Improving Predictive Maintenance with Oil Condition Monitoring.

The need to improve productivity is a continual demand on any business and there are a myriad number of ways to achieve it. In a manufacturing environment, maximising machinery availability is a key element in the equation.

In this paper we take a look at some of the different options available to achieve this objective using a Predictive Maintenance strategy and Condition Monitoring technologies.

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INTRODUCTION

As its name suggests, predictive maintenance aims to determine the condition of equipment in-use and predict when maintenance activities need to be undertaken. The objective is to minimise maintenance costs whilst maximising machine availability.

This strategy differs from preventative maintenance where timed or calendar maintenance is undertaken based on historical or simulation data. The preventative maintenance approach can lead to unnecessary use of resource when the machinery duty cycle is considered.

Predictive maintenance can offer savings over preventative maintenance by allowing work to be undertaken only when required.

The problem arising with a predictive routine is how do you determine the condition of the machinery? The causes of failure for a high speed electric motor, for example, can be very different from a hydraulic system.

The measurement of machinery health is defined as Condition Monitoring. There are a range of condition monitoring techniques, including the innovative oil debris sensors from Gill Sensors & Controls. In this paper we look at which techniques achieve the best results over the broadest range of parameters.

THE 'BIG FIVE'

Predictive maintenance is used to measure, through condition monitoring, when maintenance needs to be carried out based on the condition of the machine, helping to prevent unplanned equipment failure.

There are five primary root causes of machine failure; balance, alignment, looseness, lubricant quality and contamination. Alignment and looseness could also be attributed to wear which can be one of the ways the two conditions arise, with wear leading to contamination.

Within these five broad headings lies an expansive number of ways in which failure can arise. Some of those most frequently encountered are;

Bearing Defects – Bearings invariably operate under heavy, variable loads often in extreme environmental conditions. With the forces applied to bearings, defects can progress quickly leading to friction, bearing damage and gearbox failure.

Shaft Misalignment – This can be a common issue due to the temperature changes the shaft experiences, particularly on longer length shafts. Stress developed inside the shaft can damage couplings; lead to bearing fatigue and even cause shaft breakage.

Couplings – Damage to the coupling can be caused by misaligned shafts potentially leading to shaft separation. Badly damaged couplings can lead to rotor cracks, gearbox failure and damaged shafts.

Insufficient Lubrication – Bearing wear and gear teeth damage caused by insufficient or contaminated lubrication contributes directly to equipment failure. However, inaccessibility or lack of inspection points can make it difficult to undertake oil condition monitoring.

Broken/Worn/Chipped Gear Teeth – Lack of lubrication can cause excessive wear as can shaft misalignment which puts increased load on the input gear leading to poor gear meshing, both of which degrade the oil by increasing contamination, further exacerbating the problem. Gear damage and misalignment can lead to failure of the gearbox.

This is not a definitive list but indicative of the range of problems that can result in unplanned downtime and loss of output. It also illustrates there are two condition monitoring techniques that will cover the 'Big Five' – oil condition and vibration.

PROS AND CONS

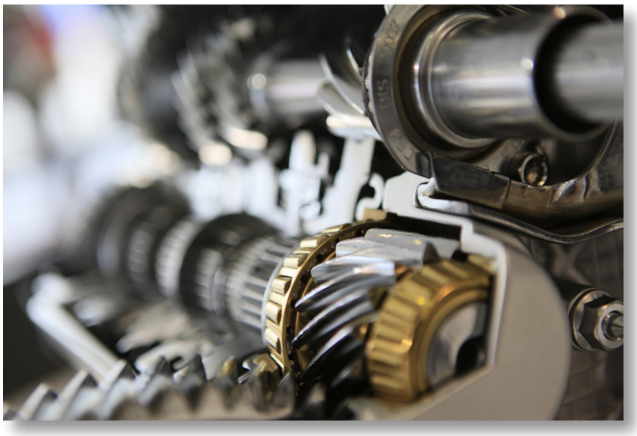
Vibration has been the most popular technique for a number of reasons, primarily because most of the conditions described above will generate some form of vibration. The sensors are usually relatively small and easy to mount on the outside of the equipment, so can be fitted without stopping the machine.

They operate continuously in real time and can transmit to a PLC, asset monitoring system either hard wired or, in some cases, wirelessly. Alternatively, hand-held units are also available, reducing capital outlay, but limiting the measurement to where an operator has access.

The biggest difficulty is that the overall vibration signal from a machine is derived from many components and vibration monitoring requires a thorough understanding of the frequency response of all the components.

This requires a skilled operator to be able to determine what 'normal' vibrations are, what indicates a change in condition and what level the abnormal vibrations need to achieve to signal an alert. Some systems can be programmed to do this 'filtering' work, but still requires a trained operator to set the system up.

The other factor to keep in mind is that vibration monitoring normally requires more than one sensor on each piece of equipment. Although each application will vary, a typical motor/gearbox assembly, for example, could require four sensors – two on the motor at the drive and non-drive ends and on the gearbox input and output shafts. They may also be different measurement types such as radial and axial.



Although vibration sensors can be low cost, the potential need for multiple devices needs to be considered when evaluating the cost/benefit ratio compared to other monitoring technologies.

Oil Condition Monitoring is also a popular technique although until recently, it too, required the use of skilled personnel.

An oil sample is drawn off from the machine and sent to a laboratory where a number of parameters would be measured and a report sent back to the machinery operator. More recently, analysis kits have been introduced that allow the oil to be analysed on-site, but they can have reduced functionality or less sophisticated measurement equipment.

Although a full laboratory analysis will provide an extensive view of the oil condition and machinery health, it does also have some drawbacks. It is relatively expensive, the oil needs to be drawn off the machine in a repeatable condition and oil contamination needs to be prevented.

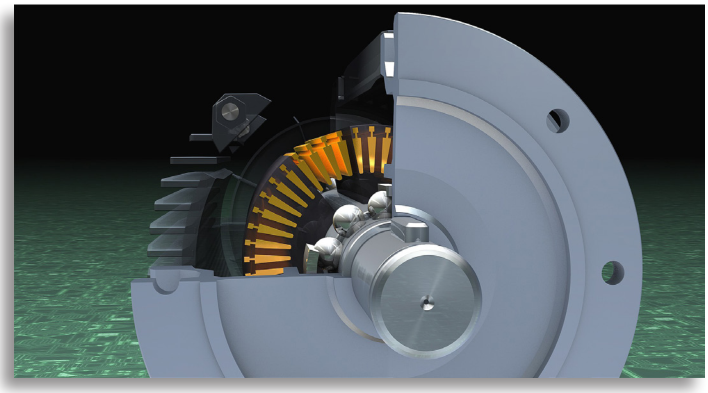
There is also the delay between sampling and the time taken to receive results. It can be 2-3 days which introduces a downtime cost and if you suspect a fault it may be too long to prevent failure. As with vibration monitoring, the results require analysis by trained staff to interpret and understand them correctly.

The cost of analysis increases with the number of parameters measured and requires access to the machine at a location where the oil can be drawn off before it has passed through filtration. For health and safety reasons it may require the equipment to be halted whilst the oil sample is obtained.

To retain the benefits of oil condition monitoring but to mitigate the drawbacks, in-line sensors have now been developed. Generally they measure a single parameter but provide continual, real-time analysis and range from particle counters to sensors which measure the viscosity or acidity of the oil, an indicator of the state of the oil itself. They can report their data locally or transmit into an asset management system.

THE PERFECT MATCH?

Oil condition and vibration have reached the levels of usage they have because they can provide a lot of information about machinery health. However, independently they are unable to provide coverage of the 'Big Five'.



If an electric motor starts to have a problem with a shaft bearing, it is only vibration monitoring that is going to provide you with the necessary indication of a problem. However, if a bearing is starting to fail in a gearbox, it will deposit debris in the oil before it produces a measurable increase in vibration levels.

The principal of preventative maintenance is to provide the earliest possible indication of a problem developing allowing maintenance to be carried out in the most timely, cost effective way. In some studies it has been estimated that oil condition monitoring can provide up to 10 times earlier warning than vibration monitoring. Oil condition also has advantages in low-speed machinery (< 5 rpm) where the amplitude of the vibration signal may not be strong enough to overcome the noise factor.

Monitoring the oil will give an early warning of component breakdown, but gearboxes generally have multiple bearings so this will not help pinpoint where the exact problem is, which additional monitoring by vibration will assist with.

If you already have vibration monitoring, would adding oil condition monitoring improve the performance of your preventative maintenance programme and provide a sufficient return on investment?

TWO IS BETTER THAN ONE

In an article from Practicing Oil Analysis magazine, the example of the Palo Verde Nuclear Generating Station is given. They combined vibration and oil condition monitoring into a common group that worked together.

In an assessment of bearing defects detected by the technologies, they found that oil condition was responsible for 40% of the defects found, vibration was responsible for 33% and both techniques converged on the remaining 27% of the defects found. The loss of either technology would have reduced their detection performance and their ability to control the root causes of machine failure.

This combination of the two measurement techniques covers the 'Big Five' causes of machine failure. After all, there is little point in implementing a preventative maintenance strategy with only one technology which does not, on its own, prevent all of the most common causes of failure.

An additional function to preventative maintenance, other than simply preventing a breakdown, is to understand the root cause of a failure.

The combination of a primary and secondary means of detection provides more data that will enable a deeper understanding of a failure, thereby guiding changes in maintenance, operation or design that will permanently eliminate the cause of a breakdown.

With the arrival of real-time measurement sensors for oil condition monitoring this combination has become more practical and affordable than the sampling and laboratory technique. The new generation of sensors compliment the vibration sensors in terms of continuous measurement with outputs that can be accessed locally or combined onto an asset management system dashboard.

The commercial availability of more powerful magnets has also increased the capabilities of ferrous debris sensors. It is now possible to collect larger failure particles as well as wear debris. Capturing the debris allows inspection of the particles, aiding problem diagnosis.

GEARBOXES, FOR EXAMPLE

For an example of this complimentary approach, let's look at gearboxes.

Pretty much every plant in the world uses gearboxes which are tough on most lubricants because of heat, aeration and chemically active particles. Likewise, misalignment, imbalance and looseness are also a risk.

Occasionally, gears go wrong, with gear tooth wear and gear tooth fracture the most common failure modes. Using vibration analysis to detect wear related gear faults can be challenging due to the number of competing vibration signals. Oil condition, on the other hand, can provide excellent results in detecting contact fatigue, abrasion and adhesive wear, making it an ideal choice for early detection of these modes of failure.

It is unlikely breakage of a gear tooth will produce a detectable quantity of wear particles, especially if the failure is caused by a sudden impact or defective material. By monitoring the gear mesh frequency using vibration analysis a broken gear tooth would be pinpointed every time.

Together, vibration and oil condition come together for monitoring the essential health of gearboxes.

WHAT HAVE WE LEARNT?

In conclusion detecting and analysing machine faults requires both oil condition monitoring and vibration analysis.

- Both methodologies are required to understand and manage the root causes of machine failure.
- In many cases one technique will serve as the primary indicator with the other as the secondary confirmation.
- Oil condition is generally stronger in failure detection for gearboxes, hydraulic systems and reciprocating equipment.
- Vibration analysis is generally better in detecting high-speed bearing failures and localising the point of failure, depending on the application.
- For determining which wear mechanism is inducing failure, oil condition is often stronger.
- Correlation between oil condition and vibration analysis is very good, but there can be contradictory instances.

By combining oil condition and vibration monitoring a number of benefits compared to conventional condition monitoring practices can be realised. These include accurate, efficient and early fault detection as well as the ability to perform root cause analysis.

WHAT NEXT?

Gill Sensors and Controls have produced another paper on 'Improving Machinery Productivity with Oil Debris Sensing' which can be read via their website **gillsc.com/condition**.

You will also find details of the Condition Monitoring Sensors which capture and retain fine and coarse ferrous debris particles with independent channels measuring both in real-time. In addition it will also measure water-in-oil contamination, oil presence or temperature indication as a third channel. Visit the website **gillsc.com/condition** or contact **info@gillsc.com** for more details.

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