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A Case Study on Condition Monitoring & Fault Diagnosis

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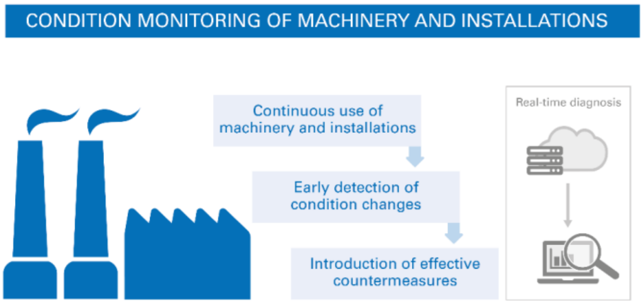
Abstract – *The following write up shades light on what Condition Monitoring is. It also gives us an idea of how the condition monitoring works along with some of its types. The write up also gives us information related to fault diagnosis using various sensors which are attached on to the machinery or on a particular equipment. This writeup also gives us an idea of what are the advantages and the disadvantages of the condition monitoring in real time. Since Condition Monitoring is a process how can it be implemented, this is also discussed in the following paper. The types of condition monitoring is also discussed along with techniques related to them being implemented.*

***Key Words*: Condition monitoring, Fault Diagnosis, Sensors, Electrical Monitoring, Electromagnet Measurement, Laser Interferometry, Performance monitoring.**

1.INTRODUCTION

Condition Monitoring is the process of monitoring a parameter of condition in a machine. The parameters which can be monitored include vibration, temperatures, cycle time, amplitude, etc. this monitoring is done in order to identify significant change which may lead to development in fault. The process is majorly a predictive maintenance process. Condition Monitoring is a major component of the techniques which are designed to help determine the condition in order to estimate the performance of maintenance is to be done. This process allows us to schedule maintenance and useful to avoid major consequences. It is a unique benefit which can be helpful in increasing the life span before the component starts to develop a major failure.



Condition Monitoring process is normally used in rotating equipment or auxiliary systems along with some other machinery components which include compressors, motors, pumps, engines and presses. It is a type of NDT (Non-Destructive Testing) method and FFS (fit for service) evaluation which is used for static plant equipment such as boilers, piping and heat exchangers. Traditional Condition Monitoring was mainly based around vibration and its analysis related to an object but modern technique uses various sensors to scale different parameters which give us the real time value. This technique can also alert the person in-charge if and when the change is detected.

2. How does Condition Monitoring works?

Not a long time ago Condition Monitoring was carried out by an engineer holding a stick in front of a machine to feel vibrations and to check if the equipment is running correctly or not. However, as the time passed the process has developed itself so much with the use of digital technology and internet. Modern condition monitoring is a real time process which means engineers can now schedule maintenance as per their requirement. This would help both the engineers as well as the company to have a fixed date on which there will be a scheduled maintenance for their machineries and stuff. This allows maintenance to be scheduled at a more efficient time which leads to a less downtime.

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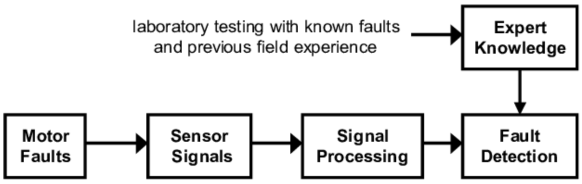

Condition Monitoring also prevents other components in a certain machine from failure as a knock-on effect from one part breaking down. As this process is predictive maintenance, it is a greater advancement from the reactive maintenance, which is in short, a process in which the action is taken after a certain failure has occurred in a machine or its components. This heightens efficiency and removes unexpected downtimes from a work schedule as well as minimizing inspection procedures.

This process can be broadly parted in three steps: -

1. **Installing of the Monitoring System**

   This is the first step in condition monitoring. In this we would first install the monitoring hardware system onto the serviceable equipment. This requires some kind off retrofitting or modification of the existing assets, with different items of equipment requiring different approaches or instrumentation.

2. **Baseline/ Foundation of Data Management**

   The second step in the monitoring system is the create a data management system. This can be done after the monitoring system is installed, you can begin to measure the performance of the equipment. This gives us a baseline against the equipment that we are monitoring to we it can be optimised on its operating conditions going into the future.

3. **Ongoing/Real Time Monitoring**

   The system can now monitor the machines or the equipment using various sensors and the software will evaluate the performance and provide us with diagnostics. The system will now send alerts when an abnormality is detected and access the data to determine if immediate action needs to be taken or not. If not, then the machine can operate for a while longer before its due for its maintenance.

3. TYPES OF CONDITION MONITORING

There are many different types of monitoring techniques which can be implemented to evaluate the condition of the equipment. This type of monitoring includes sensors along with some physical techniques. Since many techniques can determine the same fault, we can get the best result if we use them together to deliver an overall picture of a machine's operation.

Condition Monitoring types includes:

a) Electrical Monitoring

Electrical monitoring involves the use of the principles of deviation in electrical parameters to find defects or faults. These parameters include capacitance, frequency response, induction, pulse response and resistance to locate potential issues. This method uses the measurement of degradation trends to determine whether action is required to prevent system failure.

Techniques include:

- Alternating current field measurement (ACFM)
- Battery impedance testing
- High potential testing
- Megohmmeter testing
- Motor circuit analysis
- Power signature analysis
- Surge testing

b) Electromagnetic Measurement

This type of condition monitoring identifies cracks, corrosion, weaknesses and other defects by measuring field distortions and eddy current changes. Magnetic fields are applied to surface walls and, as they interfere with one another, they create patterns which can be used to identify deterioration in material quality and surface features. Also, of use in tubing, electromagnetic testing shows defects as disturbances that can be measured and analyzed.

Techniques include:

- Magnetic particle inspection
- Magnetic flux leakage
- Metal magnetic memory method
- Pulsed eddy currents
- Remote and near field eddy current
- Saturated low-frequency eddy currents
- Other eddy current testing

c) Laser Interferometry

Laser interferometry uses a highly accurate, laser-generated wavelength of light to measure changes in wave displacement. Based on the interference in light waves generated by a laser, it is used to locate subsurface and surface defects in materials including composites. It works by capturing and measuring the interference patterns using an interferometer. These patterns can show differences in material characteristics such as the presence of corrosion, cavities or surface defects in the material.

Techniques include:

- Digital holography
- Electronic speckle pattern interferometry
- Holographic interferometry
- Laser stereography
- Laser ultrasonics
- Strain mapping

d) Motor Circuit Analysis (MCA)

MCA, or motor circuit analysis consists of a range of computerized tests on an electric motor to determine its condition and if there any possible sources of potential failure. MCA tests focus on electrical imbalances and degradation of insulation, which are the main causes of motor failure. The tests are usually split into voltage-based or current-based tests and include go/no-go tests and those that need to be tracked over time to determine failure development.

Inspections include:

- Air gap
- Insulation
- Online and offline testing regimes
- Power circuit/current signature
- Power quality
- Rotor
- Stator

e) Oil Analysis

As machines wear out or overheat, contaminants are deposited into lubricating oils, equipment fluids and other operating liquids. This technique collects and tests these oils, fluids and lubricants to reveal the presence of any contaminants in order to interpret how close a machine may be to failing.

Techniques include:

- Dielectric strength testing
- Ferrography
- Fourier transform infrared spectroscopy
- ICP / atomic emissions spectroscopy
- Microbial analysis
- Particle quantification index (to check iron content)
- Potentiometric titration/total acid number and total base number
- Presence of water tests
- Sediment tests
- Ultraviolet spectroscopy
- Viscosity/kinematic viscosity testing

f) Performance Monitoring

This most traditional type of condition monitoring involves visual inspections and the use of an engineer's physical senses to judge how a machine is functioning. Used in conjunction with output tracking and manufacturing performance measurements allows an engineer to identify any deviations from the expected results, which could indicate a problem with the equipment. These types of inspection are still valuable today, especially when more advanced technological tests are not possible, although they are reliant on a degree of experience, record-keeping and expert interpretation.

Techniques include:

- Audio inspection
- Downtime analysis
- Flow rates
- Output or performance trends
- Pressure
- Temperature
- Touch inspection
- Visual inspection

g) Radiation Analysis

Some of the more thorough non-destructive testing methods, these types of condition monitoring use radiation imaging to find internal defects in equipment or parts. These methods are based on the differential absorption or radiation through a material, since corroded areas and flaws absorb differing amounts of radiation to unaffected areas. The absorption rates can be measured and analyzed to find any defects and these techniques are also used to insect castings, sintered parts and weldments.

Techniques include:

- Computed radiography

- Computed tomography (CT)
- Direct radiography
- Neutron backscatter
- Neutron radiography
- Positive material identification (PMI)

h) Temperature Measurements

Machinery and parts tend to heat up as failures develop, indicating misalignments, imbalances, poor lubrication, worn components, mechanical stress, or electrical overheating. Thermography can identify such thermal anomalies by capturing images of the thermal radiation patterns emitted from equipment, allowing the use of data collection and analysis to identify potential failures or part degradation. This type of condition monitoring is used to identify issues such as overheated electrical connections, pipe leaks or pressure vessel weaknesses.

Techniques include:

- Comparative thermography
- Comparative qualitative thermography
- Comparative quantitative thermography
- Lock-in thermometry
- Pulse phase thermometry
- Pulse thermometry
- Temperature-related color changing fluids
- Temperature-related color changing paint stickers

i) Airborne Ultrasonic Monitoring

Ultrasonic monitoring techniques use high-frequency sound waves to detect part defects including leaks, part seating and cavities. Used for equipment, bearings and rotating parts, these methods can detect tiny changes in friction forces that may otherwise be missed using techniques like vibration analysis. These monitoring methods can offer an early warning system for machine part deterioration that may otherwise have been masked by ambient plant noise and temperature.

Techniques include:

- Acoustic emission testing
- Acoustic ranging
- Airborne ultrasonics
- Automatic and continuous ultrasonic inspection
- Backwall echo attenuation
- Dry-coupled ultrasonic testing
- Internal rotating inspection
- Long-range ultrasonic testing
- Phased array testing
- Time-of-flight diffraction
- Ultrasonic backscatter technique
- Ultrasonic thickness and gauging

j) Vibration Analysis OR Dynamic Monitoring

Wear on machine parts, bearings, rotors or shafts can cause them to vibrate in unusual patterns that can be monitored, recorded and analyzed. These vibration patterns can be used to identify defects and potential failures, including those due to misalignments, imbalances or even design flaws. Of course, technology has advanced since the days of holding a wooden stick against a machine (as mentioned above) but the theory remains much the same.

Techniques include:

- Shock pulse analysis
- Broadband vibration analysis
- Fast Fourier transforms
- Power spectral density (PSD)
- Spectrogram/spectrum analysis
- Time waveform analysis
- Ultrasonic analysis

4. ADVANTAGES

There are many benefits which are offered by condition monitoring for various purposes like maintenance scheduling, operating cost, reduced downtime and safety. It also helps us to determine what the exact problem is and its cause.

As such, the advantages of condition monitoring are:

i. Avoid Unplanned Downtime
ii. Protect Your Other Assets
iii. Eliminate Unnecessary Maintenance to Maximise ROI
iv. More Efficient Maintenance
v. Improved Safety
vi. Improved Asset Efficiencies

5. DISADVANTAGES

Along with the advantages stated there are some disadvantages as well, these disadvantages are particularly related to the initial setup of the Condition Monitoring System.

i. High Installation Cost
ii. High Operational Cost
iii. Unpredictable Maintenance Scheduling

6. CONCLUSION

This process is now becoming more common across the industry as a method to ensure the safe working environment and improve efficiencies. This method directly helps an industry in various ways such as saving both time and money on uninvited failures related to any machinery or its equipment. While there are still some instances where preventive maintenance is preferred to CM-assisted predictive maintenance, many asset owners are realizing the benefits of condition monitoring system.

**Pictures/images are subjected to availability on Internet.

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