STUDY OF EFFECT OF SOLID CONTAMINANTS IN THE LUBRICANT ON BALL BEARINGS VIBRATION

ONKAR L. MAHAJAN[1] & ABHAY A. UTPAT[2]

[1&2]Mechanical Engineering Dept., SVERI's College of Engg. Pandharpur
E-mail: onkar.mahajan10@gmail.com, abhayutpat@rediffmail.com

Abstract- In deep groove ball bearings contamination of lubricant grease by solid particles is one of the main reason for early bearing failure. To deal with such problem, it is fundamental not only the use of reliable techniques concerning detection of solid contamination but also the investigation of the effects of certain contaminant characteristics on bearing performance. Nowadays the techniques such as vibration measurements are being increasingly used for on-time monitoring of machinery performance. The present work investigates the effect of lubricant contamination by solid particles on the dynamic behavior of rolling bearings, in order to determine the trends in the amounts of vibration affected by contamination in the Grease and by the bearing wear itself. Experimental tests are performed with Deep-groove ball bearings. The Dolomite powder in three concentration levels and different particle sizes was used to contaminate the grease. Vibration signals were analyzed in terms of Root Mean Square (RMS) values and also in terms of defect frequencies.

1. INTRODUCTION

Rolling element bearings are common components in rotating machinery. Bearings are in a central position in the monitoring of the condition of rotating machinery. Measurement is usually carried out at the points at which a shaft is supported with bearings and hence the vibration generated by the bearing is included in the vibration signal whether the signal is analyzed or not. The goal in the development of vibration measurement methods for rolling bearings has usually been to develop techniques for detection of bearing faults in their earliest stage.

The objective of this article is to investigate the effect of contamination of lubricant by solid particles on the dynamic behavior of rolling bearings. Dolomite Powder at three concentration levels and different particle sizes was used to contaminate the lubricant. Experimental tests have been performed on the ball bearings lubricated with grease, and the trends in the amount of vibration affected by the contamination of the grease were determined. The contaminant concentration as well as the particle size is varied. Vibration signatures were analyzed in terms of root mean square (RMS) values. From the results, some fruitful conclusions are made about the bearing performance. The effects of contaminant and the bearing vibration are studied for both good and defective bearings. The results show significant variation in the RMS velocity values on varying the contaminant concentration and particle size According to Juha Mittain [1] Bearings did not reach their calculated lifetime, fifty percent reasons for that are due to poor lubrication and contamination. The acoustic emission signal measured from a grease lubricated rolling bearing during its running indicates risks in the lubrication of the bearing. By reducing the level of the acoustic emission the risk of premature failure of the bearing can be reduced. Mr. According to N. Tandon [3], he states, each bearing has a characteristic rotational frequency. With a defect on a

particular bearing element, an increase in vibration energy at this element's rotational defect frequency may occur. These characteristic defect frequencies can be calculated from kinematics considerations, i.e. geometry of the bearing and its rotational speed. For normal speeds, the bearing characteristic defect frequencies lie in the low-frequency range and are usually less than 500 Hz. The review taken from, Trolex Sensors Application Data Issue B. 10/02, indicates, At high frequencies, failure of a machine may result from excessive forces which break down the lubrication allowing the surface of bearings to fail (due to metal-to-metal contact). These excessive forces are directly proportional to acceleration (Force = mass x acceleration)

2. PREPARATION OF SAMPLE AND EXPERIMENTATION

For the planned experimentation, the required Experimental Setup is available at SVERI's College of Engg. Pandharpur, under Mechanical Engineering Department. It has the following specifications

2.1 Bearing selection :

In this project work we have used 6206-2RS deep groove ball bearing. Geometry of bearing is shown in fig. and geometrical specification given in table. The RS indicates the "Rubber Seal".

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

Table -2.1- Geometrical properties (6206) of ball bearing

2.2 Sample preparation

In this study the samples of contaminated grease are used in bearing. The samples are prepared by varying weight percentage of contaminant of that weight of grease and sizes of contaminant. The quantity of grease taken is 5gm. The Dolomite Powder is taken in the sizes of 53µm, 75µm and 106 µm. Each size is added in the grease in different concentration levels as 5%, 15% and 25%. Every time a new bearing is taken for study. In this way total 9 sample bearings are taken for study. Grease which is initially in the bearing is removed with the help of kerosene and newly prepared contaminated grease sample is filled in it.

2.3 Frequency equations required

Table -2.2 Frequency Equations

Where,

n:-No. of balls, Fr:-Shaft Rotation Frequency, BD:-Ball Diameter, β -Contact angle, PD:-Pitch Diameter

Ball-pass frequency for the inner race	**Fi**	$\frac{n}{2} Fr[1 + (BD/PD) \cos \beta]$
Ball-rotational Frequency	**Fb**	$\frac{PD}{BD} Fr\left[1 - \left(\frac{BD}{PD}\right)^2 (\cos^2 \beta)\right]$
Ball-pass frequency for the outer race	**Fo**	$\frac{n}{2} Fr[1 - (BD/PD) \cos \beta]$
Fundamental train frequency	**Fc**	$\frac{1}{2} Fr\, [1 - (BD/PD)\ \cos \square]$

The calculated fault frequencies at various speeds are given in Table 2.3

Table 2.3 : Fault frequencies at various speeds

Sr. No.	**N**	**(Fr)**	**(Fi)**	**(Fo)**	**(Fb)**	**(Fc)**
1	1080	18	97.90	64.09	82.49	7.12
2	1820	30.33	164.96	108	139	18.329
3	2900	4.66	270	176.83	227.59	19.64

Where, Shaft Frequency (Fr), Inner-race Frequency (Fi), Outer-Race Frequency (Fo), Ball Rotational Frequency (Fb), Cage Frequency (Fc) in Hz and Speed in RPM (N).

2.4 Experimental Procedure

The amount of grease applied to the bearing for lubrication is 5 g (the grease quantity is based on ball bearing geometry calculation). 5 % of grease quantity, which is 0.25 g of Dolomite particles, is added as contaminant. Similarly, 15 % of grease quantity and 25 % of grease quantity (0.75 and 1.25 g, respectively) of Dolomite particles are added as contaminants.

The test is followed in a sequence of three steps. In the first step, the bearing is running in healthy grease in order to stabilize the grease temperature. In the second step, the test was continued in healthy grease to collect the vibration data at different speeds. In the third step, the contaminated grease was applied to the bearing. A separate bearing is used for each concentration level of the test. Vibration signals with contaminated grease are acquired from the bearing housing at different speeds. The above procedure is repeated for all concentration levels. Finally, vibration results of the defective bearings in healthy grease were compared to vibration results of the bearings in contaminated grease. Data were recorded and analyzed with respect to peak values and the root mean square (RMS) values.

3. RESULTS AND DISCUSSION :

Fig. 3 shows the signature values obtained from FFT analyzer for the bearing lubricated with clean grease and Fig. 4 shows the signature obtained from a bearing lubricated with contaminated grease. The contaminant added is Dolomite powder 53 µm size and 5% concentration. Both the bearings are running at 1800RPM. Such graphs are obtained for every sample. The acceleration values for particular defect frequency is collected for all the samples and by using those values different comparative graphs are drawn in Microsoft-excel. The explanation of those graphs is explained as below.

The conclusion from the graph-1 can be drawn as, for the lower speed the contaminant affects the inner-race more where as the Outer-race and Balls have nearly the same effect. For low speed for 53µm size, as the contaminant concentration is increased there is appreciable increase in the acceleration value at inner-race defect freq. This value of acceleration goes on decreasing for higher particle size and higher concentration levels. This may be happening because for lower size and for lower concentration the particles are accumulating at inner-race portion. Also the same pattern is observed for higher particle size, as the concentration increases there is increase in acceleration value at inner-race defect frequency.

For the peed 1820rpm, there is considerable increase in the acceleration values at 15% concentration for 53µm and 75µm particle size at outer-race and ball defect frequencies; but at the same speed for 106µm size as the concentration level goes on increasing, the acceleration values at all the defect frequencies goes on decreasing. When the speed was kept highest according to design, there is considerable decrease in acceleration values at inner-race defect. This is happening because, the higher size particles are not coming in contact of ball and inner-race. For 106 µm size at 15% concentration the highest acceleration values are attained at all the defect frequencies.

The conclusion from Graph-2 and Graph-3 can be drawn as, as the operating speed goes on increasing, the contaminants affect more on Outer-race, followed by Balls and Inner-race. For the speed 2900rpm, the acceleration values at all the defect frequencies show the considerable increment. For 53µm particle size, as the concentration is increased, there is an increment in outer-race acceleration values, and it shows the decreasing pattern in acceleration values at inner-race defect frequency. On the other side for 106µm size particle, as the concentration is increased, there is an increasing pattern in acceleration values at inner-race defect frequency.

The graph-3 shows the variation in RMS acceleration values according to speed for all the contaminant sizes and for all concentration levels. For all the samples the same pattern of curve is observed which shows that, as the speed goes on increasing the RMS acceleration value also goes on increasing. This increase in RMS value shows that the bearing is suffering from a severe damage at all the portions. At higher speed the bearing suffers the most because of the contaminants.

For the same bearing sample if the operating speed is changed, the acceleration value also goes on changing for every defect frequency. As the operating speed is increased, there a considerable decrease in acceleration value at Inner-race defect frequency is observed. This may be happening because at higher speed the particles are thrown in outward direction because of the centrifugal force and hence they are not coming in contact of inner-race. The exactly opposite phenomenon is observed in case of outer-race defect frequency, as the speed is increased, the acceleration value also went on increasing. The same pattern is observed in case of ball-defect frequency.

4. CONCLUSION

In the present work, ball bearings were tested in order to study the effect of solid contamination. The method of vibration analysis was effective in characterizing the trends in vibration due to solid contaminant in lubrication. The metal Dolomite was considered as solid contaminant. The results show, as the contaminant is added in the lubrication, even in small amount, there is a considerably increase in the vibration signatures of Ball bearings. As the parameters like speed and load are varied, the acceleration values also go on varying. As the particle size is increased, the corresponding acceleration values also go on increasing up to certain limit, then it stars getting decreased. This may happening because, the contaminants occupy the corners presend in the bearing by virtue of their weight, hence they doesn't come in contact with rotating elements. The same conclusion is valid for increasing contaminant concentration alongwith increase in contaminant size. At the speed of 1820RPm, with smaller particle size and varying concentration level, we get the desired results. At other points there is a mismatch in obtained and expected results.. This may be happening because, the particles may not come in direct contact with rotating elements

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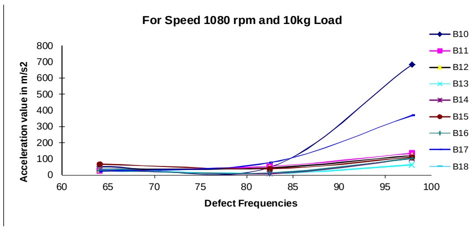
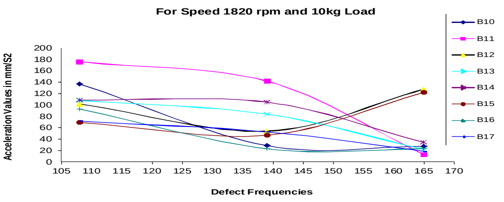
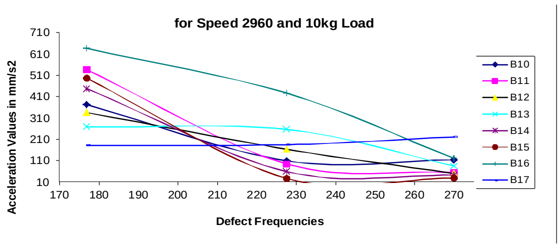


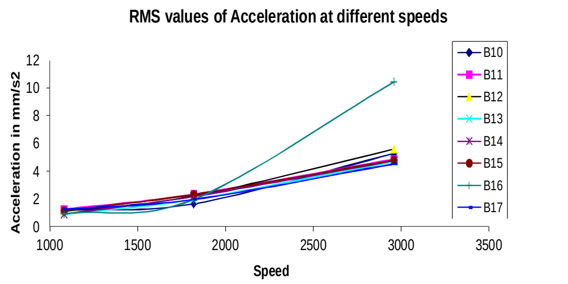
Graph- 1: Acceleration Values VS. Defect Frequency at speed 1080RPM -



Graph-2 : Acceleration Values VS. Defect Frequency at speed 18200RPM



Graph- 3: Acceleration Values VS. Defect Frequency at speed 2960RPM



Graph- 3: RMS Acceleration Values VS. Speed in RPM

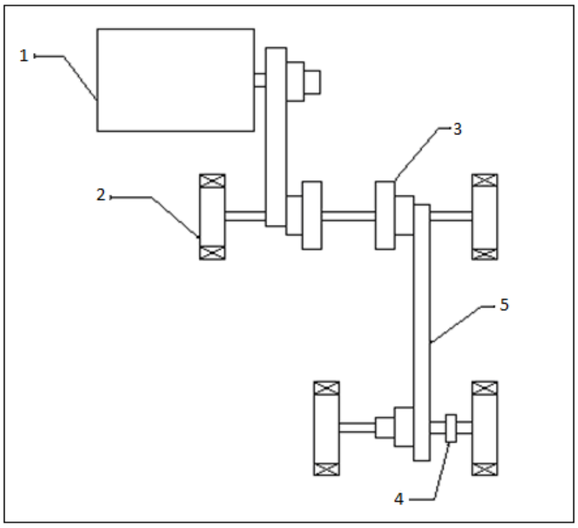


Figure1-Experimental setup
1:-Motor, 2:-Plamerblock, 3:-Cone pulley, 4:- Test bearing, 5:- Belt

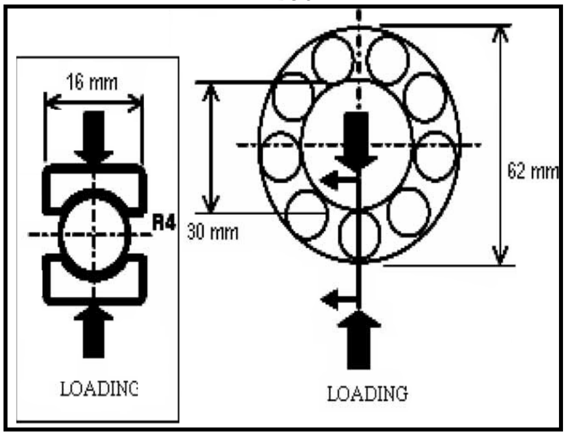


Figure 2- Bearing geometry

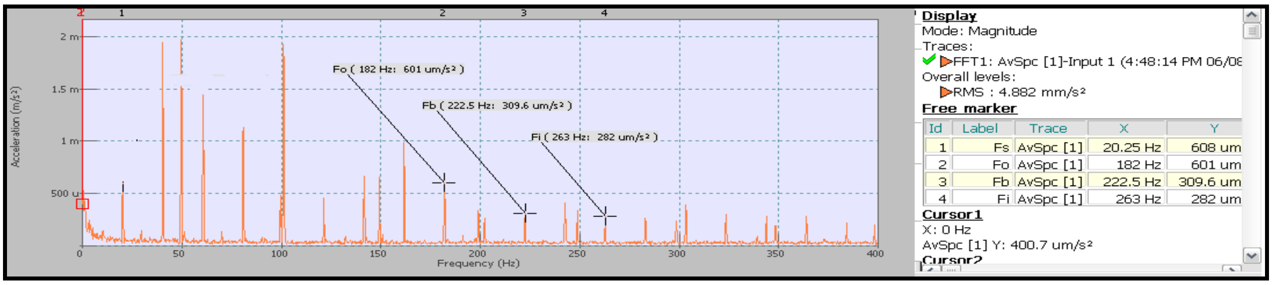


Figure 3. Signatures of Bearing Lubricated with Clean Grease

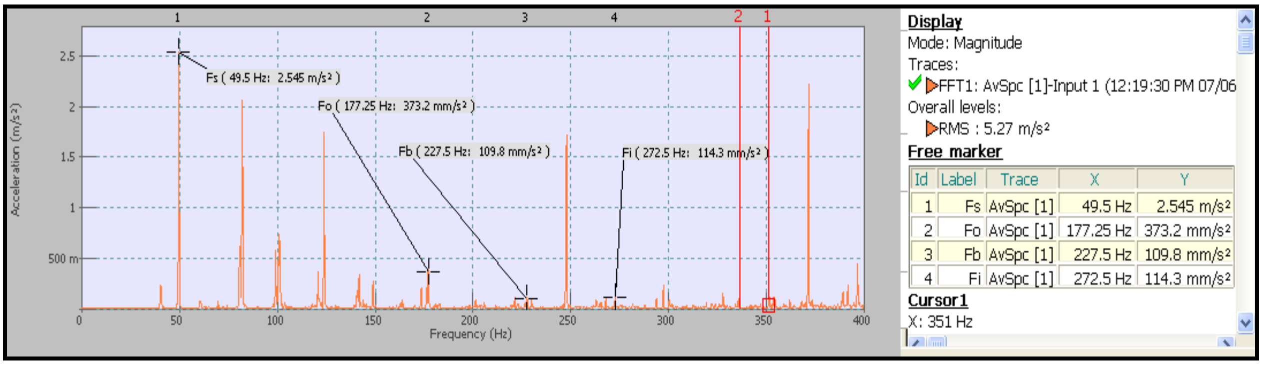


Figure 4. Signatures of Bearing Lubricated with Clean Grease