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Investigation on performance of DC motor in exhaust application using vibration based condition monitoring

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ABSTRACT

In allusion to the issue of the preventive maintenance in industry 4.0 a proactive approach on maintenance such as predictive maintenance is gaining more and more scope. This paper provides a brief insight on the basic methodology for analysis of complex vibration signals taken from the machine of interest. In the past several years there have been several developments in the field of condition monitoring however reducing the complexity of the analysis has helped in achieving better results. This paper has proposed a novel and effective method to simplify the use of vibration-based condition monitoring analysis of a motor in a industrial segment. Also using the method of vibration based condition monitoring it was possible to establish the efficacy and efficiency of the given method in a industrial space.

1. Introduction

As we move to industry 4.0 the demand for automation in the industries have increased. The reliability safety, efficiency, productivity all depend upon the technologies which do not fail and can be predicted. Unplanned stoppages, can lead to decreased market adaptability of a company. Time based maintenance primarily focuses on a conservative method of preventive maintenance which happens in a fixed period of time. This system has been flanked by various disadvantages due to which there has been exploration into other kinds of maintenance techniques. One such maintenance techniques which has become popular is condition based monitoring system is popularly known as predictive maintenance [1-3]. The ability of this maintenance technique to predict the failure helps in reducing the mean time between the failures and its inclusive operational capability of social cyber physical systems has helped to increase the machine life and also helped in optimization of the operational cost considerably. In this paper an effort has been made to discuss about various [8] maintenance technique available, the methodology of how a condition based monitoring system can be implemented effectively is taken up with the example of a vibration analysis of a motor in a paint shop of an industry.

2. DIFFERENT METHODS OF CBM

A.MCSA (Motor current signature analysis)

MCSA is one of the most famous methodologies since it gives sensor less analysis of rotor and bearing problems. MCSA requires the estimation and control of extensive consistent state information and an exact estimation/gauge of the rotor speed for getting a dependable and high-goal evaluation. However MCSA isn't so powerful for applications where there is a rapid fluctuation of load or input. The earlier MCSA strategies expected to have stationary characteristics and high SNR for signal. The non-stationary characteristics of stator current are suited by the normally utilized windowing techniques. The profoundly transient and dynamic nature of the enlistment engine stator current during shortcoming conditions request examination through calculations and procedures fit to break down non stationary and non-restricted signals, for example, wavelet change or other time-recurrence strategies[5-9]. The accessibility of the advanced digitalized signal processing tools, for example, higher order spectrum analysis, high-resolution and precision analysis or subspace techniques and wavelet investigation have changed the signal handling for deficiency identification in electrical rotary engines. This advance technique of condition monitoring has been normally endeavored looking to (1-2s)f and (1+2s)f frequencies sidebands (LSB and USB individually, also the correlation of broken bars with respect to slip) for fault detection and fault gravity assessment.

However, some of the constraints of MCSA method is predominantly linked to fluctuation of speed linked directly to frequency; detection of broken bars and wrong placement of sensors which record input in machine.

There are a few limitations of the FFT, for instance it can't be utilized for non-intermittent or non-fixed signals. However, for rotary engines working under unsteady conditions, in consideration of variety in the turning speed and operating load, regardless of whether the machine is in the top of its health, the range of the vibration signal is continuously changing with respect to time. At the point, when this type of signal is fed into the frequency domain, some of the critical information about the transient component of the signal will be lost. This loss of information about transient components of a signal can reduce the credibility of vibration-based condition monitoring technique employed in a rotary engine. Hence several time-frequency analyses such as Short-Time Fourier Transform (STFT), Wavelet Analysis (WA), the Wigner-Ville

Distribution (WVD), Hilbert transform and Zhao–Atlas–Marks distribution which may be used for condition monitoring of rotating machinery in transient and unsteady operating conditions.

Other popular electrical methods that are predominantly used are flux monitoring, motor power monitoring, voltage spectrum analysis and Partial discharge (PD) monitoring.

B.Thermal Monitoring

"The concepts of temperature and thermal equilibrium associated with crystal solids are based on individual atoms in the system possessing vibration motion. The classical theory of thermal energy by atomic vibrations, though providing suitable explanations at elevated temperatures, has proved unsatisfactory at reduced or cryogenic temperatures. Quantum mechanics has subsequently provided theories based upon statistical probability that have provided possible mechanisms to explain some of the observed phenomena. A system of vibrating atoms in a crystal is highly complicated, and beyond the realm of any realizable theoretical method of analysis or calculations to verify spectral measurements from the total thermal energy of a crystalline substrate." Hence there is vast limitation for thermal based condition monitoring with regard to authentication of data.

C.Mechanical based vibration analysis

As very nearly 70 percent of basic rotating machines issues are identified with misalignment and unbalance, vibration examination is a significant apparatus that can be utilized to take out repeating issues. By and large, the general vibration level of the machine is adequate to analyse mechanical problems. Literature survey [3]shows that most of the bearing fault diagnoses are based on vibration analyses like wavelet transform and Hilbert–Huang transforms or current-based analysis. It is illustrated how eccentricity faults can be identified from vibration analysis using condition monitoring techniques

Bearing and eccentricity fault diagnoses can be effectively carried out with vibration analysis with the help of algorithms like wavelength transform ad Hilbert-huang transforms, the use of this is highlighted in the Literature survey .

Different components of vibration like RMS velocity can be determined using data extraction from spectrum of bandwidth BW, for a sampled frequency of fs which is sub set and function of frequency band f in frequency domain. Using this value of RMS, it can be used to examine various parameters of the machine.

Other techniques that are available in this segment are Noise and torque monitoring of the industrial equipment.

3. Condition monitoring architectural framework

The main reasons why more and more use of condition monitoring methods is happening in industries are primarily to reduce the breakdowns and to increase the productivity time of the machines and productivity of the industry as a whole. To achieve this high end optimization of maintenance tasks through condition monitoring, a constant monitoring of critical functions become necessary. The use of predictive maintenance helps in building a robust, reliable and healthy machinery system. Real time monitoring plays a vital role to determine the deviation in the functions of machines that would lead to production halts and delays. Condition monitoring architectural framework mainly consists on following segments

- ❖ Data acquisition (both online and offline)
- ❖ Data pre-processing
- ❖ Data cloud processing
- ❖ Data post processing
- ❖ Algorithm development

Data acquisition techniques

This is a primary steps where in the sensors are mounted on the machines which act as an acquisition centres. This in turn is controlled by a Central Processing Unit that would look after the data logging. Data acquisition can be continuous in nature or periodic in nature. The selection of the type is dependent upon the criticality of the machine. Once the type of data acquisition method is selected the selection of sensors plays an important role in the accuracy and reliability of data. Sensors are mainly of three types embedded sensors; specific external sensors and multipurpose sensors. Each of the sensors serves a purpose in their own way. The most commonly used sensors in the field of predictive maintenance are multipurpose external sensors these sensors can be applied on various equipment's and which are capable of measuring vibration, temperatures, impact forces etc. Embedded sensors as the name suggests are already implanted in the machine. However they do not add up for any extra cost.

Data pre-processing

Once the data is collected from the sensors it is critical that this data is reviewed before it is sent to a central Processing Unit this helps in reducing the confusion data latency and reduces unwanted information. In data pre-processing irrelevant and incomplete data is removed it also helps to check the health of the sensors, selection of data specific to the problem storage of data for a limited period of time and sending the correct and legible data to the cloud computation.

Data cloud computing

After pre-processing the data is fed into a data management system was the statistics of offline and online data are analysed. The cloud computing platform acts as both storage as well as an analysis platform. The storage platform also helps in development of new techniques in the field of condition monitoring.

Date post processing

The date of post processing consists of in-depth analysis of the vibration signal taken and also helps in taking decision by the intervention of human beings. Data driven techniques ANFIS, artificial neural networks, support vector machines, auto associative kernel regulations are gaining more and more popularity due to their versatility in application in reducing and improving the productivity of the Machines in industry.

Based on the above methodology this paper focuses on a load data acquisition system of offline method, the sensors which we are used where multipurpose external sensors or accelerometers. For further processing of data an IPC was used for data manipulation and data logger hardware was used for storing the data. In data post processing human interference was used to analyze the collected data.

Experimentation

In our experiment, 100HP motor of kirloskar make was considered. The main functionality of this motor was to act as exhaust system in a paint shop of a prominent automotive industry based in Bangalore. It was seen that this motor was the main cause of premature delays over the past couple of months. It was seen that preventive maintenance was becoming less and less effective. Hence a proactive approach of using predictive maintenance was taken into consideration.

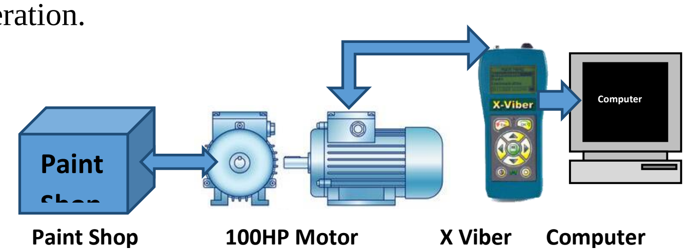


Fig1. Experimental setup to acquire vibration signal.

The first Step of predictive maintenance is selection of type of condition monitoring to be undertaken. By weighing advantages and disadvantages of different methods the decision was taken to carry out MCSA and vibration based condition monitoring. However in this paper only vibration based condition monitoring will be discussed.

For this purpose X-Viber was used as a measuring device. This device has a Resonance Frequency of 34000Hz, it uses a speed transducer which has a measuring range of 30 to 120000 RPM or 0.5 to 200Hz and a measuring distance is 0.5 to 1m. This device has a capability of measurement of route. It is also has the capability to measure and store 999 different data points and transfer the data back to extended software via USB. The trend analysis can be undertaken in the computer system as shown in Fig 1.

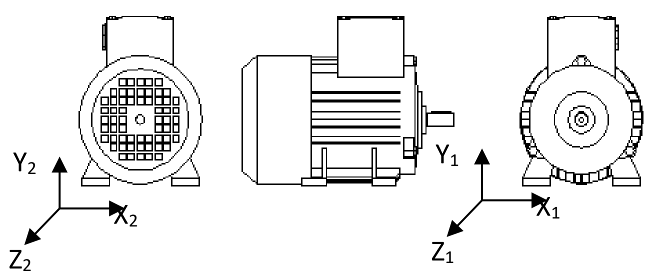
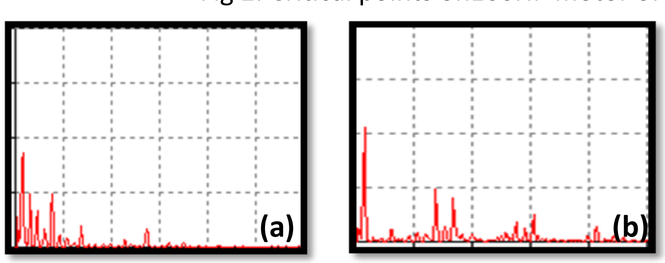


Fig 2. Critical points on100HP motor of kirloskar



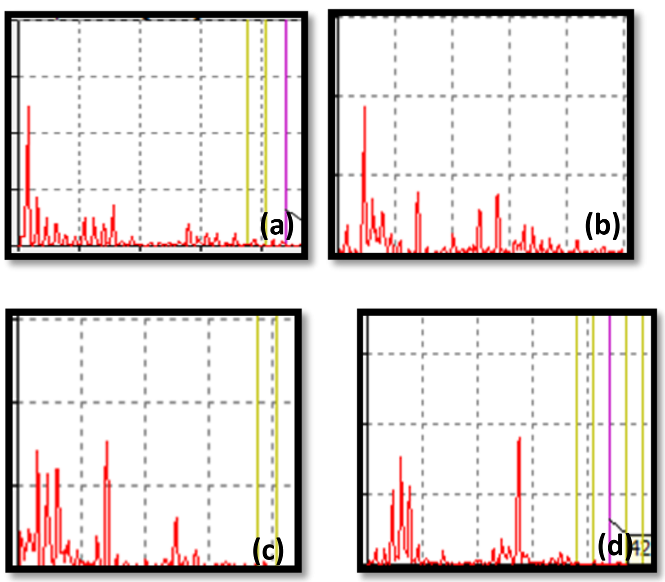


Fig 4. From left to right Vibration signature for healthy motor and its transition to 37% dynamic eccentricity with 30% more load. (a)0-5Days, (b)5-10 Days, (c) 10-15Days, (d) 15-20 Days.

After choosing the device X-Viber, the next process was identifying the critical points of the motor. The base of the motor was first inspected for any wear and tear. It was found that the base was in a very good condition and no vibration was caused due to it. Further the maintenance records of the motor were inspected for any abnormality in standard operating procedures. This was also found to be in good agreement. A total of six critical points were identified. Three of them at the back of the motor and three of them at the front of the motor as shown in Fig 2. The vibration readings were taken in X Y Z direction in both front end and back end of the motor. These vibration readings were taken on a day to day basis for a period of 150 days, during which every day the vibration data was analyzed for any abnormalities and day-to-day action was carried out to rectify the any abnormality is present. Care was taken that the reading was taken every day at the same time and with same accuracy and precision. From the analysis and averaging of various vibration signatures it was found that there was a presence of an eccentricity of 37% with normal load as shown in Fig 3. The magnitude of the peaks was found to increase with increase in loads. The vibration signatures of dynamic centricity were compared with principle slot harmonics or PSH. Once the fault of dynamic centricity was determined the corrective actions were carried out by the maintenance team. Post day to day a maintenance based on vibration signatures the delay time reduced considerably as shown in Fig 4.

4. Conclusion

It was seen that during the initial days the average delay time was 28 minutes and the maximum delay time was 70 minutes. After the implementation of the predictive maintenance in the system the delay time was reduced by 95%.This considerable reduction in the delay time will help in increasing the productivity, efficiency of the machines in an industry. Step by step maintenance plays a vital role in the successful implementation of the predictive maintenance technique. Also it was observed that choice of the measuring device and the placement of the sensors accurately and precisely every day in the same location also has a considerable impact on the overall results. The method of analysis of the data obtained for data post processing requires a systematic scientific approach to get credible results as shown in Fig 5.

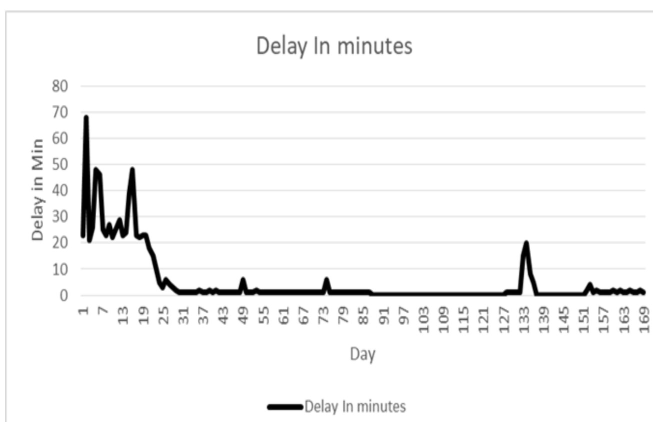


Fig 5. Delay time of the motor in 157 days

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