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CONDITION MONITORING AND VIBRATION TESTING OF CENTRIFUGAL PUMPS

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Abstract

Condition monitoring is the process of monitoring a parameter of condition in machinery, such that a significant change is indicative of a developing failure. It is a major component of predictive maintenance. The use of conditional monitoring allows maintenance to be scheduled, or other actions to be taken to avoid the consequences of failure, before the failure occurs. It is typically much more cost effective than allowing the machinery to fail. Serviceable machinery includes rotating machines such as centrifugal pumps.

Condition monitoring is defined as monitoring the parameters, which affect the life of equipment; e.g. the factors which decide the life of centrifugal pumps are precision alignment, grouting procedure, dynamic balancing of impeller, forces and moments on flanges, vibration, noise, lubricating oil condition etc.

In industries like petrochemical, power, oil and gas industries and in nuclear installations, pumps are important equipment right from concept to installation, commissioning and commercial operation.

Predicting the residual service life of equipment is difficult but possible. The loss caused by sudden equipment failure may prove to be disastrous to an organization. In a way it hampers production, the down time putting the image of the organization at stake. The techniques developed over a period of time to predict these failures, apart from conventional techniques (look, listen, feel, smell etc.), are Statistical Process Control, Machine Performance Monitoring and Condition Monitoring. The recent development of micro-processor and signal analysis technology has allowed the development of powerful, effective and at the same time relatively inexpensive systems for continuous condition monitoring of different machine parameters.

Modern condition monitoring methods have encouraged the manufacturers to invest in new manufacturing technology. Condition monitoring is forcing organizations to take a proactive approach and hence helping them to achieve the operational excellence with the minimum of investment.

This paper highlights the available business needs and advanced technologies of condition monitoring in order to determine centrifugal pump condition in testing and operation.

1. INTRODUCTION

In modern processing and manufacturing plants, it is not uncommon to find fans, pumps, turbines, compressors and other rotating equipments combined in continuous processes. However the unexpected failure of just one of these critical machines can disrupt an entire process with staggering losses in terms of production, man-power and equipment repair or replacement. Failure of a single bearing or coupling can produce catastrophic results. These facts, together with increasing costs for new equipment, have placed increased demands on plant maintenance to keep existing equipment operating efficiently and reliably. Outmoded "breakdown" maintenance programs and programs of periodic inspection and overhaul are being replaced or supplemented by modern non-destructive techniques, which allow on-stream detection of developing problems. Monitoring of bearing temperature, ultrasonic testing, lubrication analysis and many other techniques are being used to combat failures and unscheduled downtime. However, the most significant improvements in machinery reliability have resulted from monitoring and analyzing machinery vibration. The measurement and analysis of vibration not only provides a means of detecting mechanical problems, but also makes it possible to identify the specific problem.

In this paper an attempt is made to elaborate the process of monitoring of certain parameters like vibration, bearing temperature, noise, current drawn, power absorbed, lubricating oil/grease contamination. The analysis of these parameters is out of the purview of this paper.

2. VIBRATION

The concept of using vibration and analysis for predictive maintenance is based on three simple facts:

1. Firstly it is normal for machines to vibrate. Even machines in excellent condition will have some measurable vibration because of small minor defects. Therefore each machine will have a level of vibration which can be regarded as normal and acceptable.
2. Secondly when machinery vibration increases or becomes excessive, mechanical trouble is usually the result. Thus monitoring the machine's vibration level will provide a warning of trouble whenever increases are detected.
3. Finally each mechanical defect such as unbalance, misalignment, worn gears, looseness etc. generates vibrations in its own way. Therefore, analysis of the vibrations makes it possible to identify the problem as the machine operates.

2.1 Monitoring Techniques

To effectively utilize vibration measurement and analysis for predictive maintenance, and organized program of monitoring and analysis must be carefully planned and followed.
Organizing a systematic program of vibration monitoring is the first step in developing the maintenance program using vibration. This will accomplish the first objective of the program, which is to detect the mechanical problems before failure results. The monitoring techniques used depend on available manpower and equipment as well as the importance of the machinery included in the program. Monitoring techniques used include:

STAGE I: Periodic checks of rotating machinery using portable vibration meters.

STAGE II: Where machine bearings are inaccessible for any reason because of location or hazardous environment, and then install permanent transducers wired to a Predictive Maintenance Program (PMP) control center into which portable meters or analyzers can be plugged.

STAGE III: Critical machines should be protected by automatic monitors with alarms and trip/ shutdown facilities to protect them round the clock.

STAGE IV: To simplify the collection and analysis of data from a large number of machines, then add automatic data logging, trend alarms and automatic analysis.

Out of above stages, stage III & IV are explained in details as these are more relevant for condition monitoring.

2.1 .1 Stage III: The Addition Of Fixed Monitors To Give Automatic Alarms And Shut Down On Critical Machinery

If machines are of vital importance to the operation of your plant and failure can occur between conventional periodic checks, then it is economically justified to add automatic monitors to warn of trouble. These machines might be simple exhaust fan that develops imbalance, on high performance machines, such as steam and gas turbines, high-speed centrifugal pumps or a compressor that can develop problems very quickly, with little or no preliminary warning.

Automatic monitors are economically justified and should be employed for machines, which are vital for operation of plant.

For automatic monitoring, vibration transducers, (or pick-ups) are permanently installed at strategic points on the machine to continually sense the vibrations. Transducers are hard wired to the monitoring instrument, which may be mounted on a panel near the machine or in a separate control room upto 500 m away. When the vibration exceeds a preselected level, a relay in the monitor instrument operates to provide a warning alarm. A light on the monitor indicates when the warning alarm has been triggered, and an external device, such as a bell, buzzer or flashing light can be connected to provide the necessary warning. Should the vibration continue to increase to the “danger point”, a second relay operates to provide a trip alarm. Here also, the trip relay can be connected to an external warning device or operation of the monitor trip relay can be used to activate the sequence that automatically shuts the machine down – this can be important where the machine being monitored is subject to fast failure such as a high speed compressor.

The basic function of a vibration monitor is to warm of increasing vibrations; however, not all machines require the same type of monitor protection.

Regardless of monitor configuration or the number of points monitored, it should be remembered that automatic or continuous is simply intended to replace manual monitoring when periodic checks are impractical or inadequate. When a monitor sounds a warning alarm, the next step should be to analyse the vibration to identify the problem and schedule correction before failure. If analysis information is not obtained prior to a forced shutdown, then the difficult decision must be made whether to restart the machine and attempt to identify the problem, with the risk of further damage or to disassemble the machine to determine the mechanical problem.

2.1.2 Stage IV: Data Logging, Trend Alarms and Computer Interfacing

In recent years, increased reliance on one or a few high performance machines for a plant’s total production capacity has resulted in the need for improved automated control and early warning systems. This has led to an increasing demand to interface new or existing vibration monitor systems with computer capabilities. For example, some systems use use microprocessor intelligence to continually sample data from upto 48 monitor points. Such systems automatically perform the following functions:

2.1.2.1 Data logging

On a preselected periodic basis, the system automatically prints out in list form, the vibration levels, temperature levels, speed etc. at each monitor point. Such data logs can also be obtained on demand and will also be automatically presented when any monitor point reaches an alarm condition. That point which has exceeded the alarm level is identified on the hard copy data log printout.

2.1.2.2 Trend prediction

The system illustrated calculates trends and predicts when a trip level may occur. Predictions are based on periodic samples of data, which are stored for each channel. Such trend information gives operator and maintenance personnel an additional lead-time to prepare for analysis and correction of the particular problem.

2.1.2.3 Spectrum analysis

The systems will printout complete amplitude versus frequency analysis of the vibration for any channel that develops a trend alarm or is in an alarm state on the vibration monitor. This analysis will clearly identify that machinery component responsible for the vibration and greatly aid in the diagnosis of the particular problem. The objective of these automated monitor systems is to provide operator and supervisory personnel with complete and instantaneous data reflecting the condition of critical rotating machinery. Only when this type of data is available can intelligent decisions be made when problems develop.

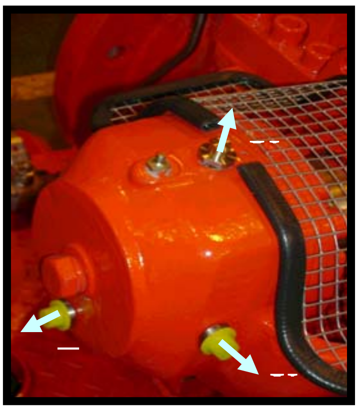
3. TEMPERATURE

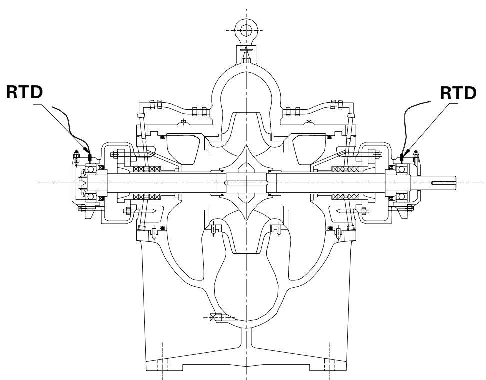
Temperature is probably the most frequently measured variable in pumps for bearings, lubrication sump and pump housing (in critical cases). There are many ways of measuring temperature, which based on variety of physical principles. Following are the basic instruments used for temperature monitoring.

1) Thermocouple
2) Resistance temperature detectors (RTD)
3) Thermally sensitive resistors (thermistors)
4) Integrated circuit sensors
5) Infrared sensors

With addition of electronic feature to above devices, it possible to take out the analogue signal and measure the temperature which in turn can be logged to data base on computer.

A typical arrangement for measurement of vibration and temperature for centrifugal pump coupled to engine is shown below.





4. NOISE

Noise/sound measurement and monitoring finds wide application in our day to day life. The development of less noisy machinery and equipment these days forms an important area of the environmental pollution control.

Sound pressure level is measured by sound level meters, microphones which convert acoustic pressure into directly proportional voltage indicated on the meter (analogue signal) through amplifier. This signal can further taken to recorder or analyzer.

5. POWER AND CURRENT

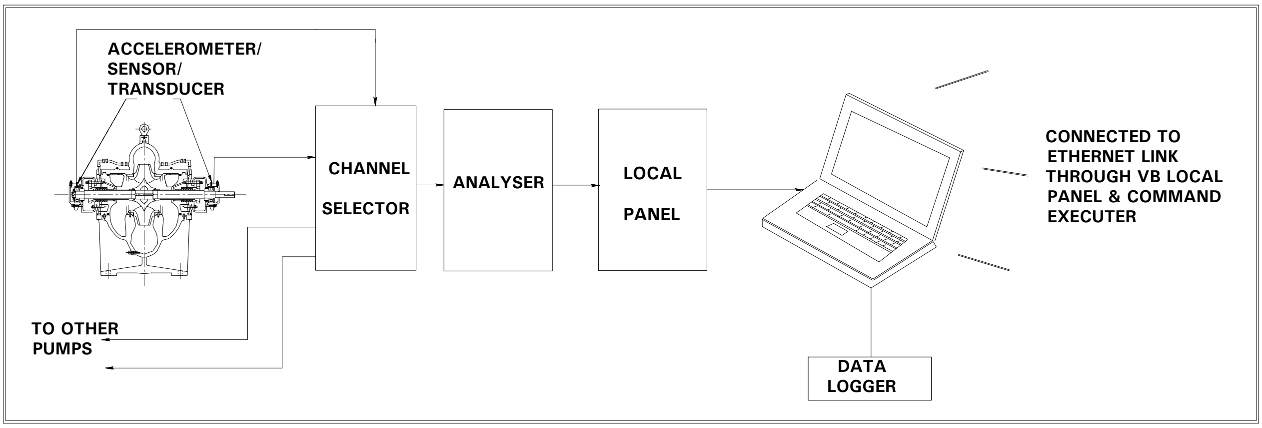
There are quite good instruments available to measure the power and current in rotating systems like pumps. These can be directly used across the input connections to the motor and signal is taken on the control panel or computer.

6. BEARING CONDITION MONITORING

Bearings may fail due to several reasons improper handling, fitting, contamination or improper design, all leads to wear of raceways and inner side of the cage. Bearing defects can be detected by using CPD (contact potential difference) probe. The CPD probe works on the basic principle that there is always a potential difference between two surfaces. As a surface passes by the stationary CPD probe, a current is generated which is measured by probe. This current is then converted into voltage (analogue signal), difference in this voltage will provide the means to detect the bearing defect.

Also with the measurement of spike energy, it is possible to identify the defect in the bearing assembly.

A typical integration of all the parameters with schematic diagram is shown below.



7. CONCLUSION

Condition monitoring in centrifugal pumps can be applied for following.

1) To improve pump reliability through effective prediction.
2) To improve pump performance.
3) To minimize downtime through internal planning and scheduling of repair.
4) To maximize pump life by avoiding the condition that reduce pump life.
5) To ensure precision alignment and minimal lubricant contamination.
6) To reduce pump life cycle cost.
7) To achieve most economic operation.
8) To protect pump from failure due to closed valves, cavitations, dry running and low flow.
9) To eliminate teardown surprises.
10) To achieve impressive return on investment.

By application of proper condition monitoring techniques & instrumentation to rotating machines/pumps, it is possible to solve many problems and guide in predictive maintenance. Through condition monitoring it will be a journey to Operational Excellence.

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