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Fault Analysis of a Bearing

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Abstract

The performance of a bearing which is dynamic in nature is very crucial to the working of a machine. The presence of defects in a bearing results in reduced efficiency or in some cases severe damage to the machine which is under consideration. Rolling element bearing is an indispensable part of any machine which finds widespread domestic and industrial applications. Different methods are used for detection and diagnosis of the bearing defects. This research is intended as a tutorial overview of bearing fault detection using vibration analysis.

The advent of the microprocessor has enormously advanced the process of vibration data acquisition and analysis in recent years. Measurement that took hours only two decades ago can now be completed in minutes and better decisions made because of better data acquisition and presentation. However, the basic process of measurement and analysis have remained essentially unchanged, just like the machines from which vibrations is measured. The results of the measurement and data analysis need to be compared with known standards or guidelines and decisions made as to whether the machine is acceptable for service or maintenance should be planned. Increasingly these processes are being handled electronically but we are still a long way from replacing the fundamental knowledge and experience of the vibration analyst.

Vibration is not the only factor instrumental in fault detection. Noise and temperature can also play key role when it comes to fault detection in bearing. There are certain ranges of temperature and noise which can be measured through certain sensors and measured against set ranges, but vibration still remains a substantial part of detection. In the following research an embedded system is used for taking reading of vibration, temperature and noise as well.

Rotating machinery maintenance cost is a significant part of total expenses of industrial plants. Current needs to reduce such expenses has risen the importance of condition monitoring. Condition monitoring and diagnostics allow the maintenance that is based on the current condition instead of the maintenance based on statistically estimated lifetime. If prognostic estimation is also a part of the condition monitoring the maintenance task can be scheduled in advance to order the necessary parts, and to reduce the overall expenses.

In most of the places a system having MATLAB is used which prove to be costly and is indeed a

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complex software to understand. On top of all that the cost of standing such system is somewhat huge and thus these systems have their limited use in big industries. In the following article we will see an embedded system which is not only economical but is efficient as well. Just a housing for a bearing with a section for sensing element and you are good to go. Because of this approach the system can be used in college laboratories, small scale industries and many such places.

In this article we will review the basic principles regarding measurement and analysis of vibration, noise and temperature in order to lay the foundation for capable fault diagnosis to be considered in future.

Objective

- To detect fault in roller bearing.
- To compare healthy and faulty bearings.
- To show the effects of three parameters (Vibration, Temperature, Noise) in bearing.
- To display the reading digitally using an embedded system.

Literature Review

Parameters responsible for occurrence of fault in the bearing are given below:-

- Out of balance
- Misalignment
- Bent shaft
- Ball bearing damage
- **Temperature**
- Cage damage
- Mechanical looseness
- Mechanical rubbing
- **Noise**
- Cracking
- **Vibration**

Three parameters out of those mentioned are analysed:-

1. Noise
2. Temperature
3. Vibration

These parameters are responsible for occurrence of faults in the inner race, outer race, cage & ball of a bearing. Except preventive maintenance it is required to minimize the fault condition in a bearing in working state.

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Temperature Measurement

- **LM35 Temperature Sensor**

The LM35 series are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. Thus the LM35 has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from the LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to trimming and calibration at the wafer level. The low output impedance, linear output, and precise inherent calibration of the LM35 make interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 is rated to operate over a −55°C to +150°C temperature range, while the LM35C is rated for a −40°C to +110°C range (−10° with improved accuracy).

- **Standard Temperature Range**

The steel used in rolling bearings, both through hardened and case carburized steels, is processed to a minimum hardness of Rockwell C 60. According to the American Bearing Manufacturers Association (ABMA) the maximum operating temperature of through hardened steels, AISI 52100 is 160°C (320°F), 440-C is 180°C (356°F), and M50 is 320°C (600°F). In general for all steels, as the temperature exceeds 200°C (392°F) the hardness begins to decrease. Thus, the rolling bearing life decreases as temperatures rise beyond 200°C (392°F).

Noise Measurement

- **Why Is Noise Calculation Necessary?**

Part 7 of the Occupational Health and Safety Regulation requires that the noise exposure be reported for all workers exposed to sound levels in excess of **L_{EX} = 85dBA**. Often the measurements alone are insufficient to produce an accurate value for L_{EX}. The measured results may require to be combined with other data or it may be subjected to some corrections (e.g. for shift length or artefacts which may have intruded upon the measurement).

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- **Voltage To Decibel Conversion**

Value of noise level <= 60 dB, bearing is in safe condition

60 dB< Value of noise level =>90dB, bearing is in unsafe condition.

Formula Used: Noise level = 0.3320*voltage

[8 bit ADC= 256 V]

85/256

Vibration Measurement

- **Architecture Of Fault Detection System**

First step of vibrations measurement of the bearing is to collect the signals. The sensing element for collecting the signals will be accelerometer. The accelerometer gives a voltage reading that corresponds to the level of vibration. The analog signals given by the accelerometer are then collected by the Data Acquisition Card and transform them into digital signals so that it can read by an analysing interface. The analysing interface (computer software) is used to perform and use the analysis methods.

- **Voltage To Hertz Conversion**

Vibration Frequency range = 15 – 157 Hz, bearing works properly

Vibration Frequency range = 157 – 300 Hz, failure occurs.

Formula Used:

$$a = Kf^2 A \times 10^{-3}$$

where, $K = 2\pi^2 \doteqdot 19.74$

f : frequency (Hz)

A : total amplitude (mm)

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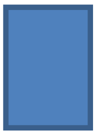
& a : vibration acc. (m/s^2)

a = [0 - 45 m/s^2] range

(For PCB – 320 series piezoelectric element)

Also, Frequency = 1.171875*voltage

[300 Hz = max. limit assumed]



300/256

Design and Fabrication

The major components used in our project are; a bearing (No. 6206), bearing housing, a flange, a PCB (having piezoelectric sensor and LM35 temperature sensor) and a lathe that is rotating our bearing with the help of flange and its housing.

Fig. 1: Flange

Fig. 2: Bearing Housing

Experimentation and Analysis

Experimentation

- Housing is mounted in the Drill Chuck which is hold by Tailstock.
- Chuck in the Headstock holds the Flange through.
- Centre alignment of Flange & Bearing is maintained.
- Piezoelectric element and temperature sensor are mounted on the housing.

When Lathe and PCB circuit is started, reading appears and noted

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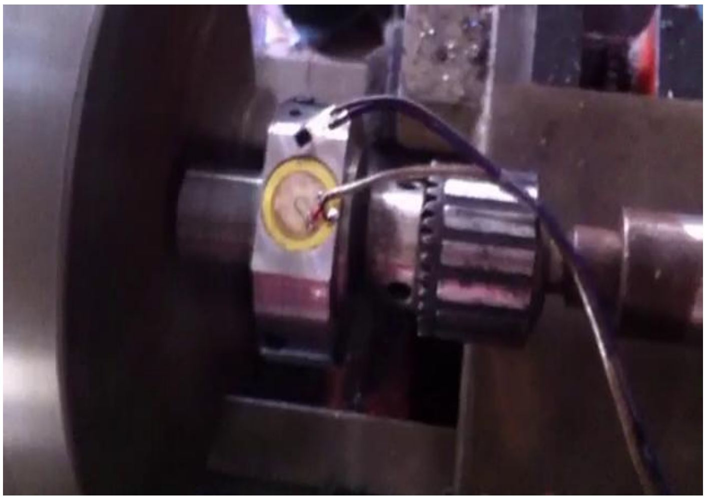

Fig. 3: Bearing mounted on Lathe

Fig. 4: Reading of Vibration & temp.

Fig. 5: Reading of Noise & temp.

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Analysis

- Experiment is performed on two bearings.
- Reading under the safe range of noise, frequency and temperature is a **healthy bearing.**
- If range of noise, frequency and temperature is unsafe to use then **bearing is faulty**.
- Comparison between healthy and faulty bearing is done.
- For temperature measurement 1-2 hour of continuous working of machine is required.

Results & Conclusions

Results

We find after testing that the bearing which show the reading of

- Noise = 30 – 50 dB normally
- Temperature = 70 – 110°C after 1 hour of continuous testing
- Frequency = 15 – 160 Hz normally

It is a **healthy bearing**.

On the other hand if

- Noise = 52 – 83 dB
- Temperature = 150°C+
- Frequency = 170 – 300 Hz

Then **bearing is faulty**.

Conclusions

a) Bearing faults can be detected and displayed digitally also. Use of MATLAB is not compulsory.

b) Fault detection by Embedded System is also helpful in preventive maintenance as this project using piezoelectric element for obtaining signal, check on machinery at particular time interval the vibration signature of machine is known and if there is deviation vibration signature from already available we come to know that machine need maintenance otherwise breakdown of machine take place.

c) In this work a method for fault detection of ball bearing was presented based on newly developed technique for obtaining signal with piezoelectric element. This work is also done with accelerometer but the cost of accelerometer is to high as compared to piezoelectric element and fault detection with piezoelectric is very much economical and useful for small scale industry.

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