

# Analysis of Effect of Solid Contaminant in Lubrication on Vibration Response of Ball Bearing

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**ABSTRACT:** In ball bearings, contamination of lubricant by solid particles is the major reason of early bearing failure. To deal with this problem, a non- invasive technique like vibration measurement is used for monitoring the performance of machines. In this paper, Present work investigates the effect of lubricant contamination by solid particles of Limestone on the dynamic behaviour of rolling bearing, to determine the trends in the vibrations of the bearing. Experimental investigations are made with deep groove ball bearings lubricated with contaminated and healthy grease. Limestone 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 the terms of the root mean square (RMS) and peak amplitude values by using FFT analyzer. 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 contaminants concentration and grain size.

**KEYWORDS:** Deep Groove Ball Bearing, Contaminant, Limestone, Grease, Particle Size, FFT Analyser.

## I. INTRODUCTION

Bearing is the component which is frequently used in rotating, mechanical system and many machines industries. In bearing, contamination of grease by foreign particles is the main 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. Present work investigates the effect of a contaminant on the rated life of bearing. Limestone 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.

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 was observed with change in contaminant concentration and particle size

JuhaMiettinen [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

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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 a 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 contaminated and non-contaminated bearing. He observed that the vibration level increased with contaminant concentration level, tending to stabilise in a limit. With particle size increased, the vibrations 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 the 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.

GaganSingotia [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 stabilize in a limit. Particle settling effect was the probable factor for vibration level decreases.

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 for hard particle, wear is more, in spite of their size, wear depends on hardness and brittleness. Ductile particles are passed over and 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.

## A. 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.

## B. Contaminants 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 Lime Stone as a contaminant in lubricant for vibration response analysis of ball bearing.

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### C. Bearing Selection

SKF (6206 2Rubber Sealed) deep groove ball bearing is used for this project. Geometry of bearing is shown below in Table.1

### D. Quantity Selection

Limestone is sieved in sieves of different sizes available in metallurgy lab of the 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

$$G=0.005 \times D \times B$$

$$=0.005 \times 62 \times 16$$

$$=4.96 \text{ gm} = 5 \text{ gm (say)}$$

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

TABLE 1  
GEOMETRICAL PROPERTIES OF BALL BEARING  
(Source-SKFCatalogue)

| 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, ( $\beta$ )    | 0      |
| Number of balls, (n)          | 9      |

### E. Preparation of Sample

Sample sizes of Limestone 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 for e.g. C1W1, C1W2, C1W3 etc. Such nine samples are prepared by adding contaminants and one sample is taken without contaminant.

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TABLE 2  
STANDARD SIEVE SIZES

| Sr.No. | On Sieve( $\mu\text{m}$ ) |
|--------|---------------------------|
| 1      | 150                       |
| 2      | 250                       |
| 3      | 355                       |

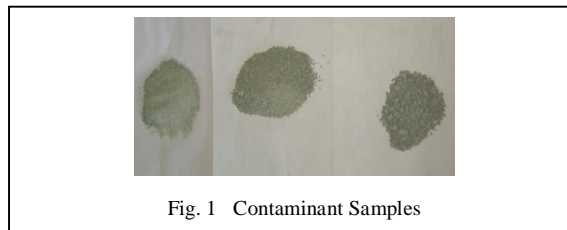


TABLE 3  
TEST SAMPLES FOR LIMESTONE

| SR NO | MATERIAL  | SIZE( $\mu\text{m}$ ) | CONCENTRATION % BY GREASE WEIGHT | SAMPLE NAME |
|-------|-----------|-----------------------|----------------------------------|-------------|
| 1     | Healthy   | Nil                   | Nil                              | Healthy     |
| 2     | Limestone | 150                   | 30                               | C1W1        |
| 3     | Limestone | 150                   | 40                               | C1W2        |
| 4     | Limestone | 150                   | 50                               | C1W3        |
| 5     | Limestone | 250                   | 30                               | C2W1        |
| 6     | Limestone | 250                   | 40                               | C2W2        |
| 7     | Limestone | 250                   | 50                               | C2W3        |
| 8     | Limestone | 355                   | 30                               | C3W1        |
| 9     | Limestone | 355                   | 40                               | C3W2        |
| 10    | Limestone | 355                   | 50                               | C3W3        |

## II. EXPERIMENTAL SETUP

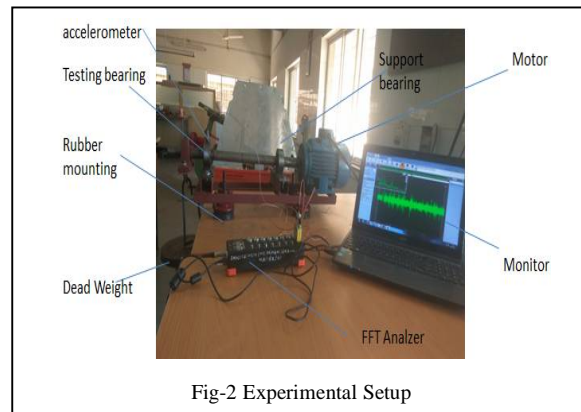
- The experimental setup for project is shown below in fig.2
- Motor: - Three phase 1 hp, 1400 rpm
- Shaft Diameter:-30 mm
- Shaft Length:-550mm

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Experimentation is carried out in three phases. In the first phase, run the ball bearing for 6 hours in healthy condition to stable the temperature of grease. The second phase run the bearing with healthy grease for 6 hours to collect vibration-related data at 1400 rpm. In last phase, vibrational data is collected with Iron ore 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. Where,

- N =Rational speed of shaft in rpm
- n=No of balls
- Fr=Shaft rotational frequency
- Pd=pitch diameter
- bd=Ball diameter
- $\beta$  =Contact angle

TABLE 4  
FREQUENCY EQUATION REQUIRED

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

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  |

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## III. RESULTS AND DISCUSSIONS

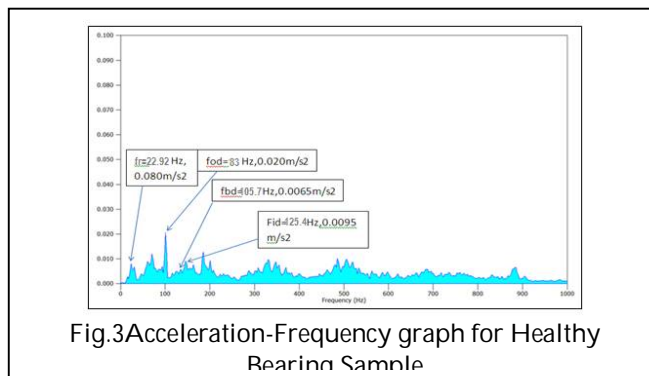


Fig.3 Acceleration-Frequency graph for Healthy Bearing Sample

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 Limestone is used as a contaminant. Fig.3 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.

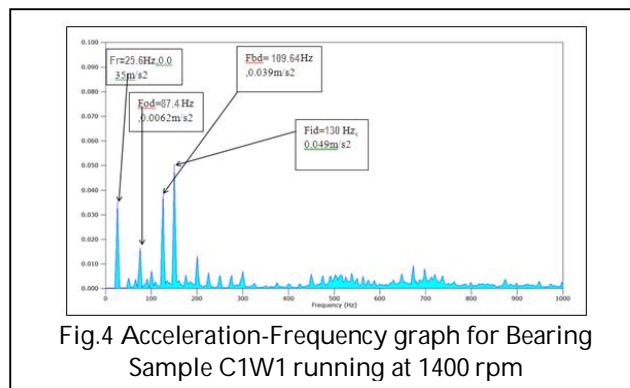


Fig.4 Acceleration-Frequency graph for Bearing Sample C1W1 running at 1400 rpm

Fig.4 shows small increase of acceleration value due to presence of the particles of limestone. This indicates that a 130 micron size particle of limestone generates small vibrations in the bearing.

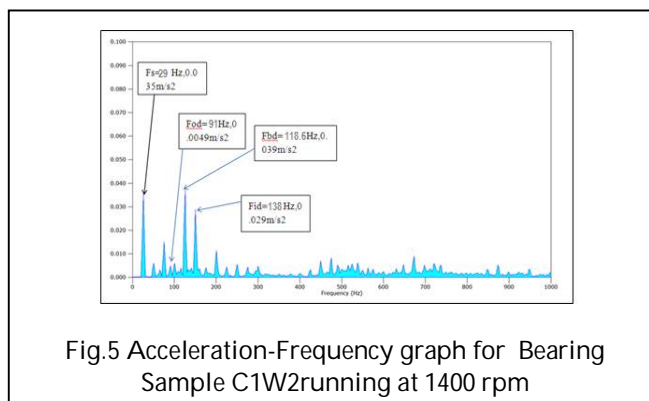


Fig.5 Acceleration-Frequency graph for Bearing Sample C1W2 running at 1400 rpm

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Fig.5 shows there is increase in acceleration value compared to sample C1W1 due to increase of quantity of contaminant in bearing.

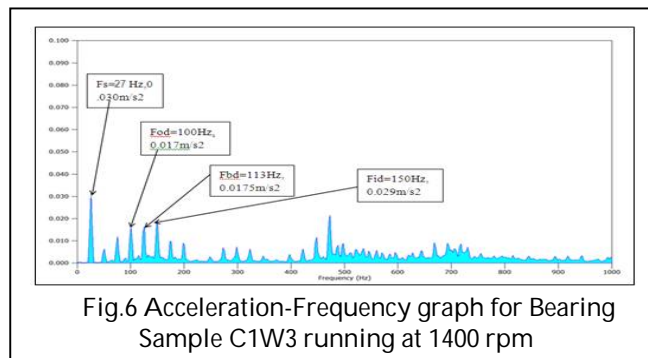
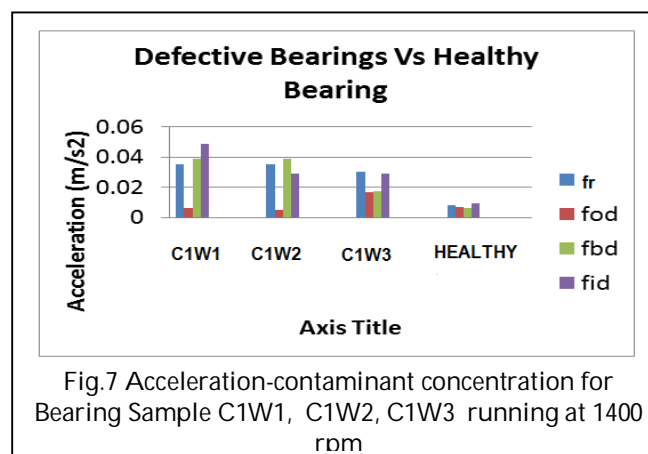


Fig.6 shows that with increase in quantity of contaminant there is decrease in amplitude of vibrations. Small particles at high concentration level may not come in contact with outer race hence acceleration values at outer race defect frequency decreases and acceleration values for inner race defect frequency increases.



Size of the particles taken for experimentation are 150 $\mu$ m, 250 $\mu$ m, 355 $\mu$ m with concentration levels varied as 30%, 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.

### III. 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. Limestone 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 up to 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



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rolling elements. For the constant speed and 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.

## ACKNOWLEDGMENT

The authors wish to express their gratitude to Sinhgad Institute of Technology, Lonavala and Prof P.D.Kulkarni, Prof.M.A.Mohite for their valuable support.

## REFERENCES

- [1] M.M. Maru and R.S.Castillo"Study of Solid Contamination in Ball Bearings through Vibration and Wear Analyses", Tribology International, Vol.40,pp.433–440,2007
- [2] V Hariharan, "Condition Monitoring Studies On Ball Bearings Considering Solid Contaminants In The Lubricant", Proc. ImechE Vol. 224 pp.1727-1747,2009
- [3] JuhaMiettinen, "Influence Acoustic Emission Of Rolling Bearings Lubricated With Contaminated Grease", Tribology International Vol.33 ,pp.777–787,2000
- [4] S. Raadnui and S. Kleesuwan, "Electrical Pitting Wear Debris Analysis Of Grease-Lubricated Rolling Element Bearings", Wear,Vol 271, pp.1707– 1718,2011
- [5] LarsKahlman and Ian M. Hutchings, "Effect of Particulate Contamination in Grease-Lubricated Hybrid Rolling Bearings ", Tribology Transactions,Vol.42, pp. 842-850,2008
- [6] P.Kamalesan, "Vibration Studies On Ball Bearing Considering Solid Contaminant In Lubricants, South Asian Journal of Engineering and Technology Vol.2 ,pp.121,2016
- [7] N. Tandon, "Condition Monitoring Of Electric Motor Ball Bearings For The Detection Of Grease Contaminants", Tribology International ,Vol 40,pp.29–36,2007
- [8] GaganSingotia, "Experimental Study Of Various Solid Contamination In Ball Bearings", IJERT ,Vol.5,Issue 3, ,ISSN 2249-61,2013
- [9] Koulocheris and A. Stathis, "Experimental Study Of The Impact Of Grease Particle Contaminants On Wear And Fatigue Life Of Ball Bearings", Engineering Failure Analysis, Vol.39, pp.164–180,2014
- [10] X Ai , "Effect Of Debris Contamination On The Fatigue Life Of Roller Bearings", Journal of Engineering Tribology,pp.563,2001
- [11] SKF Catalogue- Rolling Contact Bearing

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