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CONDITION DIAGNOSTICS OF ROTARY MACHINERIES USING VIBRATION ANALYSIS

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ABSTRACT

Various kinds of machines are used in nearly every aspect of daily lives; from the domestic appliances like vacuum cleaner and washing machine up to the industrial machinery used to manufacture nearly every product we use on a daily basis. When a machine fails or breaks down, the consequences can range from annoyance to financial disaster, or personal injury and possible loss of life. The failure of machines can usually be predicted much earlier before the failure. Long before the failure stage, the condition of machine begins to deteriorate due to wear and tear of the various moving parts. The wear always manifests itself in terms of signals like mechanical vibrations, noise, acoustics, thermal emission, smell, pressure; relative displacement etc.Usually change in vibrations level provides good indication of change in the condition of machine. Abnormal vibrations in machines cause accelerated wear .Evan a small insignificant increase in the level of vibration causes a sharp increase in bearing wear which further reduce the service life of bearing by 50%.Increased vibration levels in a machine will lead to operational difficulties sooner or later. For this reason, the early detection, identification and correction of machinery problems is paramount to anyone involved in the maintenance of industrial machinery to insure continued, safe and productive operation. This paper introduces the use of machinery vibration and the technological advances that have been developed over the years ,making it possible not only to detect when a machine is developing a problem, but also to identify the specific nature of the problem for scheduled correction.

Keywords: condition monitoring, vibration detection, vibration analysis, time domain analysis, frequency domain analysis, optimum operating parameters

I. INTRODUCTION

For better living of mankind various kinds of machines are used in nearly every aspect of daily lives; from the domestic appliances like vacuum cleaner and washing machine up to the industrial machinery used to manufacture nearly every product used. Thus machines are inevitable part of daily life. The breakdown or failure of machines causes lot of inconvenience and losses. The consequences of breakdown or failure of machines can range from annoyance to financial disaster, or personal injury and possible loss of life. The failure of machines can usually be predicted much earlier before the failure as it manifests itself in terms of signals like mechanical vibrations, noise, acoustics, thermal emission etc. Vibration is more predominant signal in most of the cases.

Vibration is the motion of a particle or a body or system of connected bodies displaced from a position of equilibrium. Most vibrations are undesirable in machines and structures because they produce increased stresses, energy losses, cause added wear, increase bearing loads, induce fatigue, create passenger discomfort in vehicles, and absorb energy from the system. Rotating machine parts need careful balancing in order to prevent damage from vibrations. Vibration occurs when a system is displaced from a position of stable equilibrium. The system tends to return to this equilibrium position under the action of restoring forces (such as the elastic forces, as for a mass attached to a spring, or gravitational forces, as for a simple pendulum). The system keeps moving back and forth across its position of equilibrium. Vibration can be defined as simply the cyclic or oscillating motion of a machine or machine component from its position of rest. It is generated in the driveline and can be experienced / sensed and seen by any person. The source of vibration can be any part / assembly of the vehicle.

Usually change in vibrations level provides good indication of change in the condition of machine. Abnormal vibrations in machines cause accelerated wear .Evan a small insignificant increase in the level of vibration causes a sharp increase in bearing wear which further reduce the service life of bearing by 50%.Increased vibration levels in a machine will lead to operational difficulties sooner or later. For this reason, the early detection and analysis of vibrations is significant for recovering of machinery problems and maintenance of industrial machinery. The first step in this regards is to understand the vibrations and their dynamics. The vibrations can be measured and controlled using suitable instrumentation.

II. CAUSES OF VIBRATION and THEIR EFFECTS

Causes :

- Forces generated within the machine namely

1. Change in direction with time, such as the force generated by a rotating unbalance.

2. Change in amplitude or intensity with time, such as the unbalanced magnetic forces generated in an induction motor due to unequal air gap between the motor armature and stator (field).

3. Resulting friction between rotating and stationary machine components in much the same way that friction from a rosined bow which causes a violin string to vibrate.

4. Sudden impacts, such as gear tooth contacts or the impacts generated by the rolling elements of a bearing passing over flaws in the bearing raceways.

5. Randomly generated forces such as flow turbulence in fluid-handling devices such as fans, blowers and pumps; or combustion turbulence in gas turbines or boilers.

- Some of the most common machinery problems:

1. Misalignment of shafts, couplings, bearings and gears
2. Unbalance of rotating components
3. Deterioration of rolling-element bearings, Gear wear etc.
4. Hydraulic problems in fans, blowers and pumps
5. Resonance, Bad design and unbalanced inertia forces

The effects :

1 Unwanted noise,

2. Early failure due to cyclical stress (fatigue failure)

3. Deviation from the tolerances in machined components and poor surface finish.

4. Increased wear leading to Poor quality product

5. Increase in rejection rate leading to additional costs.

6. Increase in field complaints leading to customer dissatisfaction

III. VIBRATION MEASUREMENT

A vibrating machine represents a troublesome problem in a factory. The abnormal vibrations in the machines cause accelerated wear.

As discussed earlier the vibrations amplitude of a machine rises with defect development. Thus vibrations become a signal which indicates variation in condition of machine. Hence a monitoring scheme based on vibration amplitude verification can work satisfactorily, in case of most of the rotating machines. The condition monitoring program involves three phases viz.

1 Detection

2 Selection of Parameter

3 Analysis

4 Correction

3.1 Detection

A vibration based condition monitoring program, involves detection analysis which highlights the causes of vibrations and the remedial correction. The detection phase is related with diagnosis activities as shown in Fig 1 and the correction is fault repairing activities.

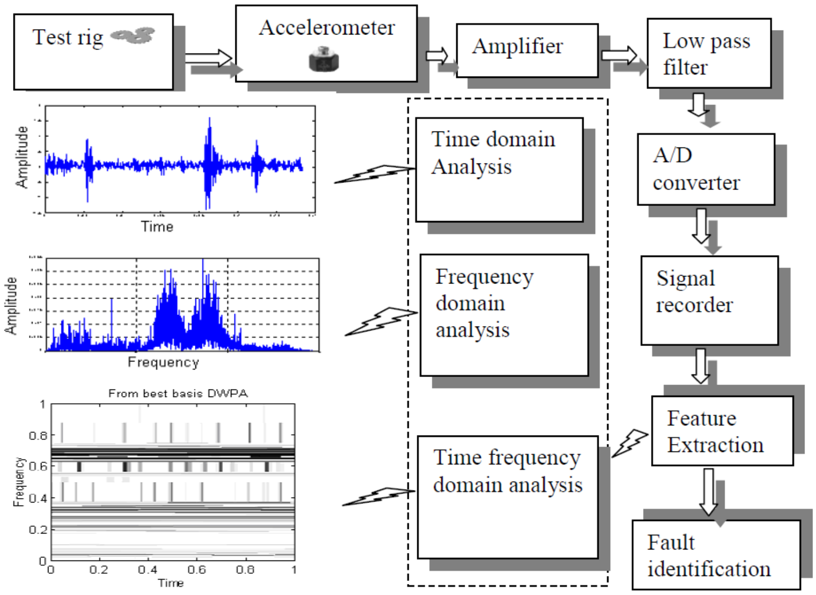

Figure 1. Overview of fault diagnosis based on vibration signals

The first step is to set up the program in the computer software that will include:

1. Listing all machines to be included in the program.
2. Identifying the bearing locations where readings will be taken on each machine.
3. Identifying the directions (horizontal, vertical and axial) where readings will be taken on each machine.
4. Identify the vibration parameters that will be measured at each location. Parameters other than vibration such as bearing temperature, speed (RPM), amps, pressures, flow rates, etc., may be incorporated as well.
5. Establish alarm or warning levels for each measurement.

6. Establish details for "spectral" (FFT) data needed for vibration analysis.

7. Organize machines into workable groups or "routes".

8. Establish a schedule for data collection for each group of machines.

Once the program has been set up in the computer software, the next step is to collect data. After the data has been collected, the operator returns to the computer and "down-loads" the data to the predictive maintenance software, following a few simple instructions. Once the collected data has been down-loaded, numerous reports can be generated to reveal those machines that have experienced a significant increase in vibration or have exceeded a preset alarm level, indicating developing problems.

The automated data collectors and computerized data handling systems basically serve the same purpose as the simple hand-held vibration meter and data sheet. However, the automated systems allow the computer to do what it does best, and that is to "crunch" the numbers in a highly efficient and rapid manner. With a data collector, one technician can take vibration readings on many machines throughout a plant in a much shorter period of time. Although most general machinery can be protected with periodic checks of vibration, some machines may not be well suited to "manual monitoring" techniques. High performance machinery such as steam and gas turbines, high-speed centrifugal compressors and pumps can develop problems very quickly, with little or no preliminary warning. Machines such as these may require continuous, on-line monitoring.

3.2 Selection of Parameter

To match the monitoring needs it is important to understand the relationship between frequency, displacement, velocity and amplitude. This governs the parameter to be monitored and select appropriate instrument to measure so as to suit these needs. Basically by monitoring the wrong parameter the condition information needed may be missed.

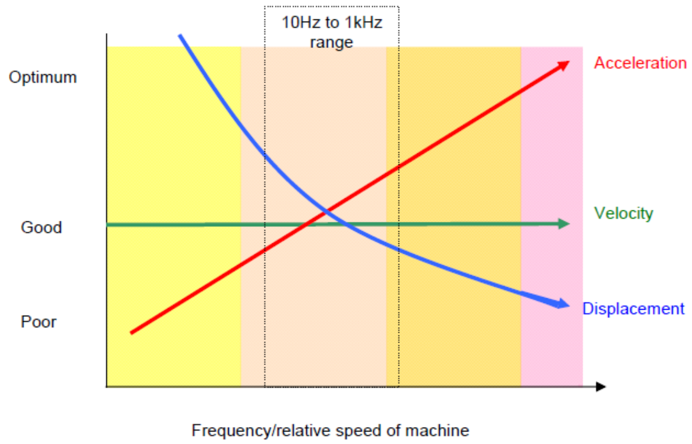

Figure 2 : Selection of Parameters for measurement

From **Figure 2** it is seen that displacement or velocity values are of good quality for low frequencies, but at higher operating speeds like in case of bearings acceleration measures are prominently used. Velocity measurement will better represent the operating conditions across the entire range of operating speeds.

3.3 Analysis

Vibration signals are to be analyzed in order to get insight of the faults present in the machine. Primarily two methods are used to analyze the signals viz. time domain analysis and frequency domain analysis. Features regarding frequency information such as frequency domain features and time frequency domain features are being widely investigated at present. These features can generally indicate machinery faults better than time domain vibration features because characteristic frequency components such as resonance frequency components or defect frequency components can be relatively easily detected and matched to faults.

The analysis made on the basis of these detections helps in

- Preventing defects
- Knowing the machine's reliability
- Deciding life of the machine
- Forecasting defects and failures
- Planning for rectification
- Deciding frequency of inspection and check-ups

Once machinery problems have been detected by manual or on- line monitoring, the obvious next step is to identify the specific problem(s) for scheduled correction. This is the purpose of vibration analysis – to pinpoint specific machinery problems by revealing their unique vibration characteristics. A systematic vibration analysis can then be carried out to identify the more common machinery problems, including Unbalance, Misalignment, Looseness, Defective, Bearings, Resonance, Eccentricity, Worm Gears, Motor Electrical Problems.

3.4 Correction

Fault correction work is the outcome of the analysis phase of the vibrations monitoring based maintenance program. On the basis of the expert's opinion who has analyzed the vibrations data the fault diagnosis has been drawn. With respect to this diagnosed causes the remedial actions of repairs, programmed replacements, modifications, reinforcements or overhauling are decided and executed.

Once problems have been detected and identified, required corrections can be scheduled for a convenient time. Of course, in the meantime, any special requirements for repair personnel (including outside repair facilities), replacement parts and tools can be arranged in advance to insure that machine downtime is kept to an absolute minimum.

If the vibration problem is diagnosed as unbalance, in many cases the same instrument used to detect and analyze the problem can be used to perform in-place balancing.

IV. CASE STUDY ON FAULT DIAGNOSTICS IN ROTARY MACHINERIES

Typically machine vibration signatures indicate the type of fault present in the machine. The operating frequency of the machine is called '1X' and the frequency domain plot of the signals are matched with multiples of the operating frequencies. Typical relationship of fault and frequency are represented in table 1 given below.

Table 1: Relationship between fault and vibration signature

Typical Fault	Details	Comments
IMBALANCE	Imbalance occurs at rotational frequency equal to 1 x rpm of the out of balance part.	Amplitude is direct indication of degree of imbalance
MISALIGNMENT	Typically angular and/or offset problems	In both radial and axial directions also

	in couplings	apparent at x1rpm because of imbalance inherent to misalignment
LOOSENESS	Mechanical - caused by loose rotating parts or excessive play in machine mountings	Typically a machine will vibrate as it hits a natural resonant frequency during run up or run down - once the associated rpm is passed vibration amplitude decreases
PASSING	Usually cause a x1 frequency component and a multiple related to the number of vanes/blades	Also referred to as blade pass frequency
MESHING	Defects cause low amplitude high frequency vibration and show imbalance, misalignment and tooth damage associated with Gear Mesh Frequencies	Gear Mesh Frequency = output gear rpm x No. teeth in output gear. e.g. 32 tooth gear operating at300 rpm [300/60 =5Hz] GMF =32x5 = 160Hz
BEARINGS	Bearings indicate problems at high frequency 2- 60KHz (in the early stages of deterioration) and at low amplitude	Range of techniques available with bearing capability
ELECTRICAL	50Hz(UK)	Vibration will stop when power is turned off!

A centrifugal pump connected with 5 kW, 1440 rpm motor was tested for bearing noise. Number of points was selected at drive and non- driving ends are selected for Frequency analysis. The vibrations were monitored using portable data acquisition system ADASH with accelerometer glued to the locations. During routine monitoring an increase in vibration (overall and high frequency components) was identified at the motor drive end bearing position. The motor bearings were suspected as being faulty given the discrete high frequency components identified on the spectra and both bearings replaced. It can be seen that data taken after replacement of the machine does not contain any of the high frequency components identified pre repair. When the bearing was changed vibration and performance returned to optimum operating parameters.

4.1 Benefits

In advance replacement of the bearings the performance of the unit was improved and the shutdown of the pump and related maintenance would have caused loss of crops due to unavailability of the set for water supply.

V. CONCLUSION

Conditioned based maintenance techniques are widely used in industries. Vibration analysis based techniques are widely used over other methods. The accuracy and reliability of the results of this technique saves lot of time and cost due to timely detection of the faults and corrective measures taken. However the success of the technique largely depends on the skill of the engineer diagnosing the problem. Also selection of measurement parameters also affects the performance.

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