysis methods exist to analyse the bearing vibrations. These methods can be categorized into time domain, frequency domain, time-frequency domain and other techniques [2].

Time domain analysis is the most appropriate to random signals, where other signal analysis methods are not applicable [3]. This technique facilitates fast data processing and computation. Various statistical parameters can be applied as trend

parameters to detect the incidence of bearing failures. The most frequently used stochastic indexes are kurtosis, root-mean-square (RMS) value, peak value, skewness, standard deviation, impulse factor and crest factor.

3. BEARING TEST RIG

At laboratory conditions a test machine is necessary to perform bearing condition monitoring. Such a machine is located at University of Miskolc, Department of Machine Tools. This device is used to fulfil the bearing fatigue and measurement examinations. The equipment with its major engineering parts is illustrated in *Figure 1.*

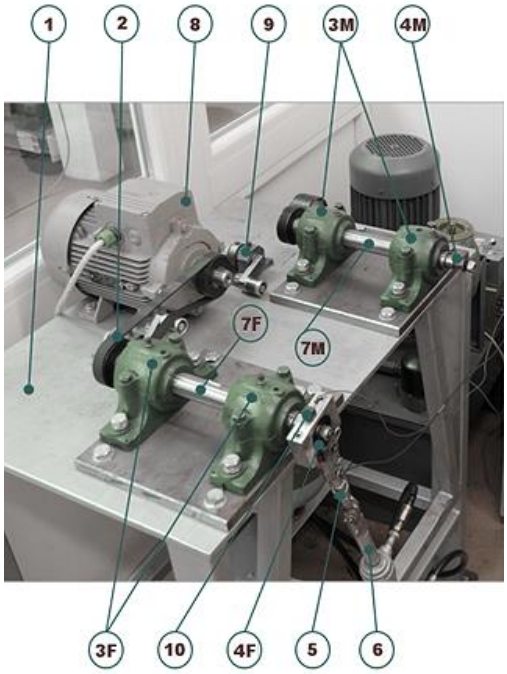


Figure 1. Bearing test machine

Symbols have the following meanings:

- 1: rigid table,
- 2: length ribbed belt,
- 3F: supporting bearings of fatigue side,
- 3M: special supporting plain bearings of measurement side,
- 4F: fatigued bearing,
- 4M: measurement position,
- 5: load cell, the adjustment of hydraulic load,
- 6: double-acting hydraulic cylinder,
- 7F: fatigue test shaft,
- 7M: measurement test shaft,

- 8: three-phase motor,
- 9: belt tensioner,
- 10: piezoelectric vibration accelerometer.

During bearing fatigue tests the fatigue test shaft (7F) works at the given rotational speed (1500 min^{-1}), while the hydraulic cylinder (6) exerts artificial load (6 kN) for the bearing (4F). After the fixed-term fatigue cycles, the examined bearing is put over to the measuring axis (7M). During the measurement investigations the shaft works (7M) at the given rotational speed (1500 min^{-1}), while the hydraulic cylinder (6) exerts artificial load (1 kN) for the examined bearing (4M).

4. EXPERIMENTS AND ANALYSIS

The experimental analysis of rolling element bearings is carried out on different ways. One method is creating artificial defect on the element of bearing. In this instance the vibration signal is being measured and compared with the data of faultless bearings. Another technique is the fatigue test when bearings operate until they get damaged. Although, the process takes relatively long time, nevertheless it can be accelerated by increasing the rotational speed and load. This study focuses on bearing fatigue tests, a 6303 type, single row, deep groove, ball bearing was analysed.

During the tests, vibration patterns were measured from the examined bearing using Kistler 8632C50, piezoelectric vibration accelerometer. The measurement cycles are performed at 9600 Hz sampling frequency. 16,384-element samples were taken within each measurement cycle. The fixed-term fatigue cycles were about 3-4 hours long. After the fixed-term fatigue cycles, vibration patterns were taken from the bearing and time-domain tests were done during which stochastic indexes have been calculated. The statistical features can be calculated by using the formulas below *(Table 1).* These indexes were computed by a program code, which runs in Maple software.

Table 1
Calculation of statistical parameters [4]

Kurtosis	$\frac{\sum_{i=1}^{N}(X_i - \bar{X})^4}{(N-1)S^4}$
Peak Value	$\frac{1}{2}\left(max(x_i) - min(x_i)\right)$
Root mean square	$\sqrt{\frac{\sum_{i=1}^{N}(x_i)^2}{N}}$
Standard deviation	$\sqrt{\frac{\sum_{i=1}^{N}(x_i - x_m)^2}{N-1}}$
Skewness	$\frac{\sum_{i=1}^{N}(X_i - \bar{X})^3}{(N-1)S^3}$

In the formulas, N is the number of discrete points, $\overline{x}$ is the value of the discrete time signal, x_i is the i-th test sample.

Kurtosis value is a non-dimensional stochastic index. This indicator is compromise measure between the intensive lower moments and other susceptible higher moments. Peak value is the disparity between the maximum negative and the maximum positive amplitudes. RMS measures the comprehensive level of discrete signal.

The temporal dependence of the statistical index is usually called lifetime curve. *Figure 2* depicts the Kurtosis value.

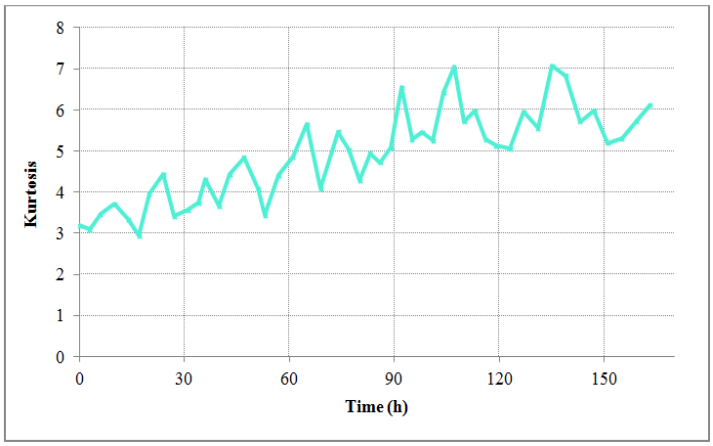


Figure 2. Kurtosis history of vibrations

It is visible that Kurtosis correlated well. The values not increased significantly after 90 hours. In *Figure 3* the peak value change is shown.

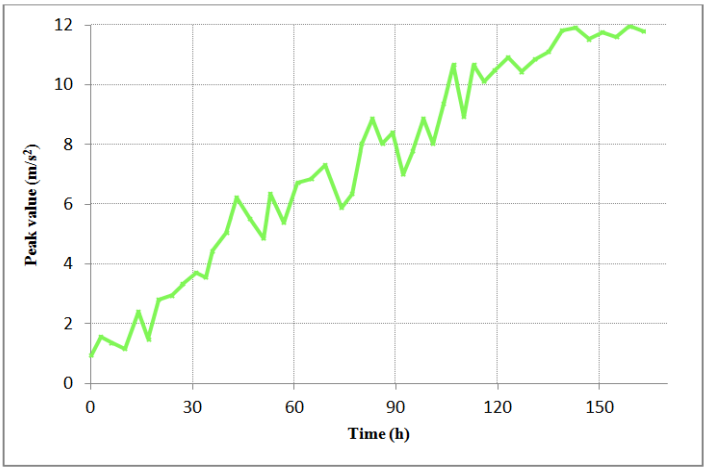


Figure 3. Peak-to-peak value history

It is clearly visible that acceleration values increased continuously by passage of time. It is apparent that it has good correlation. *Figure 4* shows the change of root mean square. The trend of RMS graph seems somehow similar to the peak graph.

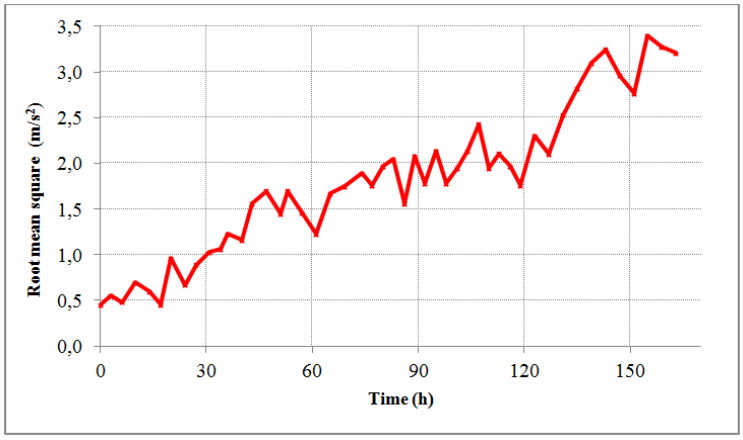


Figure 4. Root mean square value as a function of time

There is a sudden growth in the graph, at around 130–150 hours. At this time the bearing noise had increased, which can caused by exhaustion of the bearing. When the bearing exceeded its nominal lifetime, it was disassembled. As the analysis predicted, the bearing had a defect after 160 fatigue hours. The main reason of bearing failure was the cage failure, which could be caused by heavy loads.

5. Conclusion

This paper shows that vibration analysis methods, especially time domain techniques can be perfectly used in condition monitoring of roller bearings. Statistical analysis methods are accurate tools and they make possible quick data processing.

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Emberi Erőforrások Minisztériuma

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