INVESTIGATION OF BEARING FAILURES USING VIBRATION ANALYSIS

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Abstract: Bearings are important components of most machinery and their working conditions influence the operation of the entire machinery. Even if bearings are being used under excellent conditions, sooner or later material fatigue will occur. Besides other things poor operating environment contaminated or peculiarly moist areas and improper handling practices cause premature failures. This article focuses on vibration analysis methods for detecting bearing failures and presents a special lifetime test procedure.

Keywords: bearing, vibration analysis, signal processing

1. INTRODUCTION

Bearings can be found extensively in domestic- and industrial applications. Bearing failures can cause machine malfunction and even lead to dangerous accidents. In order that prevent these damages, defects should detected as soon as possible. Several methods are used to diagnosis and detection of bearing failures. Investigation of vibration signals is a very important technique for monitoring the condition of machine components [1]. Vibration analysis methods benefit from accurate results and specific information. Vibration signals collected from bearings have detailed information [2]. Different techniques are used to the experimental analysis of bearings.

2. BEARING FAILURES

Almost all bearing defect creates its own characteristic sign. Failures may grouped into secondary and primary ones in many cases. Secondary failures such as cracks and flaking are rooted in primary ones. Primary defects for example smearing, wear, indentations, corrosion, surface distress and the passage of electric current. A defective bearing usually indicates a combination of primary and secondary failures [3], [4]. *Table 1* contains the most common bearing failures and possible causes.

Table 1
Bearing faults and causes [4]

Failure modes with characteristics			Operating					Environmental factor				Lubrication					Mounting							Other					
			Overload	Overspeed	Excessive freq. of load/speed changes	Vibrations	Shaft/housing deflection	Temperature too high/low	Dust and dirt ingress	Water ingress	Electrical leakage	Wrong viscosity	(Consistency) additives selection	Lack of lubricant	Excess of lubricant	Impurities	Incorrect handling (shock loads)	Mounting procedures	Fit too tight	Fit too loose	Tilting/misalignment	Incorrect setting	Incorrect locating (clamping)	Storage	Transportation (vibration/shock)	Bearing selection	Equipment design	Manufacturing concerns	Material concerns
Fatigue		Flaking, spalling, peeling	•			•		•				•	•	•			•	•	•			•	•		•	•	•	•	•
		Burnishing, microcracks		•	•	•		•	•	•	•	•	•	•	•	•		•				•		•		•	•		•
Wear	Abrasive	Excessive wear		•	•	•	•	•	•	•	•	•	•			•			•	•	•	•	•			•			•
		Scratches, scores		•	•				•				•				•	•	•							•			
	Adhesive	Seizing marks, smearing	•		•		•	•				•	•	•	•		•	•	•	•						•	•	•	•
		Hot runners	•	•	•		•	•				•	•	•	•		•	•			•	•	•			•	•	•	•
Corrosion		Moisture corrosion								•		•					•							•	•			•	
		Fretting corrosion	•		•	•	•													•	•	•	•			•	•	•	
		False brinelling		•	•							•								•				•	•	•			
Electrical		Craters, fluting									•																	•	
Plastic deformation		Depressions	•			•	•								•		•	•	•		•	•	•	•	•	•	•		•
		Debris indentation							•						•	•	•	•										•	•
		Nicks, gouges															•	•										•	
Fracture & cracking		Forced fracture	•	•				•									•	•	•		•	•	•			•	•	•	•
		Fatigue fracture	•	•	•	•	•													•	•	•	•			•	•	•	•
		Thermal cracking	•	•	•			•				•		•	•		•	•				•				•		•	•

3. TEST EQUIPMENT

Bearing condition monitoring can be perform by using a test device at laboratory conditions. Such an equipment is located at University of Miskolc, Department of Machine Tools [5]. This device used to execute measurements and fatigue of bearings. *Figure 1* shows the test equipment in measuring position.
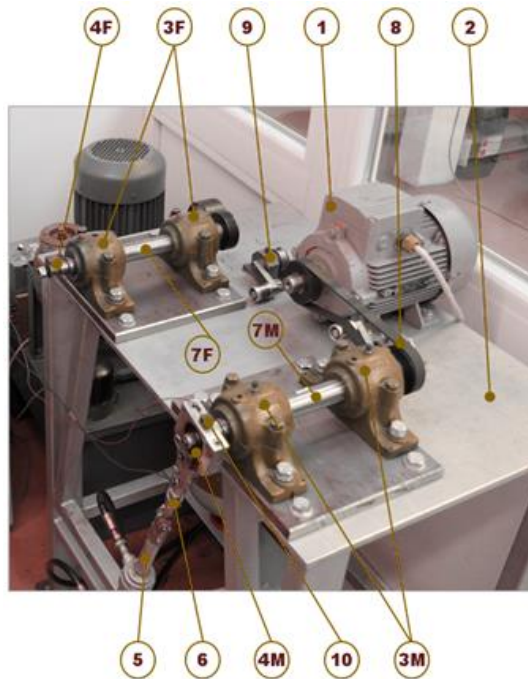
**Figure 1.** *Bearing test device*

The special symbols have the following meanings:
- 10: piezoelectric vibration accelerometer (Kistler 8632C),
- 9: belt tensioner,
- 8: three-phase motor,
- 7F: fatigue test shaft,
- 7M: measurement test shaft,
- 6: double-acting hydraulic cylinder,
- 5: load cell, the adjustment of hydraulic load,
- 4F: fatigued bearing,
- 4M: measurement position,
- 3F: supporting bearings of fatigue side,
- 3M: special supporting plain bearings of measurement side,
- 2: length ribbed belt,
- 1: rigid table.

During the fatigue cycles the loading 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). The measurements performed after each fixed-term fatigue cycles. During the measurement cycles 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

Generally, two proceedings are used experimental analysis of bearings. One method is produced artificial failure(s) on elements of bearings. Another technique is fatigue tests when bearings operate until they get permanent damage. This research focuses on fatigue test of bearings. The above-mentioned bearing test device used to examine 6303-2RS, ball bearing. During the experiments, the vibration patterns measured from bearing using Kistler 8632C, piezoelectric vibration accelerometer. The fixed-term fatigue cycles on average 4 hours long. After each fatigue cycles, vibration signals were taken from the bearing and time-domain tests were done during which stochastic indexes have been calculated. The measurement cycles are performed at 9.6 kHz sampling frequency. Five vibration samples and 16,384 element samples measured within each measuring cycle. During fatigue tests always set on 1500 min^{-1} rotational speed and the equivalent dynamic bearing load is 6000 N. Stochastic features calculated based on sampled values. These indexes computed by a program code, which runs in Maple software. Consequently, the tested bearing (6303-2RS) has near 160 hours lifetime with described data. Peak-to-peak value is a local extreme value in the time signal of the acceleration signal. It is the maximum acceleration in the signal amplitude. Lifetime curve is the temporal dependence of the statistical indexes. *Figure 2* shows the change of peak-to-peak value.
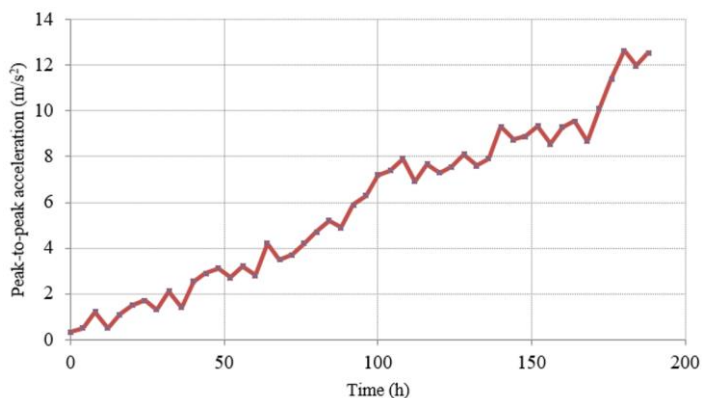

***Figure 2.** Lifetime curve of Peak value*

It is visible that the passage of time the acceleration values increased. At be-tween 172 and 188 hours there is a sudden increase in the graph. This might be due to intense bearing exhaustion or the emergence of defects at one of the sur-faces. The Root Mean Square (RMS) history of vibrations is given in *Figure 3*. The RMS graph seems quite similar to the peak graph.
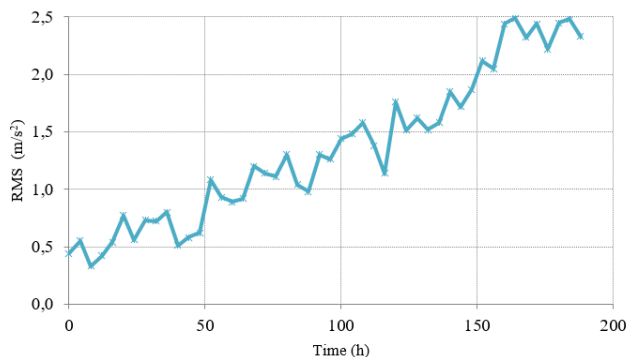
Figure 3. *Lifetime curve of Root Mean Square (RMS)*

Crest factor is one of the scalar measures that used to disclose the faults in bearings. If the Crest factor value is more than 5, there might be a fault in ball bearings [6]. *Figure 4* shows the Crest factor change. After 140 hours Crest value is above 5.
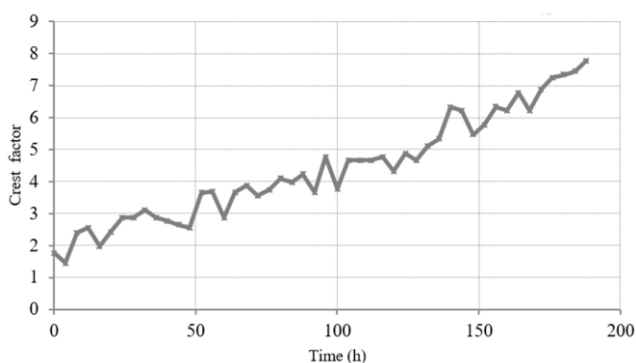
Figure 4. *Lifetime curve of Crest factor*

After the results of the time domain analysis indicated and the bearing noise increased, the bearing was taken apart to pieces. As predicted the time domain analysis after 188 fatigue hours the bearing indeed had a defect. The main reason of bearing failure was the inner ring defect. *Figure 5* shows the smeared inside surface.
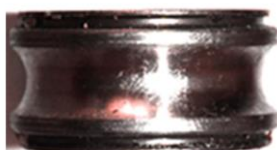
Figure 5. *Failure of inner ring*

5. CONCLUSION

Vibration based methods are well established for the condition monitoring of bearings, although they are not so effectual in detecting early defects in the bearing. This article shows that vibration analysis methods, especially time domain techniques can perfectly use in condition monitoring of bearings. Statistical analysis methods are accurate tools, and they make possible quick data processing.

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