Bearing Vibration Analysis for Optimum Performance by Condition Monitoring Techniques

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Abstract— Rapid modernization and the increasing need for high yielding productivity have led to finer development and use of hi-tech and complex machines and equipment's. Therefore, high-cost capital is involved in the production shop floor and the occurrence of incipient and frequent failures may result in production downtime and huge losses for the enterprise. So, controlled and appropriate maintenance activities are required which will minimize the occurrence of such failures and increase the reliability of the factory assets through effective plant maintenance practices. Condition based maintenance (CBM) or Predictive maintenance (Pd) can be best described as maintenance practiced when need arises (Morales, 2002). This is done by monitoring the condition of the machine (or equipment) continuously or periodically depending upon the need for the availability of the machine. The maintenance is initiated when indicators show the sign of faults in the incipient stages. In simple words, the main criterion is to maintain the right equipment at the right time. The practice of CBM is done by acquiring and analyzing the real time data, so that maintenance activities and resources can be prioritized/ optimized accordingly.

Indexed Terms- CBM, Bearing Vibration, Predictive maintenance

I. INTRODUCTION

Vibration monitoring has now become a well-accepted part of many planned maintenance regimes and relies on the well-known characteristic vibration signatures which rolling bearings exhibit as the rolling surfaces degrade. However, in most situations bearing vibration cannot be measured directly and so the bearing vibration signature is modified by the machine structure and this situation is further complicated by vibration from other equipment on the machine i.e. electric motors, gears, belts, hydraulics, etc. and from structural resonances. This often makes the interpretation of vibration data difficult other than by a trained specialist and can in some situations lead to a misdiagnosis resulting in unnecessary machine downtime and costs.

All rotating machines produce vibrations that are a function of the machine dynamics, such as the alignment and balance of the rotating parts. Measuring the amplitude of vibration at certain frequencies can provide valuable information about the accuracy of shaft alignment and balance, the condition of bearings or gears, and the effect on the machine due to resonance from the housings, piping and other structures. Vibration measurement is an effective, non-intrusive method to monitor machine condition during start-ups, shutdowns and normal operation. Vibration analysis is used primarily on rotating equipment such as steam and gas turbines, pumps, motors, compressors, paper machines, rolling mills, machine tools and gearboxes. Recent advances in technology allow a limited analysis of reciprocating equipment such as large diesel engines and reciprocating compressors. These machines also need other techniques to fully monitor their operation

A. Bearing

The bearing sector is one of the examples in which customer expectations in terms of Quality & Cost are boosted across world. This project addresses analysis of failures related to ball bearing. Detail analysis using rotor system with ball bearings Methodology is done to find out the possible causes and finally root cause. Bearing is a mechanical element which locates two machine parts relative to each other & permits relative motion between them, with minimum friction.

Fig 1 Bearing

B. Theory of Vibrations

Vibrations in the context of condition monitoring is defined as "a periodic motion or one that repeats itself after a certain interval of time" by Mobley R Keith in his book 'Vibration Fundamentals' (Mobley, Vibration Fundamentals, 1999)

Following is the equation which is called as 'Harmonic motion', describes a relation between the Vibration displacement in a spectrum with amplitude, frequency and time.

X= X0 sin (ωt)

Where,

X = Vibration displacement (mm)

X0 = Maximum displacement or amplitude (mm)

ω = Circular frequency (radians per second)

t = Time (seconds)

The period of the vibration is the time interval, T. A spectrum or profile of a vibration is shown in the following figure, which shows the period, T, and the maximum displacement or amplitude, X0.

II. PROBLEM STATEMENT

Problem identification is the crucial starting point in any project, as it sets the stage for addressing the core challenges and opportunities that the project aims to tackle. This process involves a comprehensive examination of the current state of affairs, careful scrutiny of existing issues, and a keen understanding of stakeholder needs. It often requires engaging in thorough research, conducting surveys, and consulting with experts and relevant parties. By identifying and defining the problems and objectives with utmost clarity, a project can establish a robust foundation for goal-setting and solution development. This initial step not only guides the project's direction but also lays the groundwork for a structured and effective approach, ultimately leading to the successful resolution of the identified issues.

Sandvik produces different types of crushers. Most of the failures are caused due to bearing problems. This bearing failure causes loss of production and downtime. So in order to reduce this loss bearing failure vibration analysis is to be carried out and matlab program is to be developed for validation.

(a) (b) (c)

Fig 2 (a) Inner Race Crack (b) Spall on Ball (c) Outer Race Crack

III. MATHEMATICAL MODELLING

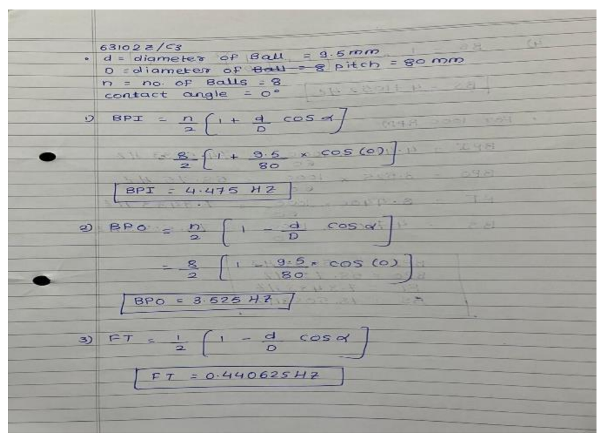

Fig 3 Mathematical equation Page 1

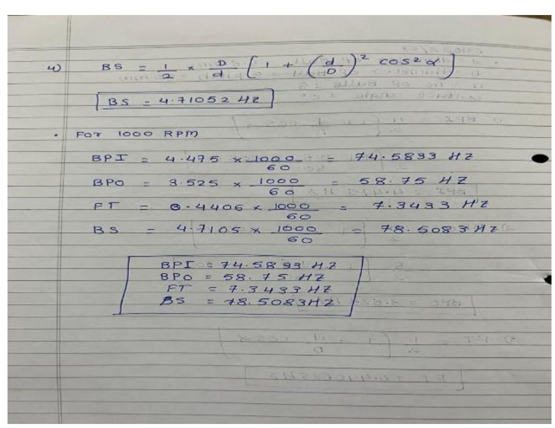

Fig 4 Mathematical equation Page 2

IV. CASE STUDIES

In order to come up with state of the art in vibrations analysis technique, it is necessary to do the ground work, evaluate the current trends and get abreast of latest tools, techniques and methodologies adopted both in research and market. Hence the case studies are taken up as a research tool in the present thesis for reviewing the current trends of vibration-based monitoring in industry. This part of the research can be termed as 'retrospection' of previous cases which are closely relevant with the thesis and can be included in the study. A look at qualitative and quantitative evidences of the historical records in same area of specialization will greatly help to organize a pathway for empirical research.

A. Key Case I

New Motor With Load- An electric motor is an electrical machine that converts electrical energy into mechanical energy.

- Motor Specifications:

Frequency (f): 50 Hz
Gross Weight: 284 kg
Input Voltage (Uin): 400 V
Output Power: 37 kW
Short Description:
37kW, 4P, Frame Size 225, 3PH, 400V, 50Hz, IP55, IMB3/IM1001

- Bearing Specifications:

SKF 6213-2Z/C3
Deep groove ball bearing with seals or shields

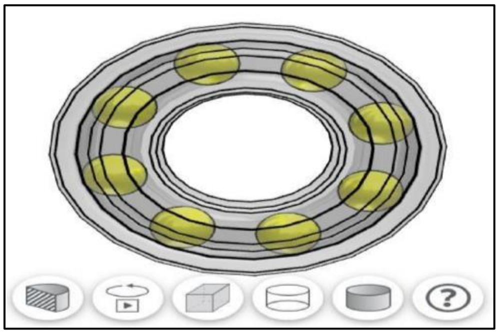

Fig 5 Bearing SKF 6213-2Z/C3

Fig 6 Experimental Setup of the Motor

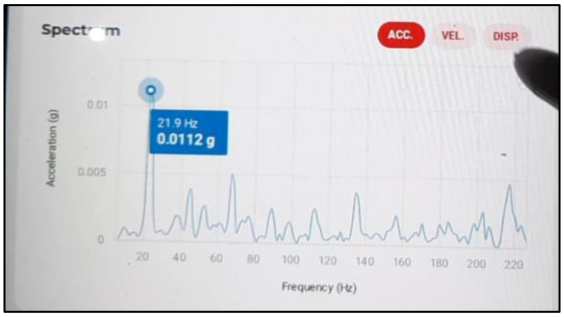

Fig 7 Effects on coupling (Frequency Vs Acceleration)

High 2x running speed peak is an indication of misalignment. The first peak is most likely a belt frequency due to a worn or loose drive belt. The second peak is the running speed of the machine (1 800 RPM). Note: 2X amplitude is not always present

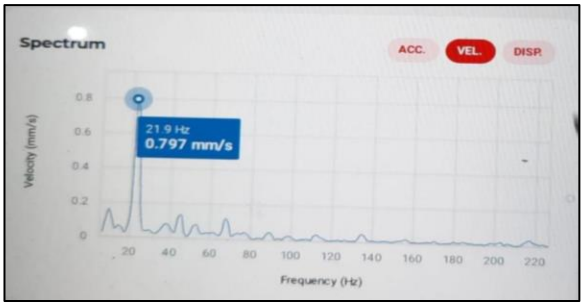

Fig 8 Effects on coupling (Frequency Vs Velocity)

Couplings with 2x amplitudes below 50% of 1x are usually acceptable and often operate for a long period of time. When the vibration amplitude at 2x is 50 to 150% of 1x, it is probable that coupling damage will occur. A machine exhibiting vibration at 2x running speed that is greater than 150% of the 1x indicates severe misalignment. The machine should be scheduled for repair as soon as possible.

B. Key Case 2

In Case II we have done the experiment on the new Motor with same Driven Bearing as in bearing used in previous case study.

- Motor Specifications:

Frequency (f): 50 Hz
Gross Weight: 284 kg
Input Voltage (Uin): 400 V
Number of Poles (High): 4
Output Power: 37 kW
Short Description:
37kW, 4P, Frame Size 225, 3PH, 400V, 50Hz, IP55, IMB3/IM1001

- Bearing Specifications:

SKF 6213-2Z/C3
Deep groove ball bearing with seals or shields

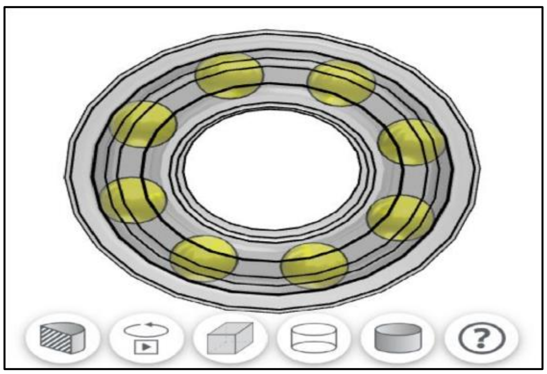

Fig 9 Bearing SKF 6213-2Z/C3

Fig 10 Experimental Setup of the Motor

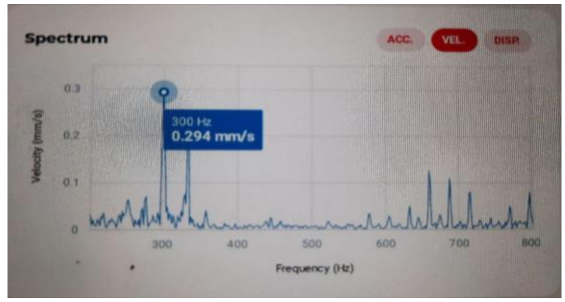

Fig 11 Amplitude of vibration

Couplings with 2x amplitudes below 50% of 1x are usually acceptable and often operate for a long period of time. When the vibration amplitude at 2x is 50 to 150% of 1x, it is probable that coupling damage will occur.

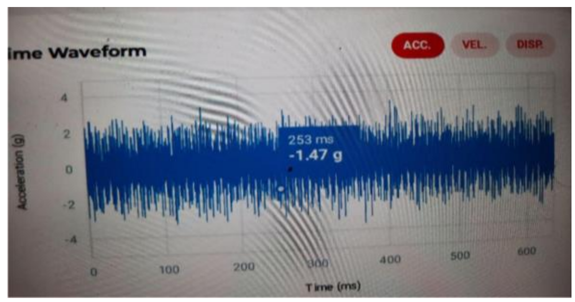

Fig 12 Effects on coupling (Frequency Vs Acceleration)

A study completed in this project by data collection shows that FFT transform is useful tool in finding out all possible root causes and predict root causes based on systematic study. Also bearing failure is the High Severity Field Concern causing failure of whole machine & affects the production rate as well as the Safety of the operator.

C. MATLAB Simulation

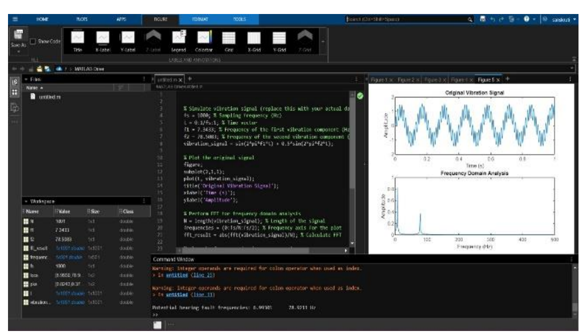

Fig 13 original vibration

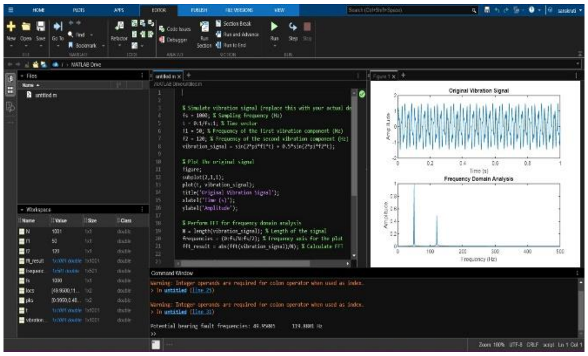

Fig 14 vibration and Frequency

CONCLUSION

In this work, different types of bearing fault are detected by 2 to 3 test cases, bearing failure vibration analysis also carried out. By using MATLAB application is to Developed to record fault, frequency, time and amplitude, the conclusions for different types of bearing are as follows.

A. SKF 6213-2Z/C3 -Deep groove ball bearing with seal

- A study completed in this project by data collection shows that FFT transform is useful tool in finding out all possible root causes and predict root causes based on systematic study. Also bearing failure is the High Severity Field Concern causing failure of whole machine & affects the production rate as well as the Safety of the operator.
- After Analyzing the experimental graphs, we can conclude that the above bearing is a Fully Healthy Bearing
- And some high peak Points in graph shows that there is some Misalignment in the Bearing and this is because of the reading were taken on the motor with heavy load.

B. SKF 22326 CCJA/W33VA405- Spherical roller bearing for vibratory applications

- A study completed in this project by data collection shows that FFT transform is useful tool in finding out all possible root causes and predict root causes based on systematic study. Also bearing failure is the High Severity Field Concern causing failure of whole machine & affects the production rate as well as the Safety of the operator.
- After analyzing the experimental graphs, we can conclude that the above bearing is a Fully Healthy Bearing.

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