Analysis of Solid Contaminants in Grease Lubricated Deep Groove Ball Bearing through Vibration, Shock Pulse and Temperature Measurement

Vipin Kumar Satankar, Vilas Warudkar

Abstract*-- In rotating machinery, automobiles and aerospace, rolling element ball bearing are in common. For frictionless and continuous running bearing is lubricated with grease and oil, Grease are contaminated with various solid and liquid particles. This is one of the major reasons for bearing failures. When Ball bearing gets operated in contaminated conditions, particles of dirt may enter the bearing, the generated vibration and vibration level being dependent on the amount, the size and the composition of the entering contaminant particles. Some manufacturers state that in this case, no typical frequency pattern is generated, although an audible and disturbing noise may be created. Solid contamination is an important question related to the monitoring of rolling bearing performance because of its action on fatigue failure acceleration resulting from surface denting. In this respect, this project work deals with the effect of contamination of lubricant by solid particles on the dynamic behavior of rolling bearings. Generally different materials such as Silica, metal-burr, dolomite-powder, and iron-ore, all at three concentration levels and different particle sizes were used to contaminate the lubricant. Here metal-burr is used as a contaminant. Experimental tests have been performed on the 6207 deep groove ball bearings lubricated with grease, here we analyze and study the effect of solid contaminants in lubrication through vibration, shock pulse and temperature measurement. 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 for each test. Vibration signatures were analyzed with respect to root mean square (RMS) values of amplitude in terms of velocity, shock pulse in terms of pulse per seconds, temperature in terms of °C and what is the effect of contaminants on the performance of ball bearing, determined.

***Keywords:** 6207 deep groove ball bearings, solid contamination, greases, vibration, shock pulse and temperature.*

I. INTRODUCTION

Lubrication, lubrication is an important factor in rolling bearing which is essential for low friction, proper operation and long life of any machine element used in automobiles, aerospace like airplane, aircraft and ship etc. The bearing for works properly, it is required maintenance strategies. In bearing operation there are three maintenance strategies used- 1. Run to break, 2. Preventive maintenance, 3.Condition based maintenance. [1] For obtaining the greatest effectiveness of the bearing in the operation, condition-based maintenance (CBM) methods are being widely used. Detection of the probable faults when bearings are at early stages can prevent the failure and which results in extra cost. In Condition Monitoring (CM) the current condition and predicts the future condition of bearing while in operation. The most common and reliable techniques for obtaining information about internal conditions are vibration, debris, shock pulse and lubricant analyses. Other condition monitoring methods such as acoustic emission, temperature analyses and performance analyses are used in order to obtain the condition of ball bearing. [2,3]. Among all the methods of condition monitoring of ball bearing, vibration analyses is most widely used method due to various advantages as compared to others method. [4].

In application, it is found that 85 to 90 % bearing is lubricated with grease. [5]. Due to continuous running of ball bearing (surface contact), uneven environment, human error and all other factors, lubricant greases gets contaminated. Contaminants in grease strongly affect the performance, rated life time and behavior of ball bearing. These Contaminants may be solid or liquid or both solid and liquid. Solid contaminant like such as Silica, metal-burr, dolomite-powder, and iron-ore all at different concentration levels and different particle sizes (56µm, 75 µm, 106µm) were used to contaminate the lubricant, small particles produced noise and mechanical vibration. These vibrations affect the performance and reduced the rated life of ball bearing up to 22%. [6, 7, 8].

According to Timken industries 50% bearing is failed due to inadequate lubrication. The term inadequate lubrication may classify in eight categories- 1. Overfilling 2. Incorrect grease 3. Incorrect lubrication system and intervals 4.Mixing greases 5.Under filling 6.Debris contamination 7.Worn out greases 8.Water contamination.

In rolling element bearings, contamination of lubricant grease by solid particles is one of the several reasons for an early bearing failure. In this respect, this thesis work deals with the effect of contamination of lubricant by solid particles on the dynamic behavior of rolling bearings. Generally different materials such as Silica, metal-burr, dolomite-powder, and iron-ore, all at three concentration levels and different particle sizes were used to contaminate the lubricant. Here metal-burr (from grinding) is used as a contaminant. Experimental tests have been performed on the ball bearings lubricated with grease, and the trends in the amount of vibration affected by the contaminations of the

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grease were determined. The contaminant concentration as well as the particle size is varied for each test. Vibration signatures were analyzed with respect to root mean square (RMS) values of amplitude in terms of acceleration and also with respect to acceleration values at particular defect frequencies. From the results, some important conclusions are made about the bearing performance. The results show significant variation in the overall RMS acceleration value and also on acceleration value at every particular defect frequency on varying the contaminant material, particle size of the contaminant, contaminant concentration and running parameters like speed. [9]

II. THE EXPERIMENT

The experiment has been performed on the workshop setup, for this purpose some materials are required. With the help of SPM T30, take the reading of vibration, shock pulse and temperature of 6207 deep groove ball bearing. The list of required materials and instrument are given below-

MATERIALS-

a) Diesel.
b) Metal burr.
c) 6207 Deep groove ball bearing.
d) Lithium based grease and Calcium based grease.
e) Reflecting tape.

INSTRUMENTS-

a) SPM T30 machine.
b) Dial gauge.
c) Milligram weighing machine.
d) Speed mixer.
e) High air pressure nozzle.
f) Laser alignment.

III. METHODOLOGY

Rolling element bearings are common components in rotating machinery. Bearings are in a central position in the monitoring of the condition of rotating machinery and it is generally considered as essential component of any rotating machine. Due to high load and high running speed, ball bearing is used in machinery. In the present work, 6207 deep groove ball bearing is used for experiment. The load carrying capacity of deep groove ball bearing is depends on the size and no. of balls. If bearing is failed, this results in complete breakdown of machine. This failure may be occurred due to various reasons. Here we consider failure due to presence of solid contamination in greases. Solid contamination of metal-burr is considered. The Metal-burr material at three concentration levels and three different particle sizes are used to contaminate the lubricant and used for testing.

3.1 METAL-BURR SELECTION

For contamination of greases in ball bearing, metal-burr at different concentration level (5%, 10% and 15% by weight of grease) is used for experiment. Metal-burr form as a result of grinding of raised edge or small piece of material remaining attached to a work piece after a modification process is collected form industry.

3.2 GREASE SELECTION

- When temperature less than 100°C, grease is best and suitable for lubrication in various rotating machinery and bearing.
- Grease is suitable for low and moderate speed.
- When product of bore (mm) X speed (rpm) less than 2, 00,000, grease is suitable.
- In this project work bore (35 mm) X speed (1487 rpm) = 44610 less than 2, 00,000, thus grease is used as lubricant.

In the experiment, two different greases are selected. The greases are similar NLGI grade and easily available in market. Theses greases are

a) Lithium grease mineral based oil (LiX).
b) Calcium sulfonate complex grease (CaSX).

3.3 MIXING GREASES AND METAL-BURR

Metal-burr at different concentration level was mixed homogenously into the greases using a mixer. The mixer runs at 900 to 2000 rpm for 10 minutes, so that the greases mixed properly with Metal-burr. By mixing the greases with Metal-burr at different concentration level, n no. of sample has been prepared. Due to laborious, we are considering only 20 samples for our experimental work.

3.4 METHODS

The experimental work has been performed on 6207 deep groove ball bearing and the increment value in vibration, shock pulse and temperature is determined with the help of manual reading taken by SPM T30. Every experimental test followed by a sequence of three steps-

- In the first step, 6207 ball bearing is running in healthy grease 4 hours, so that stabilize the temperature of grease present in ball bearing.
- In the next step of test, the test is continued in healthy grease to collect the vibration, shock pulse and temperature data at constant speed of 1487 rpm.
- In the last step, the contaminated grease is applied on ball bearing and takes the reading of vibration, shock pulse and temperature.

The above procedure is repeated for each sample test and vibration, shock pulse and temperature data is recorded. With the help of collecting data, calculate performance and reach the result. Experimental setup which is used in this work is shown in below figure.

FIGURE 2.1 Experimental setup

3.5 SAMPLE PREPRATIONS

The test sample has been prepared for experiment. Metal-burr at different concentration level is used in greases

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for contamination. Total 20 samples has been prepared, 18 contaminated grease sample (M_1LC_1, M_1LC_2, M_1LC_3, M_2LC_1, M_2LC_2, M_2LC_3, M_3LC_1, M_3LC_2, M_3LC_3, M_1CaC_1, M_1CaC_2, M_1CaC_3, M_2CaC_1, M_2CaC_2, M_2CaC_3, M_3CaC_1, M_3CaC_2 and M_3CaC_3 respective sample number from 2 to 10 and sample number from 12 to 20) and 2 (sample number 1for L and 11 for Ca respectively) healthy grease sample.

- Grease weight is selected by empirical relation-

G = O.OO5 x D x B = 0.005 x 72 x 17 = 6.12 gm ≈ 6 gm.

- Solid contaminant particles (Metal-burr) are used for contaminating the greases. The three different percentage of Metal-burr (5%, 15%, 25% by the weight of grease) are used for contamination of lubrication with different particles sizes (53, 75,150 µm).

IV. RESULTS AND DISCUSSION

Vibration Results:-

From the experiment, the RMS value of vibration obtained through SPM T30 in term of velocity. The vibration value observed in 3 different directions (axial, vertical and horizontal) on each ball bearing.

- Due to presence of solid contamination in greases, effect on the vibration reading of bearings noticeable like liquid particles (max. 3.6 mm per sec), which is sufficient to affect the performance of ball bearing.

a) Lithium based contaminated bearing reduced the bearing life up to 34.8%.

b) Calcium based contaminated bearing reduced the bearing life up to 21.675%.

- As the contaminant concentration increases, there is appreciable increment in the vibration value (1.2 to 3.6 for lithium based grease sample and 1.1 to 3.2 for calcium based grease sample).
- As the contaminant is added in lubricant, even in small concentration, there considerably increase in the vibration, as the particle size is increased, the corresponding value of vibration increases up to certain limit, then it starts getting decreased. This may happening because, the contaminants occupy the corners presend in the bearing by virtue of their own weight because of the centrifugal force, hence they doesn't come in contact with the rotating elements. The same conclusion is valid for increasing the contaminants concentration along with in contaminant size.
- Lithium grease viscosity (50 mm2/sec) is lower than calcium grease (60 mm2/sec), but vibration reading is high as compared to calcium grease sample (lithium grease sample 3.6 mm/sec and calcium grease sample 3.2 mm/sec). Thus we can say that viscosity increases, vibration decreases.
- Viscosity also affect the bearing life (Lithium grease sample reduced performance up to 34.8% and calcium grease sample reduced performance up to 21.675%).

Shock Pulse Measurement Result:-

- With increasing the percentage of concentration level of contamination in greases, normalizing dBm values are increasing for ball bearing (dBm values increases from 22 to 42 dBn for lithium based grease and dBm values increases from 21 to 40 dBn for calcium based grease).
- For all test sample dBm and dBc values are decreasing with given time interval, this is due to homogeneity of contamination.

Temperature Measurement Result:-

- For the entire test sample initial temperature is 25 to 26 °C. When setup is running continuously without contamination lubricated bearing temperature is increases up to 27 to 40 °C in given time interval.
- When contamination is added to greases, temperature goes up to 53°C, it's clearly defined that contamination effect the bearing temperature and it increases.
- Temperature effect for different particle sizes is different for different concentration level of metal burr. It increases up to 48 to 53 °C (it is negligible).

V.CONCLUSION

Ball bearing was tested in order to study the vibration, shock pulse and temperature value caused by presence of solid contaminant like metal burr in the different greases. The vibration was analysed in term of its RMS value, shock pulse in term of pulse per second and temperature in term of °C. All the result shows a regular pattern in the reading. With increasing the contamination concentration level in greases, the value of vibration, shock pulse and temperature are increases. As the contaminant is added in lubricant, even in small concentration, there considerably increase in the vibration, as the particle size is increased, the corresponding value of vibration increases up to certain limit, then it starts getting decreased.

This work can be accelerated or reference for future work. Following things can be extended on this work-

a) By using the Condmaster®Pro software, draw the vibration graph in time domain and compare with liquid contaminated ball bearing graph (reading).

b) Other type of ball bearing can be tested on the workshop setup with different solid particles like Silica, dolomite-powder and iron-ore.

c) Other type of methods like debris wear, stator current can be applied.

d) Effect of temperature on ball bearing and induced thermal stress on ball bearing can be calculated.

e) Both, solid and liquid contamination of greases is considers and finds the result what is effect on performance of ball bearing.

f) Displacement and acceleration parameter of vibration may be considered for vibration analysis.

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