

# **Importance of Condition based Maintenance - An Overview**

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**ABSTRACT** : Vibration monitoring and analysis is increasingly being used as a tool for safe Operation of machinery and efficient maintenance planning. Vibration in a machine indicates the presence of some form of defect in the machine. As compared to other parameters such as temperature, oil contamination etc., vibration responds much quickly to any deterioration in the machine condition. Operating machines give rise to vibration and deterioration in the machine condition produces a corresponding increase of the vibration level. These vibrations are transferred to bearings housings. Thus the bearing housings become the ideal measurements points for vibration.

## **I. INTRODUCTION TO VIBRATION**

Vibration analysis consists in listening inside the machine. Each component vibrates differently and generates a characteristic noise that leaves a typical fingerprint in the spectrum in the form of a linear pattern. If damage is present, the pattern stands out from the noise floor. This allows the specialist to recognize, for example, whether the problem comes from unbalance, misalignment or bearing damage. In addition to an accurate diagnosis it is generally also possible to determine whether urgent action is necessary or whether it can wait until the next scheduled servicing.

### **Vibration analysis - The benefits**

The bottom line is that vibration analysis benefits both the operator and the maintenance technician:

- Enables the identification of machine faults
- Provides information on root causes
- Localizes the affected components
- Optimizes spare parts logistics
- Allows early planning of maintenance measures.

**Frequency Analysis** By sending a signal through a filter and at the same time sweeping the filter over the frequency range of interest it is possible to get a measure of signal level at different frequencies. The result is called frequency spectrum.

**Role of frequency analysis**The frequency spectrum gives in many cases a detailed information about signal sources which cannot be obtained from the time signal. This permits many kind of diagnosis to be made. The frequency content can be found in many different ways using scanning filter or as it is the case mostly today a digital treatment of a record using fourier transform.

### **Methods and signal forms in vibration analysis**

- **FFT analysis**: often used for detecting the most common machine faults, such as misalignment or unbalance.
- **Order analysis**: Variant of FFT analysis used for machines with variable RPM; instead of the frequency, the multiple of the rotational speed (order) is analyzed in the spectrum;
- **Envelope analysis**: used for diagnosis of damaged gear toothings and roller bearings.
- **Cepstrum**: facilitates the diagnosis of gear and bearing damage.
- **Time waveform**: suitable for analysis of the measured signal and for detecting beats and transients (random pulses).
- **Orbit**: used for analysis of shaft vibrations – especially in shafts with sleeve bearings.

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- **Phase measurement:** used together with the FFT analysis to differentiate machine faults, such as unbalance, misalignment or loose parts.
- **Resonance analyses:** for identification of natural frequencies and natural vibrations in a machine or structure. Methods include impact tests, recording of the run-up and coast-down curve and measurement of the shaft bending lines.

## II. LITERATURE SURVEY

Subimal Bikash Chaudhury<sup>1</sup>, Mainak Sengupta, Kaushik Mukherjee<sup>2</sup>) paper presents on “Vibration Monitoring of Rotating Machines Using MEMS Accelerometer”. This paper proposes the basic design for the development of a low cost MEMS accelerometer based vibration sensor by integrating the basic sensor and intelligence of vibration analysis, together. This module can easily be deployed for different rotating machines for vibration monitoring.

S Sendhil Kumar M Snethil Kumar<sup>2</sup>) paper presents on “Condition Monitoring of Rotating Machinery Through Vibration Analysis. This paper gives the brief idea of condition monitoring in a nutshell referring to vibration analysis .It gives a brief idea of condition monitoring with reference to vibration analysis.

Ms Prajakta M. Patil<sup>3</sup>) paper presents Condition monitoring of rotating shaft is done using vibration analysis and also crack detection analysis. Here in this project condition monitoring of rotating shaft is done using vibration analysis and also crack detection analysis, accelerometers used along with a device called as Fast Fourier Transform (F.F.T.) Analyzer.

P.Venkata Vara Prasad, V.Ranjith Kumar<sup>4</sup>) paper presents on “DETECTION OF BEARING FAULT USING VIBRATION ANALYSIS AND CONTROLLING THE VIBRATIONS”. In this study, vibration response of the rolling bearings to the defects on outer race, inner race and the rolling elements is obtained and analyzed. The results reveal that vibration based monitoring method is successful in detecting the faults in the bearing.

Kundan Kumar, Prof.K.H.Munde<sup>5</sup>) paper presents on “CONDITION MONITORING VIBRATION ANALYSIS OF DEFAULT SHAFT”. In this paper shows the behavior of shaft under normal & defects condition & its effects on its performance is shown. In order to run the machines efficiently condition monitoring of machines is important. Vibrations are found almost everywhere in rotating shaft.

## III. MAXIMIZING THE P-F INTERVAL THROUGH CONDITION-BASED MAINTENANCE

By extending the P-F Interval, Condition-Based Maintenance (CBM) methods provide the earliest possible prediction of equipment failure, with maximum benefit: minimum production loss, reduced maintenance labour and materials costs, extended equipment life, and reduced capital expenditures.

As a maintenance professional, unless you have been sleeping under a rock these last ten or so years, you will have at least heard of the “P-F Curve”, even if you don’t understand it, or use it to your advantage. The P-F Curve (Figure 1) is a common way to represent the behaviour of an asset (pump, motor), or asset component (belt, bearing) before actual functional failure has occurred.

There is a sense in which failure is a process, not an event. We can say that (most) failures take time, and for that we can be thankful. It’s really the causes of failure that take time, of course. Common causes leading to failure like wear, stretch, deterioration, misalignment, contamination, etc. fortunately do not lead to failure immediately, or all at once. Though failure may inevitably occur from any or all of them, many of them generally take time to develop to a level or degree that actually causes the failure. Better yet, that time interval preceding failure is often long enough to be useful. We can often rely on this time interval to detect or correct processes leading to failure, and if not avoid failure altogether, at least be able to reduce or avoid the consequences of failure.

Remember, our job in maintenance is not to “fix it when it fails”. Our job is not to avoid failure altogether. Sometimes failures are due to normal causes, and cannot be avoided. For example, belts and bearings can fail due to normal wear alone, such failure can’t actually be avoided. Rather, our job is to maintain physical assets in such a way that we can avoid the consequence of failure, whatever its cause.

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A little wear, deterioration or contamination is not necessarily a problem; a lot of wear, deterioration or contamination is almost always a problem. The good news is that when these kinds of failure causes take significant amounts of time to actually create loss of function, we can often choose from alternative courses of action. If the consequence of failure is small or negligible, we may choose to do nothing, especially if doing something costs more or has more negative consequences than doing nothing. However, if the consequence of failure is not negligible, for example when production loss or costs of repair are high, then it will almost always be worth the effort to detect the failure “process” as early as possible before the failure, so that we may take whatever corrective action required to either avoid the failure, if possible, or reduce its consequence.

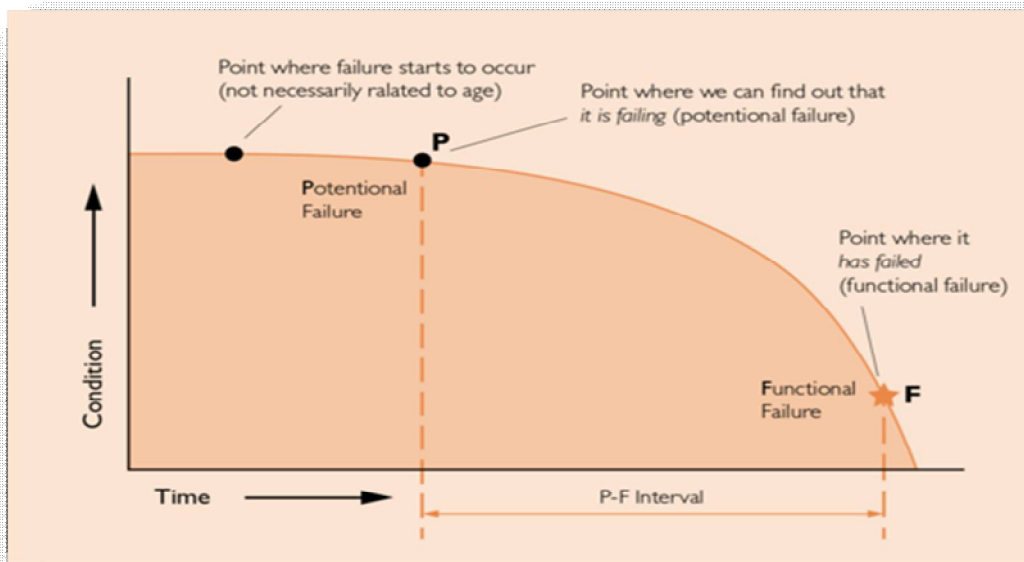


Figure 1. P-F Curve represents the behaviour of an asset (pump, motor), or asset component (belt, bearing) before functional failure has occurred.

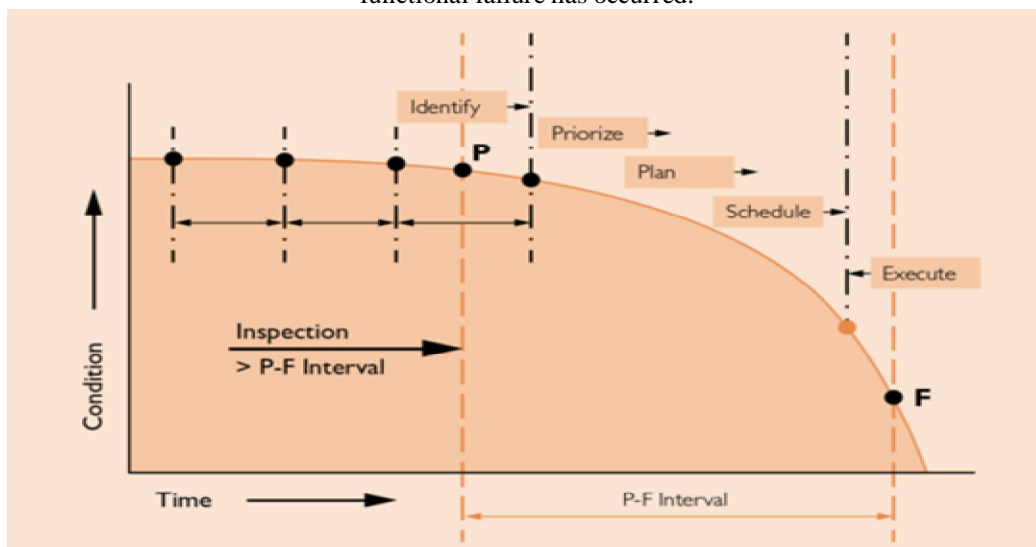


Figure 2. Inspection intervals must be less than the P-F Interval. In practice, inspection intervals equal to  $\frac{1}{2}$  the P-F Interval is usually acceptable.

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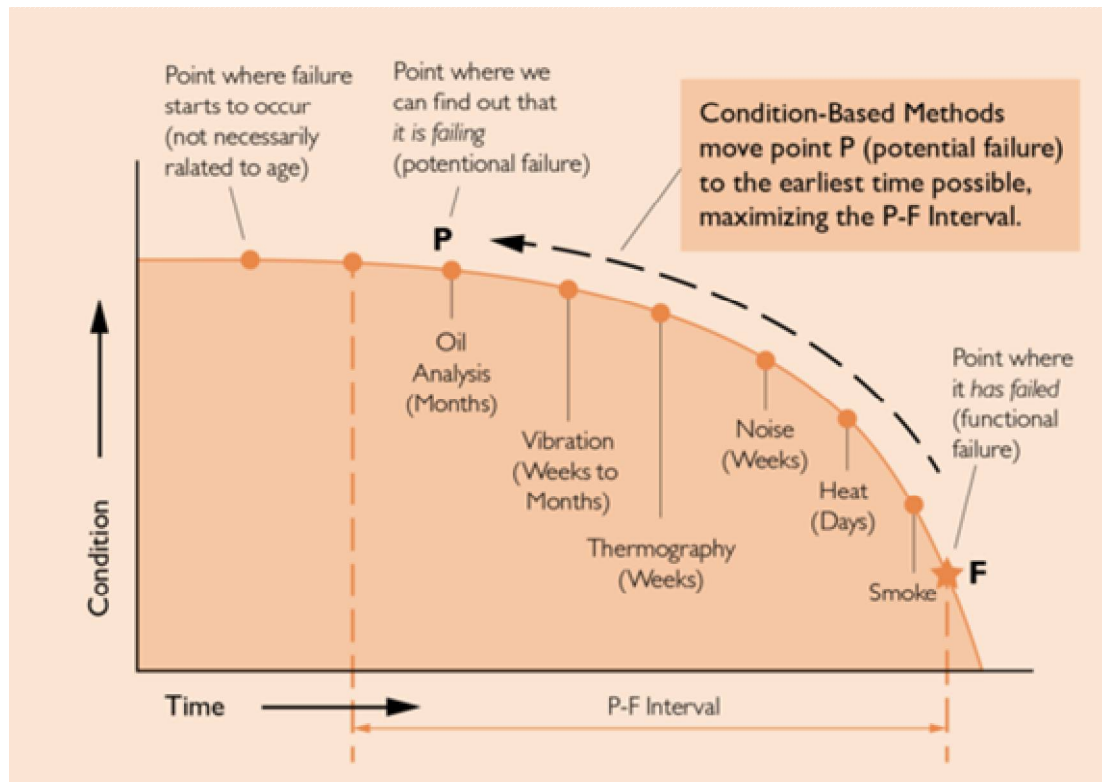


Figure 3. Maximizing the P-F Interval, which can be days, weeks, or months depending on Inspection Methodology!

### The P-F Curve and the P-F Interval

The horizontal (X) axis of the P-F Curve represents time-in-service for an asset, or asset component. The vertical (Y) axis represents some measure of performance, rate, condition or suitability for purpose. The curve shows that the performance or condition of an asset or component declines over time leading to functional failure, i.e. loss of function for which it was intended. The curve may take various shapes, linear or exponential, but is generally represented as exponential as shown in **Figure 1**.

The P-F Interval is the key. It may be days, weeks or months, but whatever it is, it must provide a sufficient “window” of time between the latest inspection and functional failure to prioritize, plan and execute the necessary maintenance activities before the failure (**Figure 2**). Obviously the longer the P-F Interval, the better it will be.

### Maximizing the P-F Interval Using Condition-Based Maintenance Technologies

The method and frequency of inspection makes a difference in the length, and therefore the utility of the P-F Interval. Generally, technologically-based Condition-Based Maintenance (CBM) methods (on-line inspections) provide the greatest P-F Intervals (**Figure 3**), and are less disruptive than alternative time-based, shutdown inspections. The avoidance of off-line inspections, which often cause loss of production, can make CBM methods economically feasible.

## IV. INTRODUCTION TO CONDITION MONITORING

Condition monitoring is a maintenance technique that monitors the condition or health of machinery or structures and advises when upkeep is necessary. It consists of collecting system data through sensor equipment and then processing it into meaningful information. Decision making strategies are then employed to determine when maintenance is required. Fault diagnoses is at the core of condition monitoring. Implemented techniques are utilized to detect fault conditions and even identify specific machines faults.

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Maintenance strategies are classified by three developmental stages:

1. Break down maintenance
2. Preventive maintenance
3. Predictive maintenance

-Break Down Maintenance:

This provides the replacement of defective part or machine after the machine becomes incapable of further operation. Break down maintenance is the easiest method to follow and it avoids the initial costs and training personnel and other related upfront costs.

-Preventive maintenance:

In preventive maintenance, maintenance is scheduled on calendar or hours to run and is performed irrespective of machine condition.

-Predictive Maintenance:

Trending and analyzing machinery parameters we can detect the developing problems in early stages. Hence repair works can be carried out before failure of a machine.

The most commonly used techniques of condition monitoring are:

1. Lubricant Sampling and Analysis
2. Corrosion Monitoring
3. Motor Current Analysis
4. Acoustic Emissions Detection (e.g., ultrasound)
5. Vibration Measurement and Analysis
6. IR Thermography
7. Process Parameter Trending (e.g., flows, rates, pressures, temperatures, etc.)
8. Process Control Instrumentation (measurement and trending)
9. Visual Inspection (look, listen and feel).

## Types of Condition- Monitoring Systems

Condition-monitoring systems are of two types: periodic and continuous. Periodic monitoring systems acquire measurements from equipment at selected time intervals; the analysis of the collected data is generally performed in the office or laboratory. The measurements may be on-line or offline, depending on what is being measured and the access required. Continuous monitoring systems collect almost always on-line the measurement values at selected points on the equipment and this data is continuously compared with pre-established levels or criteria. "Set-points" are usually established for the purpose of providing automatic warnings and/or equipment shutdown, depending on the consequence of the impending failure.

## Available Condition- Based Technologies

Table 1 shows the variety of condition based measurement techniques that have been developed for applications to a wide range of mechanical and electrical equipment. More are being developed all the time, technologies are being improved, usability (user-friendliness) is being enhanced, product features are being added and prices/performance points are becoming more attractive. Selection of appropriate techniques for your particular applications will of course be a function of several variables:

- Applicability of the CBM technology to the potential failure modes to be detected
- Applicability of the CBM technology to the equipment design itself
- Operational features of the measurement equipment
- User qualification and training requirements (principles of both the technology and measurement equipment)
- Pros and cons of using the technology for the selected failure mode in your specific equipment context
- The economics of purchase, operation, training, and usability of the selected technology.

If the consequence of failure is high, there is almost always a relevant measurement technology and a vendor in the market with equipment to measure it. Economics notwithstanding, there will be measurement products out there that


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will allow you to see critical failures in progress giving you the opportunity to take corrective action at the earliest, most advantageous time possible, with least hassle and lowest cost.

**Table 1. Available Condition-Based Technologies and Their Applications.**



APPLICATIONS	Mechanical										Electrical									
	Eddy Current Thickness	Vibration Monitoring	Lubricant Analysis/Final Analysis	Wear Particle Analysis	Bearing Temperature Analysis	Leakage Detection	Performance Monitoring	Ultrasonic Monitoring (Bearing)	Ultrasonic Flow	Infrared Thermography	Precise Timing & Trending	Proximity Position	Visual Inspection	RF Monitoring	Insulation Resistance	Motor Current Signature	Motor Circuit Signature Analysis	Polarization Index/Dissipation Factor	Cable Condition Monitoring	Transformer Oil and Gas
Generators	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				
Turbines	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				
Pumps	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				
Electric Motors	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
Diesel Generator Engines	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				
Condensers	●					●	●	●	●	●	●	●	●	●	●	●				
Conveyors	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				
Heavy Equipment/Cranes	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				
Circuit Breakers										●	●	●	●	●	●	●				
Valves					●	●	●	●	●	●	●	●	●	●	●	●				
Heat Exchangers	●					●	●	●	●	●	●	●	●	●	●	●				
Electrical Systems																	●	●	●	●

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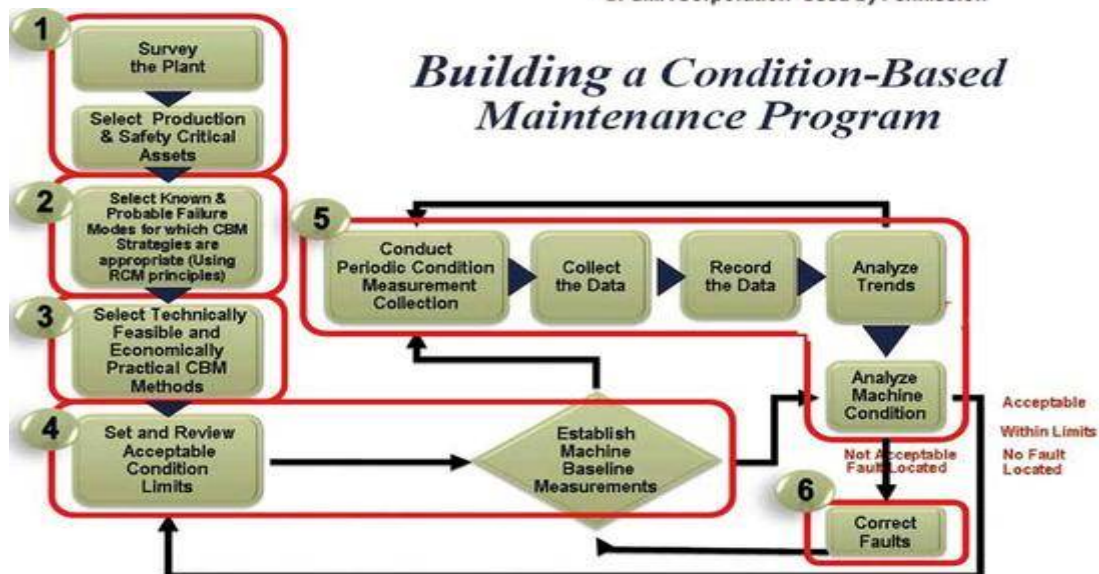


Figure 4. Building a Condition-Based Maintenance Program.

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## Building a Successful CBM

Program Here are some of the major steps in establishing an effective, sustainable Condition- Based Monitoring program (shown in Figure 4):

1. **Select the Assets** A good place to start is with your critical assets, those with substantial safety, production and cost risks.
2. **Identify Known and Probable Failure Modes** Apply Reliability-Centred Maintenance (RCM) principles and identify failure modes for which CBM strategies are appropriate.
3. **Select CBM Technologies** Select technically feasible and economically viable CBM measurement technologies for the identified CBM-appropriate failure modes.
4. **Establish Baseline Measurements for Selected CBM Technologies** Set acceptable condition limits, alarms and set-point triggers.
5. **Establish and Execute the CBM Program** Develop the program, establish responsibilities, assign resources (train as necessary) and conduct the program. Collect and record the measurements, trend and analyze the data.
6. **Act!** Take appropriate action based on the analysis.

## V. THE BENEFITS OF CONDITION-BASED MAINTENANCE

Maintenance When implemented properly, Condition- Based Maintenance (CBM) has the ability to reduce both the time between maintenance activities (TBM) and time to repair (MTTR) with resultant savings in labour costs and reduction of downtime production losses. These benefits are achieved from predicting potential failures ahead of time, providing the maintenance staff with time to prioritize, plan and execute the work most efficiently and economically. Spare parts inventories and/or expediting costs are reduced as well when there is sufficient lead-time to order parts on an “as needed” basis.

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