

# Condition Monitoring of Rotating Equipments by Vibration Analysis

Vivek M S<sup>1</sup>, Avinash Sugathan<sup>2</sup>, Jagan A G<sup>3</sup>, Sujith Chandran<sup>4</sup>, Abins Ali<sup>5</sup>

B. Tech students, Department of Mechanical Engineering, KMEA Engineering College Aluva, Kerala, India<sup>1,2,3,4</sup>

Assistant Professor, Department of Mechanical Engineering, KMEA Engineering College Aluva, Kerala, India<sup>5</sup>

**ABSTRACT:** The rotating machines that are being used in an industry may be consisting of faults like unbalances in rotor, bearings and jerks on the foundation etc. Identification of faults such as rotary unbalances, rotor bends, cracks, rubs, misalignment etc. may be made with vibration analysis techniques. Study on these aspects led to the development in predictive maintenance program which helps the maintenance engineer to schedule when the repair is to be done. This helps to reduce the damage to the machine from forced failure. Vibration analysis may be done by measuring the velocity, displacement and acceleration of the vibration produced during the rotation of machine elements. Thus, the variation in the vibration can be monitored and preparations for repair of the equipment can be done at exact time. In this project work we have conducted studies to find out the remedies for the problems that may arise due to vibration of rotating machines like centrifugal pumps, forced draft fans, rotary compressors, motors, etc. that are being used in the process industry. The project basically in its form tries to find out the vibration level of each machinery and then compare with the previous measurements base line reading or standard such as ISO 10816. It is also proposed to make case studies of some selected rotating machines as part of this project work. As part of the case study, vibration correction process of various equipment's has been made at FACT Udyogamandal, Ernakulam and obtained good results. This paper gives the brief idea of condition monitoring by vibrational analysis.

**KEYWORDS:** Condition Monitoring, Fault Detection, Maintenance, Vibration Analysis.

## I. INTRODUCTION

Most prime movers have vibration problems due to their inherent unbalance by various reasons. Any motion that repeats itself after an interval of time is called vibration or oscillation. The study of vibration deals with the study of oscillatory motion of bodies and forces associated with them. Vibration is a to and fro movement of machine or its components. Vibration is inversely related to the lifetime of the machine. The numerical description of vibration is amplitude and frequency. Amplitude describes severity of vibration. The overall vibration measurement is usually expressed in terms of 'rms', which is an indication of the energy of vibration. The 'rms' will be always lower than peak amplitude but the 'rms' does not give the idea on which component is failing. Frequency give the rate of vibration and its unit is cycle per second (CPS). There are mainly three factors that cause vibration; repeating forces, looseness and resonance. When defining vibration, the three characteristics which required are amplitude, frequency and phase. Measure of vibration velocity is a direct measure of vibration severity. The vibration measurement is to be made at different points and in different direction usually horizontal, vertical and axial. The most preferred location for vibration measurements of bearings are the places where the forces and loads are applied. It gives good idea about the imbalance of the rotating system. The rate with which the machine components oscillates is called the vibration frequency. The magnitude of vibration is expressed by its vibration amplitude. Vibration displacement is simply the total distance travelled by the vibrating part from one extreme limit of travel to the other extreme limits is travelled. Peak to peak vibration displacement is normally measured in units called mils. 1mils = 0.001 in.

## II. OBJECTIVES

To identify the reasons for the cause of a significant vibration increase, cause of excessive vibration of rotating equipment's, the sources of cracks in a shaft, exact location of vibration problem in equipment, the mechanical looseness, the unbalance, misalignment of components, the electrical problems, gear defects, bearing defects and the overall analysis of the rotating shaft and its co-relation with FEA analysis.

### III. CONDITION MONITORING & ANALYSIS

Condition monitoring is the activity of maintenance for monitoring the condition of the internals of any running equipment without disrupting the operation. The monitoring is done by collection of data of various parameters. Condition monitoring makes use of advanced technologies in order to determine equipment condition and potentially predict failure. This is an in-depth analysis of a machine condition often involving the joint application of a number of techniques. The objective is to confirm whether a fault exist and to carry out fault diagnosis type of fault, location and corrective action required etc.

### IV. VIBRATION MONITORING

All machines will have some vibration because of minor defects or result manufacturing tolerances. Therefore, all machines have tolerance of vibration, which may be regarded as normal or inherent, when machinery vibration increases or become excessive. Some mechanical trouble is usually the reason for the cause of unbalance of worn gears or bearings looseness, etc. Each mechanical defect generates vibration in its unique way. This makes it possible to identify a mechanical problem by simply measuring and noting its vibration characteristics. A good vibration analysis program makes it possible to detect an impending problem, analyse it's cause and take appropriate correction action before the failure occurs.

### V. MAINTENANCE SYSTEM

Techniques are designed to help determine the condition of in-service equipment in order to estimate when maintenance should be performed. This approach promises cost savings over routine or time-based preventive maintenance. The main promise of predictive maintenance is to allow convenient scheduling of corrective maintenance, and to prevent unexpected equipment failures. The key is 'the right info of equipment lifetime, increased plant safety'. Some of the main components that are necessary for implementing predictive maintenance are data collection and pre-processing, early fault detection, time to failure prediction, maintenance scheduling and resource optimization. For Predictive maintenance check plant equipment's are divided into three categories. Critical equipment's- these are the running equipment's having standby but whose failure will affect the production of the plant directly. For these equipment's Predictive maintenance is done once in 15 days. Semi-critical equipment's- these are having standby and are used in production line. Predictive maintenance check is done once in 30 days. Non critical equipment's- these are not in production line and are used as standby. They are checked once in 3 months. Preventive maintenance is the set of activities performed on equipment's periodically by improving the operational atmospheres, to prevent any possible failures. The activities performed are checking of all fasteners and bolts, checking of lube oil conditions, checking of other ancillary facilities like cooling water, seal cooling system, seal quenching system, operating parameters like suction pressures, temperature, discharge pressure, any abnormal noise, condition of seals or packing's etc. The abnormalities are corrected without disturbing the functioning of the plant.

### VI. SEVERITY OF DEFECTS

**Distributed defects:** Bearing play a pivotal role in rotating machinery. Failure analysis of the bearing is mostly studied by creation of artificial defect on various elements of the bearing and analysis is made with vibration signature tool for monitoring its condition. As localized bearing fault grows, becoming a distributed one, generate random signal with non-stationary components. In present paper effect of surface roughness on the vibration response of outer race of the ball bearing is analysed. Vibration spectrum produced by the single roughness defect under pure radial load at various locations on outer race of bearing is studied. Effect of roughness size, speed and load on the vibration response has been investigated. Results are presented in time and frequency domain. The experimental results are compared with ball pass frequency of outer race.

**Localized defect:** These defects include cracks, pits and spalls on rolling surfaces caused by fatigue. The common failure mechanism is the crack of the races or rolling elements, mainly caused when a crack due to fatigue originated below the metal surface and propagated towards the surface until a metal piece is detached causing a small defect or spall. This defect accelerates when the bearing is 13 overloaded or subjected to shock (impact) loads during their functioning and also increase with the rotational speed. Spalling can occur on the inner ring, outer ring, or rolling elements.

## Fault Diagnosis

Time Domain Technique is easiest and simplest technique to analyse the vibration signal waveform. Peak-to-peak amplitude is measure from the top of the positive peak to the bottom of the negative peak. Root mean square (RMS), measures the overall level of a discrete signal.

Frequency domain, or spectral analysis, is the most popular approach for the diagnosis of bearing faults. Frequency-domain techniques convert time-domain vibration signals into discrete frequency components using a Fast Fourier transform (FFT). Simply stated, FFT mathematically converts time-domain vibration signals trace into a series of discrete frequency components. The Fast Fourier Transform (FFT) is an algorithm for calculation of the Discrete Fourier Transform.

Time-frequency domain techniques have capability to handle both, stationary and non-stationary vibration signals. This is the main advantage over frequency domain techniques. Time– frequency analysis can show the signal frequency components, reveals their time variant features.

## VII. INSTRUMENTATION

Vibrometer (IRD 811): This is a compact, portable instrument used to measure vibration amplitude. It consists of a control and indicator input unit, signal cable and accelerometer. The bearing condition is measured in spike energy.

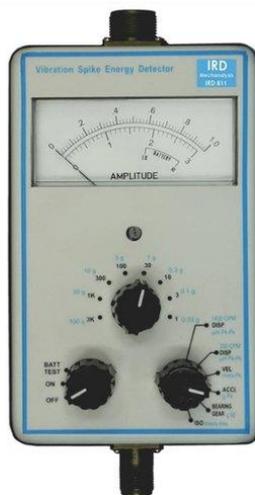


Fig 1. Vibrometer (IRD 811)

Vibration accelerometer: Newly developed tri-axial accelerometer developed specifically for route-based vibration data acquisition for industrial machinery condition monitoring is presented. The sensor incorporates a two pole (two feet) integral magnet such that it can be placed on a curved surface. When the newly-developed tri-axial sensor is mounted on the curved surface of a machine, the bandwidths of all three sensors are sufficient to capture the mechanical vibration and limited stress wave activity.

## VIII. METHODOLOGY

In this paper the following methodology for vibration analysis is being used are vibration analysis of rotating machines using vibration pick up instruments and analysis using graphical method. During the case study, the vibration pickup instrument were used for measuring vibrational data from boiler feed water pump. The required correction value for rotor balancing is determined using a single plane vector diagram. Different types of analysis are: mathematical model analysis and using computer software. e.g. - MATLAB.

**IX. RESULT ANALYSIS**

Several vibration severity guides are available for assessing the severity of machinery vibrations. The major standards are currently in use include the I.S.O, the V.D.I standards, and the B.S standards. The most widely used vibration severity criteria, which are common to ISO, VDI, BS are based on broadband vibration velocity levels between 10Hz and 1000Hz. The ISO 10816 vibration severity criteria for bearings of rotating machinery are presented in table below. In most cases root mean square value of the vibratory velocity of the machine is compared against the criteria set by the standards. The I.S.O 10816 standard provide guidance for evaluating vibrations severity in machines operating in 10 to 20 Hz frequency range. The axis of rotating shaft may be horizontal, vertical, or inclined at any angle. We can use following chart to judge the overall vibration severity of various equipment’s of different category.

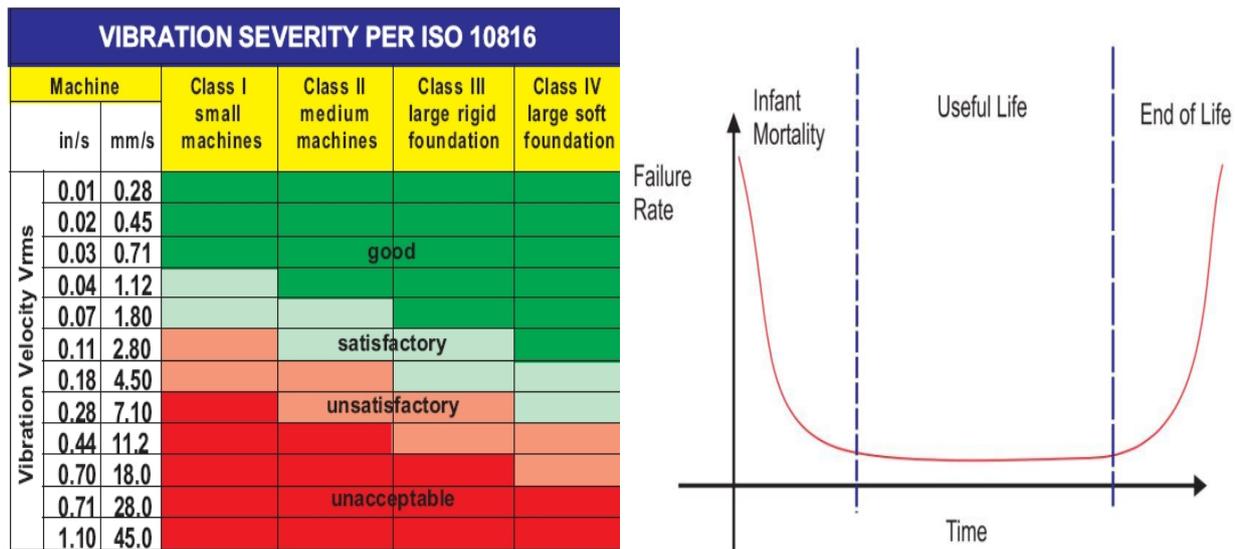


Fig 2. Vibration severity per ISO 10816 & Classical bath tub curve.

The life of a machine follows the classical bath tub curve. As per curve the vibration level decreases during the initial running in period, then increases very slowly during the normal operating period due to the normal wear, and finally increases rapidly due to the excessive wear until failure or break down of equipment occurs.

As a part of our case study in the industry we have carried out vibration analysis on Boiler Feed Water Pump-5 (Equipment no: P9310E) and obtained datas regarding vibration severity at different points using Vibrometer.

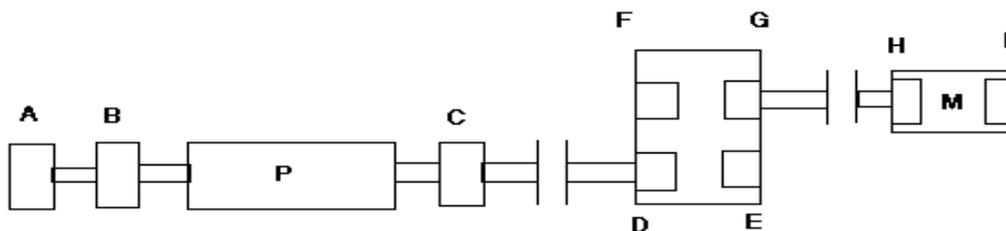


Fig 3. Layout of equipment.

A boiler feed water pump is a specific type of pump used to feed water in to a steam boiler. The water may be freshly supplied or returning condensate produced as result of the condensation of the steam produced by the boiler. These pumps are normally high-pressure units that take suction from a condensate return system and can be of the centrifugal pump type or positive displacement type. The BFP or boiler feed water pump is used in boiler feed water system to increase the water pressure high enough so it can be pumped in to the boiler drum. It helps maintain proper



working boiler providing continuous feed water supply is essential for steam boilers. The main components are casing, impeller, shaft, coupling, shaft sleeve, balance chamber, ware rings, mechanical seal.

**Specification**

Motor speed is 3000 rpm, pump speed is 3725 rpm, discharge is 75 m<sup>3</sup>/hr, head is 1425 m, mass flow rate is 14 kg/sec, output power is 60 mw and steam temperature are 160<sup>0</sup>c.

**Observation**

The vibration values i.e. horizontal, vertical, and axial readings are grater then the permissible values with respect to the baseline data and is an indication of bearing unbalance. Hence the unbalance should be checked and corrected in the next opportunity.As per the requirement of plant we, the inspection team analysed the above machine weather it is running or not. First of all, we studied the specification of machine with help of machine manufacturer's manual and also its historic data including the base line reading of the machine. And hence the coupling is replaced. The given below tables shows the vibration severity datas before and after coupling replacement.

Table 1. Condition Monitoring Report

POINT	POSITION	VELOCITY- PK/RMS mm/s	POINT	POSITION	VELOCITY- PK/RMS mm/s
A	H	12	A	H	6.8
	V	4.2		V	3
	A	3		A	2.4
B	H	11	B	H	6.6
	V	3.8		V	2.4
	A	5.2		A	1.8
C	H	15	C	H	7.4
	V	5.4		V	3.8
	A	4.4		A	2.8
D	H	3.4	D	H	2.4
	V	2.4		V	1.6
	A	3		A	3
E	H	3	E	H	2.2
	V	2		V	1.6
	A	2.8		A	2.8
F	H	3.4	F	H	2.6
	V	2.2		V	1.6
	A	2.8		A	3
G	H	2.8	G	H	2.4
	V	2.2		V	1.4
	A	3.2		A	3
H	H	3.2	H	H	2
	V	4.6		V	3.2
	A	5.6		A	3.4
I	H	4	I	H	2.4
	V	4		V	2.4
	A	7.2		A	3.2

**X. CONCLUSION**

Condition monitoring using vibration analysis will help to identify even the minute problems in the equipment there by helps to prevent the machine from failure and to increase the machine life. The various aspects of condition

monitoring, vibration analysis, predictive maintenance, sensors are reviewed and presented in this paper. The procedure for detection, diagnosis and prognosis is discussed. The frequently occurring problems in a rotating machinery is the bearing failure.

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