CONDITION MONITORING OF ROTARY EQUIPMENT: A PREDICTIVE MAINTENANCE TECHNIQUE

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Abstract - Mechanical equipment are far-flung in industries. Generally working in severe conditions, gradual deterioration of their state is common. Condition monitoring and vibration analysis has emerged as a powerful tool of predictive maintenance technique, detecting machine defects and developing flaws before the equipment fails, thereby nullifying equipment downtime. The mechanical failures account for more than 60% of breakdowns of the system. Therefore, the identification of impending mechanical fault is crucial to prevent the system from malfunction. Lifespan of equipment can be increased when faults are diagnosed as and when it occurs. Thus, periodic monitoring plays a crucial role in saving monetary and personnel capital.

Index Terms - Condition monitoring, Maintenance, Mechanical equipment, Vibration analysis.

I. INTRODUCTION

Maintenance Philosophies and the role of Vibration Analysis

Economically, the end factor that decides the success of a plant is the profit margin. Profit depends on the downtime of equipment, which in turn depends on the maintenance philosophy the plant adapted. Money saved in maintenance is directly proportional to the profit generated. The main goal of maintenance is to minimize scheduled and unscheduled downtime, improve safety and maximize the availability of production equipment.

The common maintenance philosophies followed by plants and industries are as follows

Corrective maintenance: This type of maintenance is also known as Break-down or On-failure maintenance. This type of maintenance is done after the failure of the equipment. Due to the nature of this philosophy, there is no warning of failure; there are uncontrolled production losses.

Preventive maintenance: This type of maintenance is called as time-based maintenance. In preventive maintenance, activity on the equipment is carried out based on a fixed time – calendar based, hours run based or number of equipment cycles based. This maintenance philosophy helps reduce failures, allows work, spare parts and labor to be planned. Despite its advantages, preventive maintenance is more costly and will cause frequent downtimes due to the nature of the maintenance, so it is only applicable to machines that undergo age related deterioration, otherwise it may lead to unnecessary replacement of part and components. Predictive Maintenance: Widely known as condition based maintenance, this maintenance philosophy is very advantageous to the plant as machine faults can be detected before failure occurs. This maintenance philosophy requires regular and frequent monitoring of the machine health condition. Practices such as vibration analysis, infrared thermography, ultrasound and various other forms of non-destructive testing can be used to detect deterioration of machine health and problems in the components before they fail and require the plant to be shut down. Usually critical plant equipment undergo this form of philosophy. It helps in reducing downtime, detecting root cause of the failure and managing resources such as labor and spare parts effectively.

WHY VIBRATION

Since the beginning of building machines, especially rotating machines, reduction and isolation of vibration has remained to be a key area of focus. Gradually as vibration reduction and isolation techniques have become more and more common, the need for accurate measurement of vibration has also become increasingly popular. Within the last 15-20 years, modern vibration measuring equipment have been developed for investigating high-load, high-speed machinery.

Vibration Characteristics

Amplitude – Helps in detecting the severity of the fault condition or defect.
Frequency – Helps in indicating the cause of the defect.
Phase – Helps in determining the cause of the defect.
Vibration amplitude can be measured in terms of displacement, velocity, acceleration. Displacement is measured peak to peak and usually in mils or microns. Velocity can be measured in peak or RMS and usually in inch/sec or mm/sec. Acceleration is expressed in peak and usually measured in G's. Phase indicates how a machine is moving to a reference of its part. The relationship of the movement of part of a machine to a **reference** – for example the position of both end of the shaft as it rotates.

This indicates the relationship of the movement between one or more points on a machine.

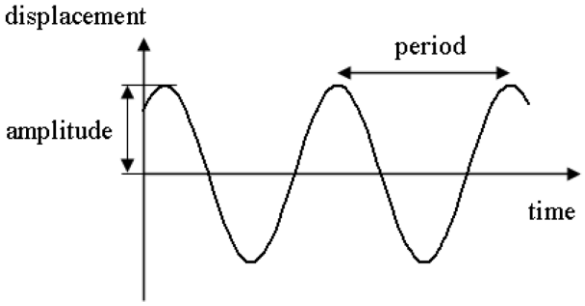


Fig. 1. Time waveform of a simple harmonic motion

II. HOW TO STUDY AND ANALYZE VIBRATION DATA

2.1. Quantifying the vibration level

The vibration amplitude, which describes the severity of the vibration, can be quantified in several ways. The Peak-to-Peak value indicates the maximum excursion of the wave, a useful quantity where, for example, the vibratory displacement of a machine part is critical for maximum stress or mechanical clearance considerations.

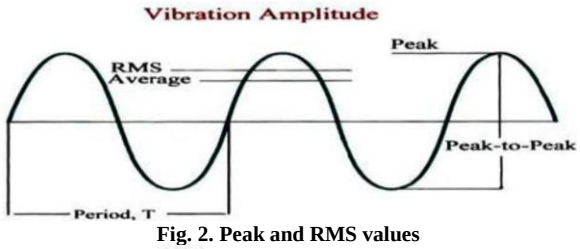


Fig. 2. Peak and RMS values

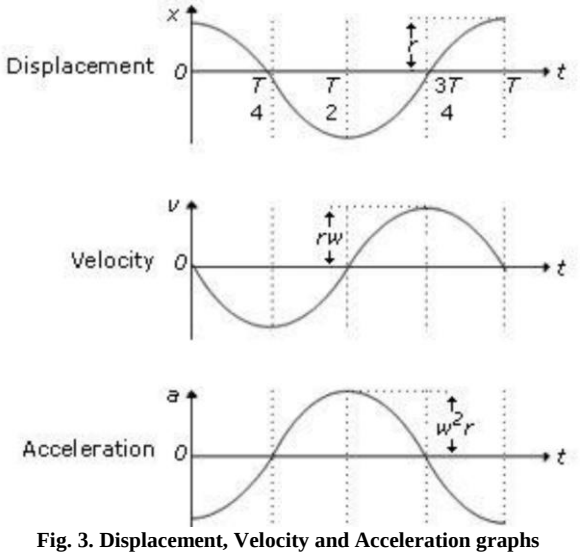


Fig. 3. Displacement, Velocity and Acceleration graphs

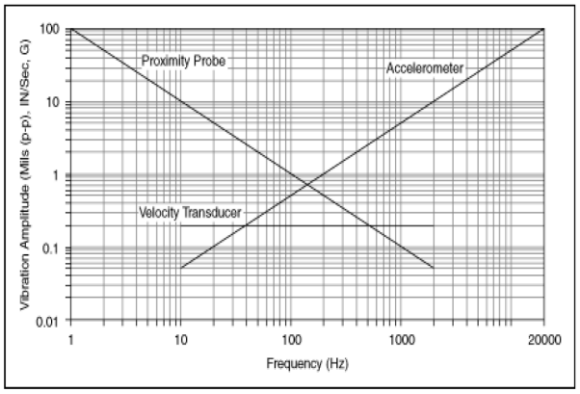


Fig. 4. Transducer effectiveness regions

2.2. What are F_{max}, Lines and Averages?

Guidelines for setting F_{max} (End Frequency)

- For machines with Rolling Element Bearings: F_{max} = 60 x RPM.
- For machines with Journal / Sleeve Bearings: F_{max} = 20 x RPM.

For machines with Gear Box: F_{max} = 200 x RPM

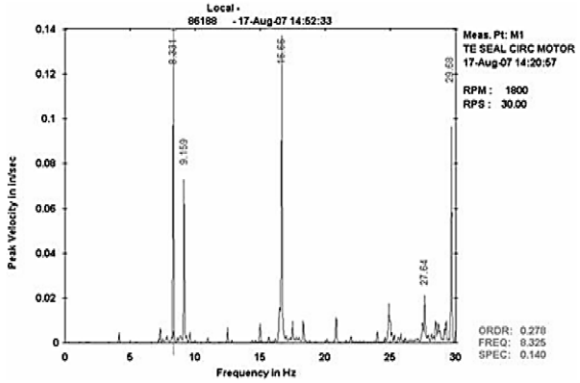


Fig. 5. Example of insufficient F_{max}

Guidelines for setting Number of Lines (Resolution)

- Number of lines determines the Machine spectrum resolution.
- Band width (BW) = F_{max} / No. of Lines.
- More the lines, less is the bandwidth & hence higher the resolution & better the accuracy.
- Typically, 400, 800 or 1600 lines are used, as more the lines more the resolution.
- Number of Signal Averaging
- Averaging is used to reduce random content in the vibration signal.
- Typically, 2-4 averages are used.
- Again, more the averages, more is the data collection time.

2.3 Time Waveform Analysis

Time waveform is the raw data generally acquired by the analyzer and also plays a vital role in the analysis process. The amplitude units and the acceleration peak to peak values will be the initial focus for the analyst. The amplitude reflects the severity of the vibration against time domain. This is also known as the machine

raw data, as it vibrates while running. The time waveform contains very important information. Although many analysts do not view the time wave form during data analysis, it should be noted that the waveform data is the source that is used to generate the spectral data and trend data that are commonly used for fault detection.

2.4 What is FFT?

FFT stands for "Fast Fourier Transform". It is possible to take a vibration time waveform, whether simple or complex, and mathematically calculate the vibration frequencies present along with their amplitudes with the help of FFT.

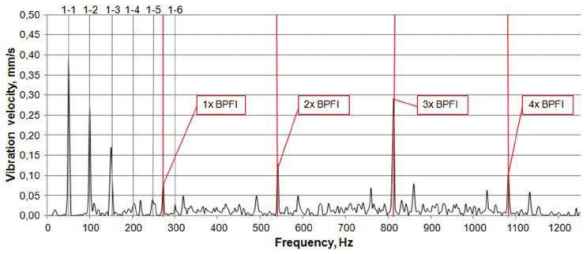


Fig. 7. Velocity Spectrum

Spectrum analysis is the procedure of doing the transformation, and is invariably done with the help of FFT analyzer. Signature term usually applied to the vibration frequency spectrum which is unique to a machine at a specific point in time, under specific machine operating conditions.

Normal Frequencies: Vibration peaks that appear in the spectrum as a normal condition of the function of the machine such as running speed, fan blade pass or pump vane pass etc.

Defect (fault) Frequencies: Calculated frequencies that appear in the spectrum only when there is a problem with the component such as a bearing defect frequency.

Fundamental Frequency: It is also called the first harmonic. Usually it's a pre-calculated frequency, such as turning speed of the machine or a frequency that is equal to a defect in the machine.

Dominant Peak: A peak in the spectrum with the highest amplitude value or a sharp maximum.

Harmonics: Spectral peaks that occur at integer (whole number) multiples of any frequency. It is possible to have a spectrum where the fundamental is not visible but the harmonics will be spaced apart by the fundamental frequency.
Sub-harmonic: Frequency that is integral sub-multiple of a fundamental frequency.

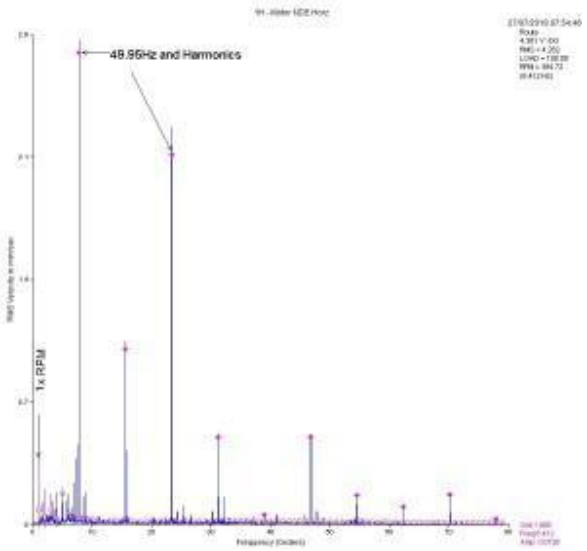


Fig. 8. Velocity Spectrum showing dominant peak [1]

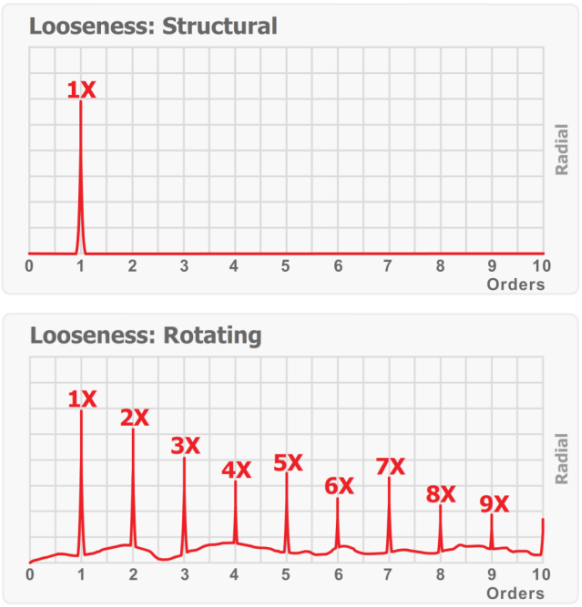


Fig. 9. Harmonic Peaks

III. METHODOLOGY

1. First, speed is measured using the tacho-probe. The required cable attachments are made to the CSI 2140, the tacho-probe is placed parallel to the disc on which reflective tape is put, at a distance such that it is not too close, but not too far, such that the beam of laser is no wider than a point.
2. After speed is determined, the accelerometer cable is attached to the probe and to the machine health analyser and then placed on suitable respective points on the model, usually on the bearing housings.
3. Adjustments are made to the model to align it properly, then above steps are repeated again.

CONCLUSION

From the project, it can be concluded that, adapting the philosophy of predictive maintenance can be beneficial to all industries and plants. Using predictive maintenance, we can increase the life spans of various machinery and avoid unwanted shutdowns and downtime. Predicting a failure before it occurs can help analyze the root cause of the occurrence of machine fault and can prevent the failure of the machine in question which might in turn cause damage to other machines in the system. Vibration analysis plays a major role in predictive maintenance and as can be inferred from the experiments, defects that are not visible to the naked eye and that seemingly do not show any physical symptoms can be detected by this method, and thus is very important in the topic of plant maintenance.

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