

VIBRATION LEVEL OF BALL BEARINGS DETERMINED BY GREASE STRUCTURE

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Abstract. Grease degradation has an important influence concerning vibration level of ball bearings in running time. Resulted sediments after chemical and thermic degradation process alter frequency spectrum, similar with waves on inner and outer races. In opposite with these, the alters bring about sediments appear and disappear in running time. So, they adhere or detach from race ways. Aquaired signals analysis give more details about estimation of ball bearings grease life reserve.

Key words: lubrication, grease, ball bearing, vibration

1. INTRODUCTION

In the last few years, manufacturers use a ball bearings lubrication method, named “for life”. This fact involve a main interest for ball bearings inside phenomena in running time, regarding grease degradation. On the other hand, recently statistical studies show that over 46% out of running ball bearings are determined by poor lubrication.

So, with the service life increasing, grease degradation increase, with main influences to overall vibration level of ball bearings.

Having in mind the greases homogeneous structure, in hard variable running conditions, these endure chemical and physical alters with influences to loosing lubricating proprieties. Of course, this fact involve a main temperature and overall vibration level increasing.

Also, can be established some correlations between structural changes, vibration level alter and grease life reserve. In fact, these aspects represent ne of the main objectives of present and future researche.

2 EXPERIMENTAL PROCEDURE

Experimental tests are done with 6204 and 6206 ball bearing type. Test machine train involves six test rigs to establish ball bearings reliability. Every test rig has inside two ball bearings used for experimental tests. The test set contains twelve ball bearings. Running speed was 2850 rpm and external radial load was 1/10 C (for 6204 type) and 2/5 C (for 6206 type). Also, every test rig involves instalations for temperature and overall electrical rezistance watching.

Tested grease contains L_i soap and it main characteristics are given in Table 1.

Characteristics	Value
Dropping point [°C]	190
Penetration [1/10 mm]	265÷295
Base oil	Mineral
Using temperature [°C]	-25÷125
Soap type	Li

Table 1: Main characteristics of tested grease

Ball bearings 6204 are lubricated by a grease quantity of 10% free ball bearing volume and 6206 by 5%, respectively.

Vibration signals aquisition is done at the begining of test period and after some running hours. The chain used in aquisition and digital signal processing is shown in Figure 1.

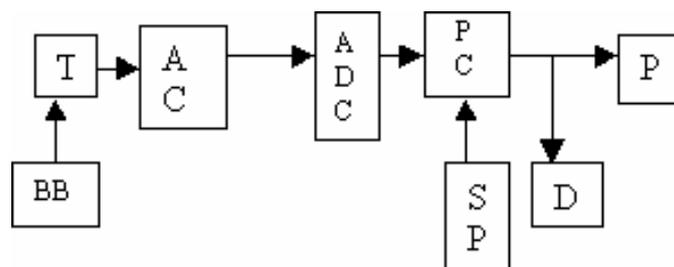


Fig. 1: Block diagram of acquisition and digital signal processing chain

Vibratory signal emitted by ball bearing is picked up by transducer T (Bruel & Kjaer 4371). Amplifier and conditioner signal AC is used to increase voltage value from T and to filter frequencies. It is a low pass filter to remove sampling errors. Also, there are five possibilities to change the highest analyzed frequency: 300, 1000, 3000, 10000 and 20000 Hz.

Then, filtered analogic signal is converted into a digital one by analog to digital converter ADC (Metra-Byte DAS 1602). Signal is processed with software package SP and personal computer PC. Display D and printer P are used to visualize obtained results.

Signals acquisition begin after the measuring chain calibration done by Bruel & Kjaer 4291 accelerometer calibrator.

3 THEORETICAL BACKGROUND

Structural degradation are reflected by vibratory signal alter appeared after running time. Having in mind this aspect, it is necessary to normalize all signals to initial signal (obtained from the beginning of running time).

Time domain signal analysis can offer some important informations. So, the characteristics of time domain statistical magnitude are shown in Figure 2.

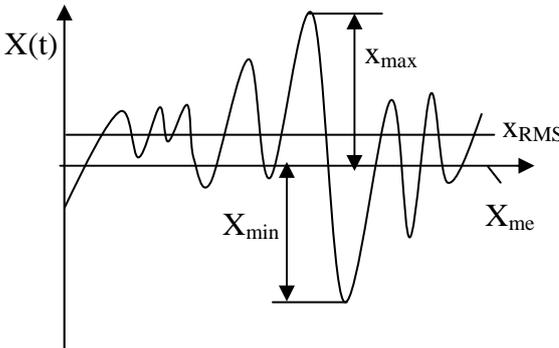


Figure 2: Characteristics of time domain signal

Symbols of the below figure represent:

- x_{med} - mean value

$$x_{med} = \frac{1}{N} \sum_{i=1}^N x_i \tag{1}$$

- x_{RMS} - root mean square:

$$x_{RMS} = \sqrt{\frac{1}{N} \sum_{i=1}^N x_i^2} \tag{2}$$

- peak value:
 - positive: $x_{\max} = \max(x(t))$
 - negative: $x_{\min} = \min(x(t))$

Using relations (1)-(2) can be computed other important values like:

- normalized effective value:

$$VEN = \frac{x_{RMS}(t)}{x_{RMS}(0)} \quad (3)$$

- normalized peak value:

$$VVN = \frac{x_{med}(t)}{x_{med}(0)} \quad (4)$$

- peak factor:

$$FV = \frac{x_{med}(t)}{x_{RMS}(0)} \quad (5)$$

- normalized peak factor:

$$FVN = \frac{FV(t)}{FV(0)} \quad (6)$$

$$K(t) = \frac{x_{RMS}(0)}{x_{RMS}(t)} \cdot \frac{x_{med}(0)}{x_{med}(t)} \quad (7)$$

In relations (3)-(6) „t“ denotes that value is considered after „t“ hours running time and „0“ denotes that is initial value.

Also, can be computed a diagnosis characteristic value:

With these values can be highlighted the grease degradation reflected in time domain signal analysis.

Having in mind that vibratory signals generated by ball bearings are random, it is necessary to compute the density of probability magnitude with equation:

$$p(x) = \frac{1}{\sigma \cdot \sqrt{2 \cdot \pi}} \cdot e^{-\frac{1}{2} \left(\frac{x - x_{med}}{\sigma} \right)^2} \quad (8)$$

The time domain time signal $x(n)$ is passed to frequency domain by Discrete Fourier Transform, defined in equation (9):

- Computed frequency spectrum contains frequencies generated by race ways faults and by grease degradation. So, it is necessary to identify frequencies generated by race ways faults to be removed.

$$X(k) = \frac{1}{N} \sum_{n=0}^{N-1} x(n) \cdot e^{-\frac{j \cdot 2 \cdot \pi \cdot n \cdot k}{N}} \quad (9)$$

$$k = 0 \dots N - 1$$

4 EXPERIMENTAL RESULTS

Because experimental results obtained for all ball bearing sets are too large, will be given only some of them.

Values VEN, FVN and K of the first ball bearing are given in Table 2 and Figure 3. Cut off frequency of these signals was 300 Hz.

Code	VEN	FVN	K
A ₁₁	1	1	1
A ₁₂	0.9976	0.95576	1.04944
A ₁₃	1.0004	1.03102	1.25655
A ₁₄	1.1427	1.07356	0.93126

Table 2: VEN, FVN and K obtained values for ball bearing code A

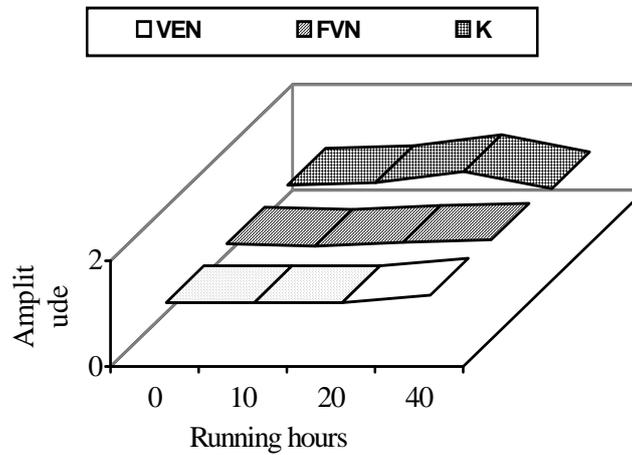


Figure 3: Graphics of table 3

Bearing codes from table 3 represent:

- A₁₁= initial value normalized by itself;
- A₁₂= value after 10 hours running normalized by initial value;
- A₁₃= value after 20 hours running normalized by initial value;
- A₁₄= value after 40 hours running normalized by initial value.

From table 3 and figure results that FVN and K have approximately same values after 20 hours running. Then, they have an increase and a decrease, respectively. Increasing of VEN after 20 hours running means that begin grease degradation process. Also, increasing of K over 1, between 10 and 20 hours running means a decreasing of vibration level. This is done by homogenize grease process. Decreasing of K after 40 hours running highlight that grease degradation process is very severe. Vibrations level probabilistic density is in accordance with the normal distribution law and for highlighting greases deterioration using this distribution law the initial stage normalization was used. The probabilistic damaging density variation for a 6204 ball bearing after 10, 20, and 40 hours of operation that were initial stage normalized is presented in Figure 5.

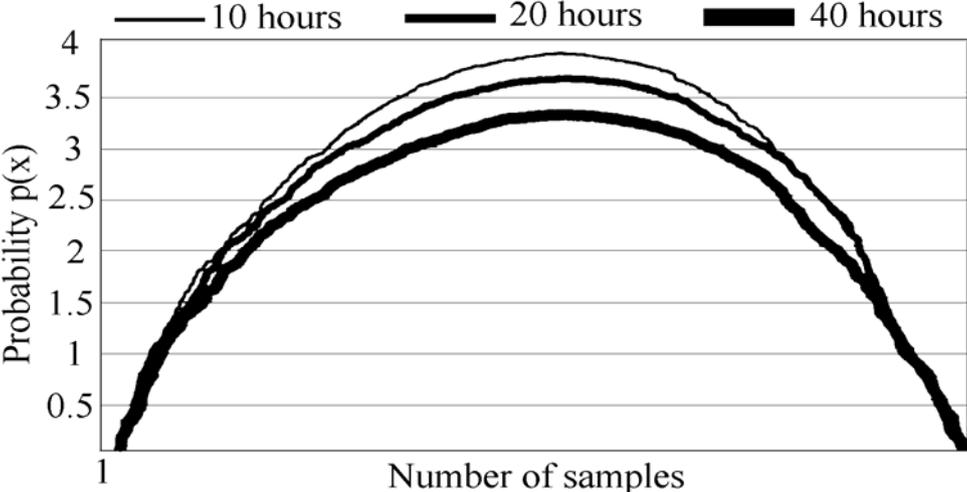


Figure 4: Probabilistic damaging density variation after 10, 20 and 40 hours

Frequency domain analysis highlight the frequency spectrum values generated by grease degradation.

Obtained frequency spectrums from a 6206 ball bearing are shown in Figure 5, where:

- b_{3j} = fresh grease;
- c_{3j} = after 5 running hours;
- d_{3j} = after the grease life reserve is finished.

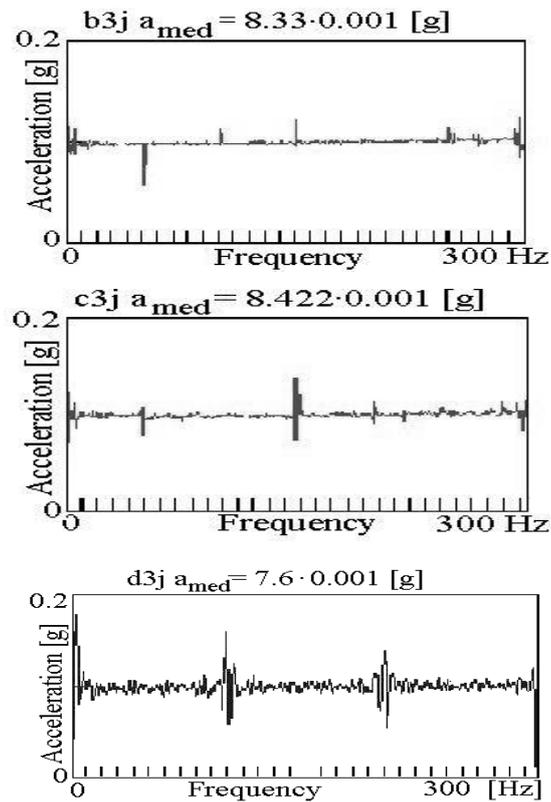


Figure 5: Frequency spectrums of 6206 ball bearing

After 5 hours some peaks appear different from natural frequencies. Some of them disappear in finally frequency spectrum, but new appear again. This phenomenon is determined by sediments resulted in grease degradation process. They alter frequency spectrum similar like race waves but, it is a difference, because they appear and disappear in running process. In order to be able to distinguish the frequencies spectra disturbances in tables 3 and 4 the natural frequencies due to inner ring rotation and the bearings race waves natural frequencies respectively are presented.

	Frequency [Hz]			
# harmonic	1	2	3	4
f_i	47.5	35	142.5	190
f_{ci}	28.67	57.34	86.01	114.68
f_{ce}	18.83	37.66	56.49	75.32
f_{be}	109.96	219.52	329.28	439.04

Table 3: The natural frequencies due to inner ring rotation

		Frequency					
		1	2	3	4	5	6
f_i	linear	229.36	506.22	783	1060	1222	1614
	non-linear	47.5	76.16	104.8	133.5	162.18	130.8
f_e	linear	169.47	339.94	508.41	677.8	847.35	1016.8
	non-linear	37.66	56.5	75.3	94.1	113	131.8

Table 4: Bearings races waves natural frequencies

5 CONCLUSIONS

1. Degradation grease phenomenon is a very complex one. It has main influences to reliability and vibration level of ball bearings lubricated “for life”.
2. Time domain signal processing, reflects very clear degradation process using diagnosis value $K(t)$.
3. Frequency domain analysis show degradation process through sediments which adhere and detach from race ways. These sediments generate new peaks in frequency spectrum.
4. Grease degradation process study using vibration tests represents one of the future possibility to detect greases reserve life.

6 REFERENCES

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