Effect of Particulate Grease Contaminants on Life Cycle of Foundry Working Ball Bearings: - A review

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Abstract:-

When we thought of bearings first thing come into mind of such a device used to reduce friction between rotating parts, while considering industrial machineries bearing proves its efficiency and effectiveness. Thus the efficient and proper functioning of bearings hugely depends on good health of bearing through condition monitoring. In this paper, an experimental setup was prepared. Firstly healthy bearing life is calculated by formulas and experimental investigation has been reported related to the vibration behaviour of healthy and contaminated ball bearing operating at cont. speed. The level of contamination is varied by weight and size of contaminant. Vibration signature are analysed in terms of acceleration values at particular defect frequencies and also in terms of overall RMS values. The result shows significant variation in RMS acceleration values on varying the level of concentration.

1. INTRODUCTION

In a dynamic bearing, defilement of oil/grease by solid particles is one among the few purposes behind early bearing damage, the impacts of grease sullying by strong particles on the conduct of rolling bearing. In this context, the present investigationanalyses impact of solid particles in lubricant on the dynamic behaviour of rolling element bearings. Silica powder in three concentration levels and different particle size are used as contaminant in the lubricant. The contaminant concentrations as well as the particle size are varied, vibration signatures are obtained in Root Mean square (RMS) values. The effects of contaminant and the bearing vibration are studied for good and defective bearings.

Bearing Life Definitions

- Bearing Failure: caused by Spalling or pitting of an area of 0.01 in^2
- Life: Number of revolutions or hours @ given speed required for failure usually calculated for one bearing
- Rating Life: Life required for 10% of sample to fail usually calculated for a group of bearings, also called Minimum Life or L10 Life
- Median Life: Average life required for 50% of sample to fail usually for many groups of bearings, also called Average Life or Average Median Lifetypically consider 4 or 5 times the L10 Life

Life of a Bearing

The life of an individual ball (or roller) bearing may be defined as the number of revolutions (or hours at some given constant speed) which the bearing runs before the first evidence of fatigue develops in the material of one of the rings or any of the rolling elements. The rating life of a group of apparently identical ball or roller bearings is defined as the number of revolutions (or hours at some given constant speed) that 90 per cent of a group of bearings will complete or exceed before the first evidence of fatigue develops (i.e. only 10 per cent of a group of bearings fail due to fatigue). The term minimum life is also used to denote the rating life. It has been found that the life which 50 per cent of a group of bearings will complete or exceed is approximately 5 times the life which 90 per cent of the bearings will complete or exceed. In other words, we may say that the average life of a bearing is 5 times the rating life (or minimum life). It may be noted that the longest life of a single bearing is seldom longer than the 4 times the average life and the maximum life of a single bearing is about 30 to 50 times the minimum life.

Vibration signal analysis on rolling element bearings

Rolling element bearings produce mechanical vibrations and noise as they rotate. When faults are present, these vibrations are increased as the motion of the rolling elements is more disturbed. These faults can be minor cracks or even spalls due to fatigue, denting, scuffing, scoring, wear, or any other kind of deformation of the contact surfaces. The spectra of the vibrations can contain [10]:

a. Bearing rotation defect frequencies (1–1000 Hz).

b. Natural frequencies of bearing components (0.1–20 kHz).

c. Random ultrasonic frequencies (20–50 kHz).

d. Frequencies due to material microstructure, stress and Rayleigh waves (above 50 kHz – acoustic emission).

Literature Survey

A literature survey is carried out in order to have a detailed know what is bearing, what are the types of lubrication, why lubrication is necessary, what can be effect of improper lubrication, what are the effect of contamination on grease

V Hariharan, and P S SSrinivasan[1] highlights the effect of contamination of lubricant by solid particles on the dynamic behavior of rolling bearings. Silica 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.Koulocheris, A. Stathis, Th. Costopoulos, G. Gyparakis[2] finds the contamination factor is based on a general characterization of the lubrication conditions but the impact of contaminant's variables such as size, hardness and concentration level is not determined in detail. In this work, greases contaminated alumina, Al_2O_3 particles of different sizes are tested aiming at finding a pattern in the relationship between particle sizes' and wear's progress. A laboratory rig is utilized for these tests and vibration analysis tools regarding bearings' condition and estimated residual life are being assessed. After the tests, optical inspections using a stereo- scope verify the vibration analyses results.Piet M. Lugt[3]the various hypotheses on the mechanisms of grease lubrication, all based on observations/measurements, indicate that there may be no unique mechanism. As an example, at low temperatures oxidation and evaporation will not give a significant contribution to "grease aging." At high temperatures oxidation will dominate. Some metals catalyse oxidation (brass cages!). This may be one explanation why there is no consensus on the mechanism. It is certain that initial filling plays a major role. Too much grease leads to excessive churning, high temperatures, and severe grease degradation. If the bearing is properly filled, two phases can be distinguished; i.e., a churning phase where excessive grease will be pushed to the shoulders of the bearing onto the seals/covers. O.L. Mahajan and A.A. Utpat[4] they find such 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 analysed in terms of Root Mean Square (RMS) values and also in terms of defect frequencies. M.M. Maru, R.S. Castillo, L.R. Padovese[5] In rolling bearings, contamination of lubricant oil by solid particles is one of the main reasons for early bearing failure. In order to deal with this 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. The method of vibration analysis (RMS of high frequency band from 600 to 10,000Hz) was effective in characterizing the trends in vibration due to oil contamination and due to the consequent bearing wear. The effect of contaminant concentration on vibration was distinct from that of the particle size. The vibration level increased with 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. Particle settling effect was the probable factor for vibration level decrease.D. Koulocheris, A. Stathis, Th. Costopoulos D. Tsantiotis[6]shows that there is a linear relationship between the abrasive wear resistance W-1 and hardness H, depending on abrasive particle size d, for non-heat treated steels. The relationship between wear coefficient k and abrasive particle size d is a parabolic. The wear resistance W-1 is inversely proportional with the square root of particle size d, for non-heat treated steels as seen in equation. The relationships for the heat-treated steels between the abrasive wear resistance and hardness H, show positive intercepts on the ordinate, depending on abrasive particle size d.C. Bishop [08] found Artificial Neural network (ANN) is composed of nodes arranged in input, hidden and output layers, with all the nodes in each layer having weighted inter-connections with all the nodes in the succeeding layer. Nodes in the hidden and output layers consist of artificial processing units called neurons. After training, neural network can recognize various conditions or states of a complex system. The number of nodes in the input layer is equal to the number of input features. Feed-forward neural network with back propagation training algorithms are used in the study. In the context of classification problems, networks with two layers of weights and sigmoid activation function for neurons in the hidden layer can approximate any decision boundary to arbitrary accuracy. Hence, architecture with single hidden layer is selected. The number of neurons in the hidden layer is decided using a trial and error method. Starting from two, the number of neurons is increased by one in each trial until the required accuracy is achieved with quick convergence. Since there are four classes to discriminate, four neurons are used in the output layer, where each output represents a condition of the bearingAkturk[9] presented a mathematical model consisting of innerrace & outerrace and ball waviness. The effect of number of waves on the amplitude of vibration and the frequency was studied and concluded that for outer race waviness, most severe vibrations occur when the ball passage frequency (BPF) and its harmonics coincide with the natural frequency.

Findings on literature survey;

a) The expected bearing life is mostly affected by lubrication contamination.

b) The papers shows the work investigates the effect of lubricant contamination by solid particles on the dynamic behavior of ball bearings, in order to determine the trends in the amounts of vibration affected by contamination in the Grease and by the bearing wear itself. Vibration signals were analyzed in terms of Root Mean Square (RMS) values and also in terms of defect frequencies.

c) We can use different particles as contamination in lubricant such as sand particles, dolomite powder, cement dust etc.

d) For calculating the expected life we can use vibration measurement method.

Causes of bearing failure:

Following are the major factors for cause of bearing failure,

1. Dirt
2. Corrosion containments
3. Insufficient lubrication
4. Overloading
5. Misalignment
6. Misassemble

Figure gives below gives classification and distribution of the reasons for which rolling element bearings did not reach their calculated lifetime. Fifty per cent consists of lubrication problems: poor lubrication and contamination

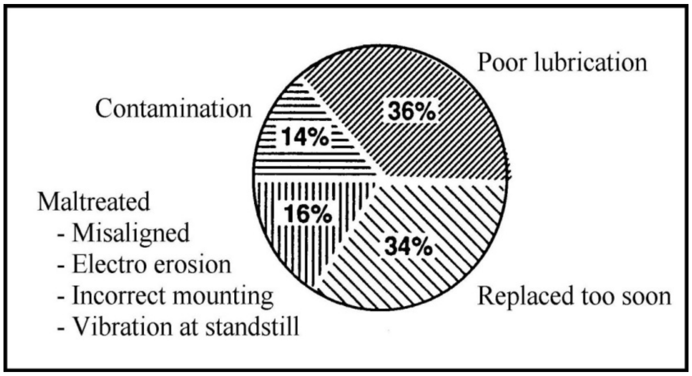

Figure 1.Share causes of bearing failure

Contaminant selection

Silica contaminant particles are used for deliberately contaminating the lubricant of the bearings. The required contaminants of different size ranges were obtained using standard sieves and alpine air classifier. The different contaminant levels were obtained using Electronic balance. The separation of particles size and contaminant level preparation was carried out for the silica particles for the selected particles size ranges and contaminant levels. Most of the researchers are used, Metal-Burr, Dolomite Iron-Ore etc. The silica sand contaminant have the different physical properties, i.e. hardness, brittleness and malleability.

a) **Silica:** This material is also taken from foundry industry. According to information collected, many times the particles of these materials are observed in Lubrication-Failed bearings. Hence this material is selected for study.

b) **Metal Burr**: It is the material collected from the grinder-waste which is used to grind the tools which are used for machining. Hence this material has the high hardness. The bearing selected is also used in grinder and other machine tools.

c) **Dolomite**: This material is taken from a metal-extracting industry. Dolomite is an Aluminium-Ore. According to the information collected, in the metal extracting industries there is a regular problem of bearing failure because of lubrication-contamination. The material is generally considered as brittle in nature.

d) **Iron Ore**: This material is also taken from same industry where in they carry outthe Iron-Extracting along with above stated materials. According to information collected, many times the particles of these materials are observed in Lubrication-Failed bearings.

The initial shapes of steel particles can be described as a mixture of distorted smooth avoids and chunks but these shapes are changed during the experiments into more plated pellets. On the other hand, corundum particles have a typical crystal shape as chunks with sharp edges and even when they are smashed down during the experiments, they continue to have sharp edges. The following data, adapted from [7], concern the shapes and possible origins of the particles:

Particle shape	Typical names	Some possible origins
	Spheres	Metal fatigue
	Distorted smooth ovoids	Quarry dusty; atmospheric dust
	Chunks and slabs	Metal fatigue; bearing petting; rock debris
	Platelets and flakes	Running-in metal wear; paint; copper in grease
	Curls, spirals, and slivers	Machining debris produced at high temperature
	Rolls	Probably similar to platelets but in a rolled form
	Strands and fibres	Polymers, cotton, and wood fibres; occasionally metal

Figure 2. Contaminant selection

CONCLUSION

Vibration analysis is playing an increasingly important role as a tool for assisting predictive and preventive maintenance. When monitoring rolling element bearings, both vibration analyses in the time domain and in the frequency domain can give useful results. The vibration analysis in time domain can indicate if there is an abnormal operation of a bearing and show the trend of the amplitude increase. In the frequency domain, vibration analysis can indicate whether the increased vibrations are caused from a certain bearing defect or from external sources. The increase of the vibration energy on the characteristic frequencies of the bearing can also indicate the progress of that specific fault. In the case of grease contaminated with solid particles, vibration analysis can indicate the severity of wear and monitor its progress. From the conducted tests it is concluded that the hardness of the contaminant particles and their size affect strongly the wear process.
A neural network approach for automated fault diagnosis of rolling element bearing from vibration data has been introduced in this paper. The time domain parameters; normal negative log like li hood value and kurtosis value, are used as input features.

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