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Experimental Analysis of Vibration of Ball Bearing Considering Solid Contaminants in Lubricants

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Abstract
Rolling element bearings are common in any rotating machinery. The rolling element bearings subjected to failure under continuous running. Therefore they have received great attention in the field of condition monitoring. Different methods are detection and diagnosis of the bearing defects. Among them the commonly used technique is vibration signature analysis. The information obtained from the system vibration can be used for identifying its response subjected to various conditions. In rolling element bearing, contamination of lubricant grease by solid particles is one among the several reasons for early bearing failure. The main objective of this project is to investigate the effect of lubricant contamination by solid particles on rolling element bearing. This work is carried out to determine the vibrations on good and defective bearing in healthy grease and contaminant grease conditions. Obtained the vibration characteristics of healthy grease tested ball bearings are compared with those of contaminant grease tested ball bearings. Vibration signals are acquired from the ball bearings assembled in an experimental rig. The radial load was applied to the outer ring of the test bearing. An accelerometer placed on bearing housing measures radial vibration both in vertical and horizontal. The SKF-LGWA type of lubricants is used in this test, and also different types of solid particles are used as contaminants. The effect of contaminant concentration and particle size on vibration is to be studied. A way of monitoring machinery performance during operation is through mechanical vibration measurement. In rolling bearings, a sudden increase in vibration can be indicative of failure occurrence. In other techniques such as grease analyses and temperature monitoring can also provide warning of faults. But here, vibration monitoring is more versatile since it can reveal a wider range of faults.
Keywords – Condition monitoring, Contaminants, Grease, Particle size, Ball bearing.

I. INTRODUCTION

In the lubrication systems occurring in rolling bearings, very high contact pressures elastically deform the surfaces, giving origin to small elliptical contact areas. The cyclic formation of the elastically deformed contacts eventually leads to surface fatigue. Spalling is known as the typical failure mechanism happening in rolling bearings lubricated by grease. The elastic deformation is subject to the existence of material defects near the subsurface region, as well as to the presence of solid particles in the contact interface. The surface initiated damage due to grease contamination has become one of the main causes of bearing failure.

II. CONTAMINANTS

The term contaminant is another name for pollution. Contaminants are any potentially undesirable substance. It usually refers to the introduction of harmful human-made substances. However, some substances that may have harmful effects at high levels occur naturally in ecosystems and may also be introduced through human activities. They can produce direct effect on lubrication for instance, in plain bearings; an increase in contaminant concentration can make the grease film thickness to decrease. Concerning wear mechanisms in rolling contacts, when hard particles go into the interface, surface damage by mechanisms such as denting is inevitable.

A way of monitoring machinery performance during operation is through mechanical vibration measurement. In rolling bearings, a sudden increase in vibration can be indicative of failure occurrence. In other techniques such as grease analyses and temperature monitoring can also provide warning of faults. But here, vibration monitoring is more versatile since it can reveal a wider range of faults. Defects in bearings can excite vibration frequencies in both low- and high-frequency bands. Several works on ranges of vibration frequencies affected by rubbing phenomena occurring in lubricated contacts can be found in the literature.

The authors found out that vibration analysis through the root mean square (rms) value was able to show that particle size and the concentration affect the dynamical response of the bearing in the 600–10,000 Hz frequency range, in distinct trends:

- The vibration increases with concentration; and

- The vibration first increases and after decreases with particle size.

In these tests, surface damage was noticed in the bearings
after they had been run in contaminated grease.

By means of the same basic procedures previously adopted for vibration analysis, the present study investigates both the dependence of the dynamical response of ball bearings on oil contamination characteristics (contaminant concentration and particle size) and its correlation to wear. Wear was characterized through surface roughness measurements and oil analyses. This study aimed at:

- determining the vibration amount specifically related to worn bearings;
- determine the vibration specifically related to the presence of solid particles in the interface;
- finding out to what extent the vibration due to the presence of contaminant was correlated to the vibration of the worn bearing;
- finding out to what extent the vibration of worn bearings can be correlated to wear damage.

III. EXPERIMENTAL METHOD

Vibration signals are acquired from ball bearings, grease lubricated assembled in an experimental set up.

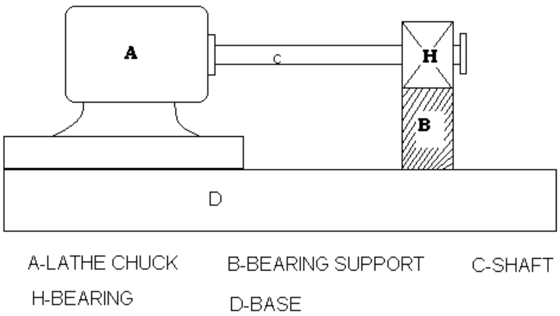

Figure 1 Experimental Lay Out

The radial load was applied to the outer ring of the test bearing. An accelerometer placed on bearing housing measured radial vibration both in vertical and horizontal. The ball bearing geometry is shown in Fig.

LGWA 2 is premium quality mineral oil viscosity (40^{o}C) based lithium complex grease. LGWA 2 has such properties that it can be recommended for a wide range of industrial and automotive applications. So LGWA 2 grease was used as lubricant. Different types of particles is used the project. In first step of the project Mild Steel (MS) particles were to be used. Particles of 90μm (T1), 150 μm (T2), 300 μm (T3) average sizes were used as grease contaminants. The sizes were obtained through screens of 600 and 300, 150 and 90 meshes, respectively.

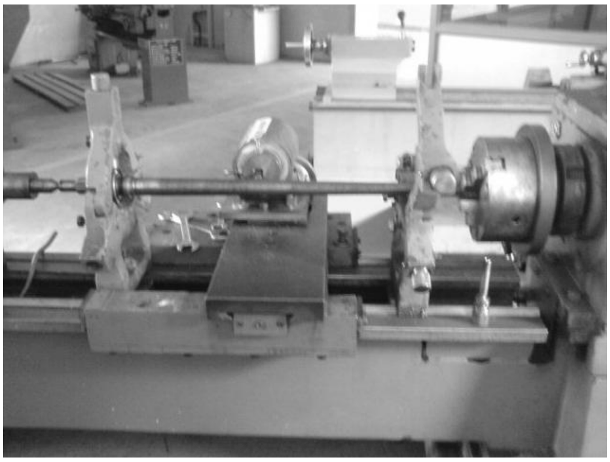

Figure 2 Experimental Set Up

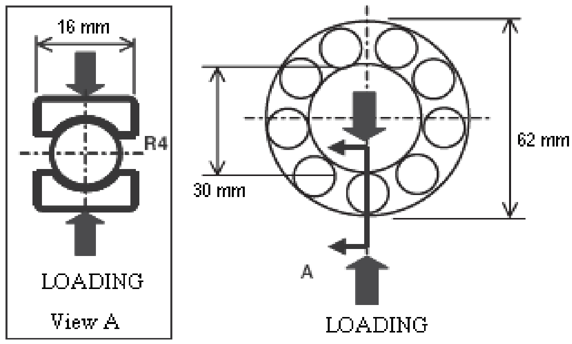

Figure 3 Geometry of the Ball Bearing

Grease quantity is based on the ball bearing geometry values .In the first step, the test bearings were filled with a particular contaminated grease mixture. The amount of grease added

G = 0.005DB

Where,

G = Grease quantity, gm
D = Bearing outside diameter, mm
B = Bearing width, mm.

Defective bearing	Healthy grease	Shaft speed
Ball bearing(6206)	SKF-LGWA	S1=740 rpm
		S2=1150 rpm
		S3=1600 rpm

Table 1 Healthy Grease Condition

Three concentration levels were selected, Grease quantity is 5 gm (grease quantity amount is based on ball bearing geometry).0.5gm (10% of grease quantity), 1gm (20 % of grease quantity), 1.5gm (30% of grease quantity). The concentration level is based on the amount of grease quantity.

Every test followed a sequence of three steps. In the first step, the bearing was running in healthy grease condition in order to stabilize the oil bath temperature. In second step the test continued to run in healthy grease condition in order to collect the vibration data in different combination of load and speed values. In the third step the powder contaminant is poured into the grease at a specified contamination condition. Vibration signals with contaminated grease are acquired from bearing housing in different combination of load and speed values. Vibration results of the worn bearings in healthy grease were compared to vibration results of the bearings in contaminated grease, in order to find out differences in the vibration trends due to the presence of contaminants alone and due to the bearing wear. Data were record and analysis with respect to the values of RMS (root mean square) related to some specific spectral frequency bands.

Shaft speed	Grease Quantity (gm)	Concentration of contamination level (% wt)	Particl e size (µm)
S1=740	5	10%=0.5gm	90
S2=1150	5	20%=1gm	90
S3=1600	5	30%=1.5gm	90
S1=740	5	10%=0.5gm	150
S2=1150	5	20%=1gm	150
S3=1600	5	30%=1.5gm	150
S1=740	5	10%=0.5gm	300
S2=1150	5	20%=1gm	300
S3=1600	5	30%=1.5gm	300

Table 1 Contamination Grease Table

IV. RESULTS

Bearing vibration in healthy grease tests, According to some previous results, the LF band is more sensitive to the operating condition, not being significantly affected by oil contamination. The difference in vibration for the analyzed frequency bands in all the studied operating conditions of different speed condition from the tests performed in healthy grease. The values were arranged according to growing rms level. Vibration signals based on frequency domain and time domain analysis.

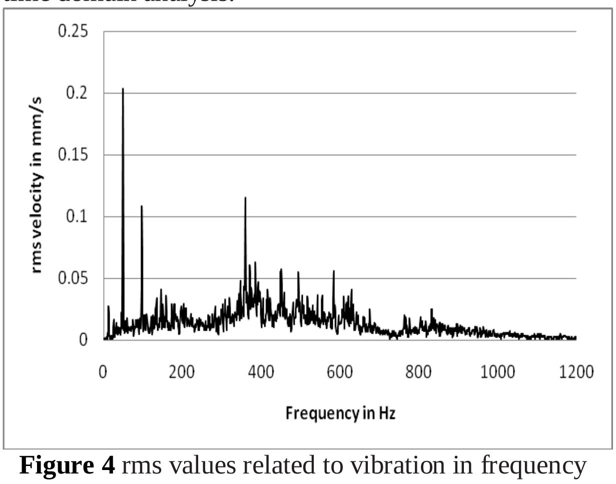

Figure 4 rms values related to vibration in frequency bands as a function of speed of 740 rpm and healthy grease vertical condition.

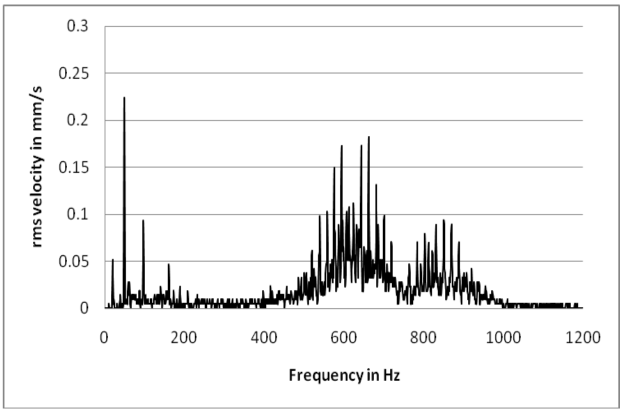

Figure 5 rms values related to vibration in frequency bands as a function of speed of 1150 rpm and healthy grease (horizontal) condition.

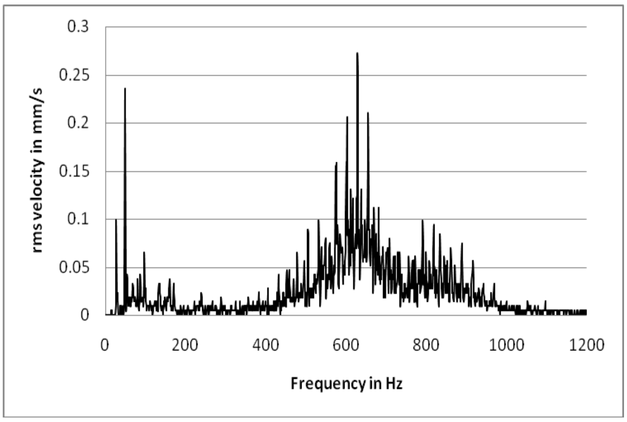

Figure 6 rms values related to vibration in frequency bands as a function of speed of 1600 rpm and healthy grease vertical condition.

Bearing vibration in contaminated grease tests, In this test defective bearing is used to analyze the vibration signals. Different types of contaminants were used to analyze the test under contaminant condition level.

In this test various sizes of particles is used. The particle size differentiates with the help of sieve shaker analyzer.

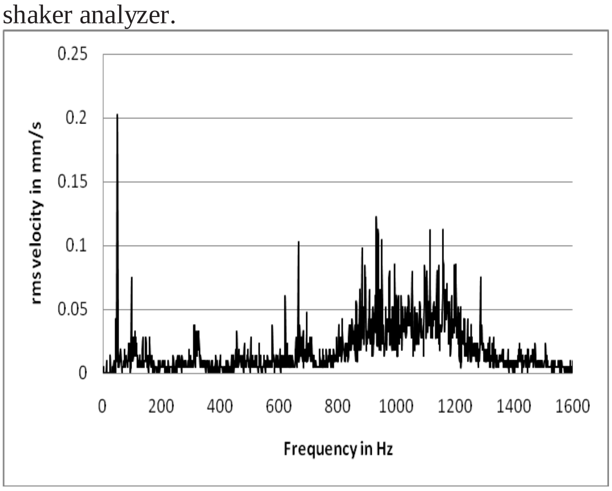

Figure 7 rms values related to vibration in frequency bands as a function of speed of 1600 rpm and healthy grease vertical condition.

(Particle size=300µm and 10% of grease amount)

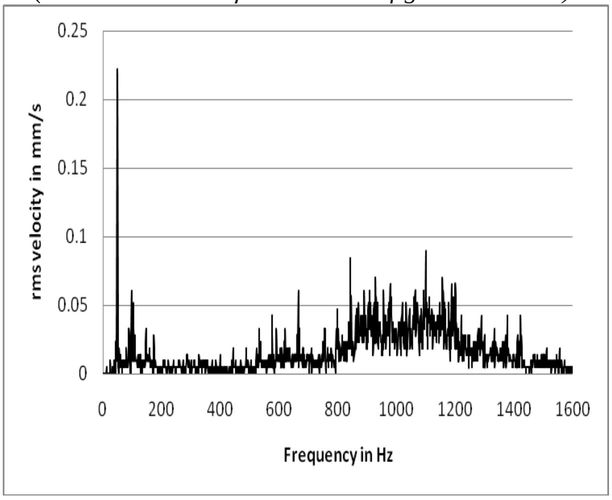

Figure 8 rms values related to vibration in frequency bands as a function of speed of 740 rpm and contaminant grease vertical condition.
(Particle size=300µm and 20% of grease amount)

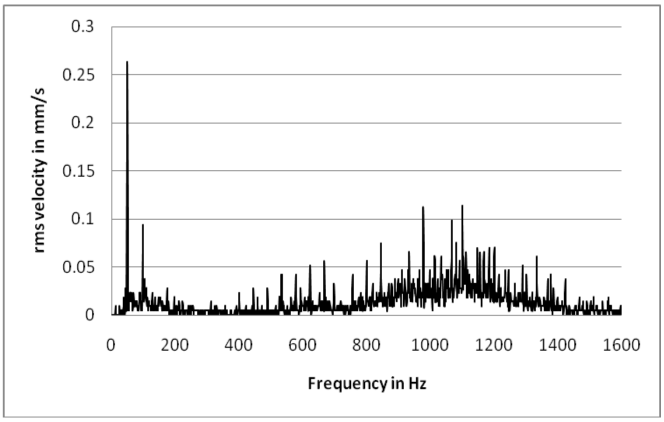

Figure 9 rms values related to vibration in frequency bands as a function of speed of 740 rpm and contaminant grease vertical condition.
(Particle size=300µm and 30% of grease amount)

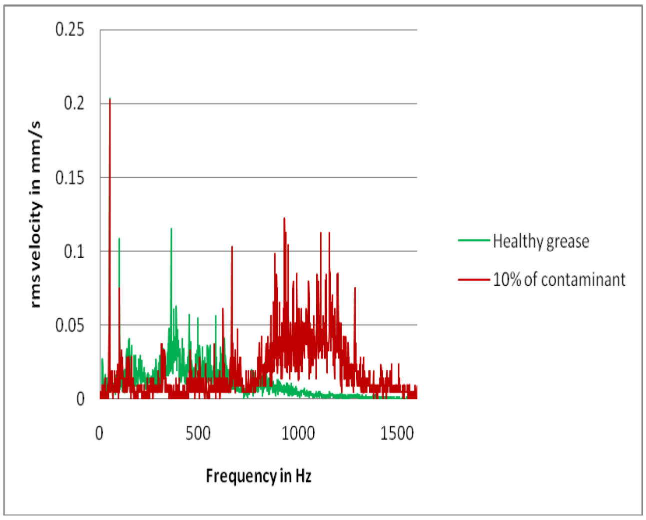

Figure 10 rms values related to vibration in frequency bands as a function of speed of 740 rpm, healthy grease and contaminant grease (vertical) condition.

V. CONCLUSION

In the present work, ball bearings were tested in order to study the effect of grease contamination on vibration level. The effect of contaminant concentration on vibration was distinct from that of the particle size. The vibration level increased with contaminant concentration level, tending to stabilize in a limit. On the other hand, as the particle size increased, the vibration level first increased and then decreased.

For defective bearing conditions, significant peaks at the bearing fault frequencies are observed.

Larger sized contamination particles increase surface waviness considerably. As a result, the vibration level increased considerably at larger particle sizes.

VI. ACKNOWLEDGMENT

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