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Vibration Analysis of Ball Bearing Considering Effect of Contaminant in Lubricant

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Abstract— In deep groove ball bearings, contamination of grease by solid particles is the major reason of early bearing failure.In order To deal with this problem,a non- invasive technique like vibration measurement is used for monitoring of the performance of machines.In this paper, Present work investigates the effect of lubricant contamination by solid particles of coal on the dynamic behaviour of rolling bearing , to determine the trends in the amounts of vibration affected by contamination in grease.Experimental investigations are made with deep groove ball bearings lubricated with contaminated and healthy grease.Coal in three concentration levels and three-grain sizes are used to contaminate the grease.Vibrations generated by bearing due to contaminants in lubricant are analysed in terms of the root mean square(RMS) and peak amplitude values by using FFT analyser.The effects of contaminant on bearing vibration are studied for both good and defective bearings.The results show significant vibration in RMS velocity values on varying the contaminant concentration and grain size.

Keywords— Deep Groove Ball Bearing, Contaminant, Coal, Grease, Particle Size, FFT Analyser

1 Introduction

BEARINGS are components which are frequently used in rotating, mechanical system and many machines industries. .In rolling element bearing, contamination of lubricant grease by foreign particles is the major cause of early bearing failure in the metal extracting industry. This research paper deals with the effects of lubricant contamination by solid particles on the behaviour of deep groove ball bearing. The present study investigates the effect of lubricant by solid particles on the dynamic behaviour of bearing. Coal in three concentration levels and three-grain sizes are used as a contaminant in the lubricant. The contaminant concentrations as well as the grain sizes are varied for each experiment. Vibration signatures obtained in Root Mean Square (RMS) values by using FFT analyser are analysed.

M.M.Maru [1] carried out the research work on the study of solid contamination in ball bearings through vibration analysis. He investigated the effect of lubricant contamination by solid contaminant on the dynamic behaviour of bearings, for determining the vibration effect of the contaminant in the oil .He performed experimental tests on radial ball bearings lubricated by an oil bath and concluded that contaminant in the lubricant is responsible for generating vibrations in bearing.

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V.Hariharan [2] performed the condition monitoring study on ball bearings considering solid contaminants in the lubricant. He investigated the effect of solid contamination in lubricant on the dynamic capacity of bearing. He used Silica powder as contaminant having three concentration level and three particle sizes.He performed experiments on the ball bearings lubricated with grease. The results showed that ,significant variation is observed with change in contaminant concentration and particle size.

Juha Miettinen [3] observed the acoustic emission of rolling bearings lubricated with contaminated grease. He worked on the acoustic emission of the rolling bearing due to grease contamination. On the basis of experimentation he concluded that, small size contaminant particles generate a higher acoustic emission pulse count level than large size particles. The acoustic emission time signal analysis method is preferable method to indicate the hardness of the contaminant particles.

S. Raadnui [4] tested the electrical pitting from wear debris formed by grease-lubricated bearing. He performed various experimental tests for wear modes and mechanisms. He assessed the effects of electrical currents as well as mechanical parameters related with grease-lubricated rolling element bearings.He tested lubricated bearings using the AC field and concluded that electrical pitting wear particles show typical characteristics.

Lars Kahlman [5] carried out the research work on the effect of particulate contamination in grease-lubricated hybrid rolling bearings.He used titorlia and quartz as contaminants in lubricant and performed experimentation. The results showed that wear in hybrid rolling bearing reduced due to the addition of small titania particles and lubrication also enhanced, leading to low running temperature under high loads.

P.Kamalesan [6] carried out the research work on the vibration studies on ball bearing considering solid contaminants in lubricants. He investigated the healthy and defective bearing under contaminated and non-contaminated bearing. He observed that the vibration level increased with contaminant concentration level, tending to stabilise in a limit. As the particle size increased, the vibration level first increased and then decreased.

N. Tandon [7] studied the grease used in the ball bearings of electric motors. According to him, the lubricating grease often gets contaminated either from external particles or particles generated within these bearings. He investigated the effectiveness of vibration, stator current, acoustic emission in detecting the presence of contaminant particles in bearing grease. Ferric oxide and silica particles were used as contaminants in grease. The results showed that level of vibration, acoustic emission, stator current and shock pulse appreciably increased as contaminant level and contaminant size increased. Acoustic emission is the best condition monitoring technique for the detection of foreign impurities in the grease of motor bearings.

Gagan Singotia [8] carried out the experiments to study various solid contaminants in ball bearings. Different techniques are used by him to analyse vibrations in a ball bearing. He observed that vibration level increased with concentration level, tending to stabilise in a limit. Particle settling effect was the probable factor for vibration level decrease.

D. Koulocheris & A. Stathis [9] studied the greases contaminated with particles of different sizes and hardness. He performed optical inspections using a stereoscope. He observed that wear is more severe when harder particles are used, but regarding their size, it seems that wear progresses in a different manner depending on particle's hardness and brittleness as soft, ductile particles are rolled over and hard ,brittle particles are crushed down.

X Ai [10] investigated the debris-induced surface-initiated fatigue failure as a major mode of failure for modern rolling element bearings. He has given contaminant analysis, particle entrainment, surface indentation, stress concentration and debris life reduction.

2. Vibration Signal Monitoring Of Bearing

- The increase of vibration level is one of the indications of a failure of running machines. Increasing level in the vibration signature provides information like bearing vibrations, resonances, and electrical faults. Different defects are generated at different frequencies. Using signal processing techniques to analyse the time and frequency spectrums it is possible to determine the defect and natural frequencies machine components. The peak amplitude of the vibration signature gives an indication of the severity of the problem and the frequency indicates the origin of the defect.Fast Fourier Transform (FFT) is the instrument used for vibration analysis which transforms and converts the vibration signal from its time domain to its equivalent frequency domain representation. Frequency is the most useful on machines that consist rolling element bearings.

3. Contaminant Selection

Different materials have different effects on the performance of the bearing, therefore contaminant material can be altered to analyse its effect on bearing vibrations.The contaminant can be varied in its concentration and sizes.There are different contaminants like a metal burr, sawdust, dolomite powder.Most of the researchers have taken these contaminants for their analysis.Here we consider coal powder as a contaminant in lubricant for vibration response analysis of ball bearing.

4. Bearing Selection

SKF 6206 deep groove ball bearing is used for this project. Geometry of bearing is shown below in Table.1

5. Quantity of Contaminant Slection

Coal powder is sieved in sieves of different sizes available in metallurgy lab of foundry.three different sizes are selected as 150µm, 250µm, 355µm respectively.These samples are added in grease in different concentration levels as 30%(1.5gm),40%(2gm)
50%(2.5gm) of grease weight.The grease weight is selected by using standard empirical relation is given by

$$G=0.005\times D\times B$$
$$=0.005\times 62\times 16$$
$$=4.96 \text{ gm}=5 \text{ gram (say)}$$

TABLE 1
Geometrical Properties of Ball Bearing
(Source-SKFCatalouge)

Property	Value
Bearing outside diameter, (D)	62 mm
Bearing bore diameter, (d)	30 mm
Bearing width, (B)	16 mm
Ball diameter, (BD)	9.6 mm
Cage diameter (Dc)	46 mm
Contact angle, (β)	0
Number of balls, (n)	9

Where , G is grease quantity (gm), D is bearing outside diameter (mm), B is bearing width (mm).From above empirial relation quantity of grease estimated is 5 gram.

TABLE 2
STANDARD SIEVE SIZES

Sr.No.	On Sieve(µm)
1	150
2	250
3	355

6.PRAPARTION OF SAMPLE

Sample sizes of coal powder having 150,250,355(in micron) are added in grease having different concentration levels as 30%,40%,50% of the grease weight respectively.The grease present in bearing in removed by using Diesel.The prepared samples are added in the bearing.These samples are given specific names as C1W1,C1W2,C1W3 etc.Such nine samples are prepared by adding coal powder and one sample is taken without contaminant.

Fig. 1 Contaminant Samples

TABLE 3
TEST SAMPLES FOR COAL

SR NO	MATERIAL	SIZE(µm)	CONCENTRATION % BY GREASE WEIGHT	SAMPLE NAME
1	Healthy	Nil	Nil	Healthy
2	Coal	150	30	C1W1
3	Coal	150	40	C1W2
4	Coal	150	50	C1W3
5	Coal	250	30	C2W1
6	Coal	250	40	C2W2
7	Coal	250	50	C2W3
8	Coal	355	30	C3W1
9	Coal	355	40	C3W2
10	Coal	355	50	C3W3

7. EXPERIMENTAL SETUP

The experimental setup for project is shown below in fig.1
Motor: - Three phase 1 hp, 1400 rpm
Shaft Diameter:-30 mm
Shaft Length:-550mm
Load:-49N

Fig. 2 Experimental setup.

Experimentation is carried out in three phases-In first phase Run the ball bearing in in healthy condition to stable the temperature of grease.The second phase run the bearing with healthy grease to collect vibration-related data at 1400 rpm.In last phase vibrational data is collected with coal powder contaminated grease for all grain sizes and its concentration level.Collected data is analysed with respect to its peak amplitude and root mean square (RMS) values at their respective defect frequencies.

TABLE 4
FREQUENCY EQUATION REQUIRED

Characteric Frequency(Hz)	Symbol	Equations
Shaft rotational Frequency	F_r	N/60
Inner Race Rotational frequency	F_{id}	n/2×fr[1+(bd/pd)×cosβ]
Outer Race Defect Frequency	F_{od}	n/2×fr[1-(bd/pd)×cosβ]
Ball Defect Frequency	F_{bd}	$(pd/bd)\times Fr[1-(bd/pd)^2\times(\cos\beta)^2$

Where,
N =Rotional speed of shaft in rpm
n=No of balls
Fr=Shaft rotational frequency
Pd=pitch diameter
bd=Ball diameter
β =Contact angle

8. RESULTS AND DISCUSSIONS

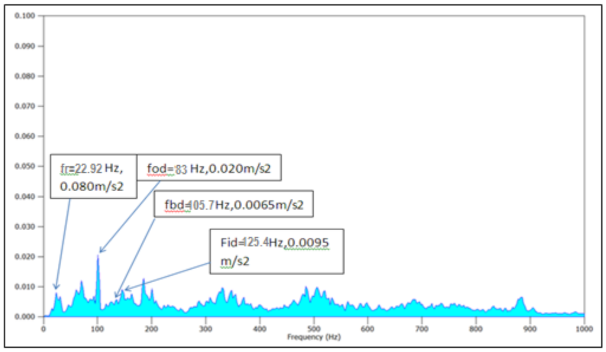

Fig.2Acceleration-Frequency graph for Healthy Bearing Sample

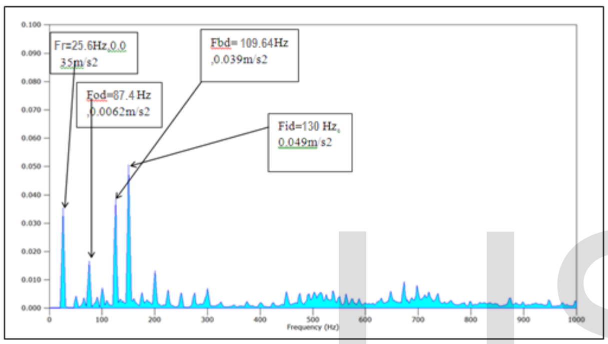

Fig.3 Acceleration-Frequency graph for Bearing Sample C1W1 running at 1400 rpm

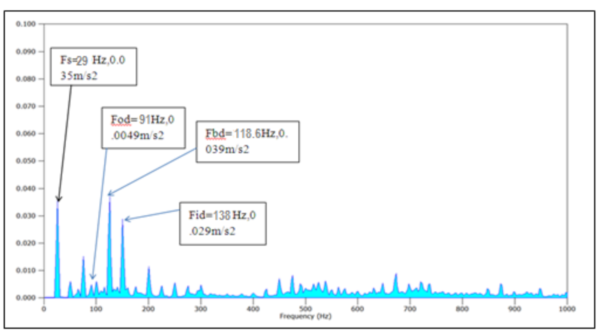

Fig.4 Acceleration-Frequency graph for Healthy Bearing Sample

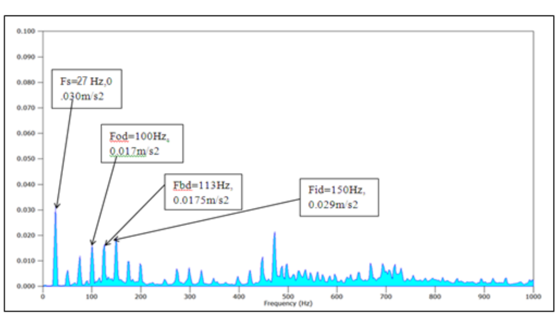

Fig.5 Acceleration-Frequency graph for Bearing Sample C1W3 running at 1400 rpm

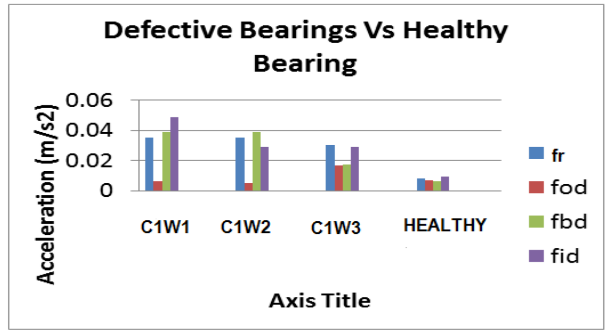

Fig.6 Acceleration-contaminant concentration for Bearing Sample C1W1, C1W2, C1W3 running at 1400 rpm

Data is analysed in terms of peak values and RMS values at corresponding defect frequencies.Above are the graphs of vibration signatures obtained by experimentation by using FFT analyser when Coal is used as a contaminant.Fig.2 indicates the graph obtained for healthy bearing without contaminated grease.Here all frequencies are at lowest level since there is no presence of the contaminant in lubricant which can produce vibrations.Fig.2,fig.3,fig.4 indicate the signatures obtained when coal is used as a contaminant .Size of the particles taken for experimentation are 150µm,250µm,355µm with concentraion levels varied as30%,40%,50%of weight of grease respectively.The graph shows that with an increase of concentration level , acceleration of some defect frequency increased and some decreased.Small particles at high concentration level may not come in contact with outer race hence acceleration values at outer race defect frequency decreases and acceleration values for inner race defect frequency increases.

9. CONCLUSION

In the present work , vibration analysis of deep groove ball bearing is done to analyse the effect of a solid contaminant in lubricant on bearing.All frequencies are at lowest level for healthy bearing since there is no contamination in grease.Coal powder is used as contaminant.The results show that due to addition of the contaminant in grease , there is increase in vibration signature of ball bearing for constant speed and load.As grain size is increased , the corresponding acceleration values go on increasing upto specific limit then it starts decreasing.This is due to contaminant occupy corners present in the bearing by virtue of its weight , therefore it does not come in contact with rolling elements.For the constant speed and

TABLE 5
FAULT FREQUENCIES AT 1400 RPM

Load(N)	RPM	Fr(Hz)	Fid(Hz)	Fod(Hz)	Fbd(Hz)
49	1400	23.33	126.89	83.07	106.92

load , as concentration level of contaminant increases there is an increase in vibrations of bearing which can cause failure.Highest peak in acceleration v/s frequency graph indicates that there is increase in vibrations of bearing due to an addition of contaminant in lubricant.

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