LUBE-TECH
NO.24

THE ROLE OF LUBRICANT CONDITION MONITORING IN MAINTENANCE PROGRAMMES

The term Condition Monitoring (CM) is understood by most in the lubricants industry to refer to the periodic analysis of a lubricant in order to monitor both the levels of additive and also, more importantly, the levels of contaminants in the lubricant.
In fact, the scope of true CM is much wider, and can include e.g. vibration monitoring, thermography, ultrasonic analysis, filter wear debris analysis, ferrography, dye penetration, radiography, etc.
This article will concentrate on lubricant CM, but firstly it would be as well to briefly review the historical development of maintenance practices over the years, which will also help to establish the relevance of lubricant CM.

It should be stressed that each piece of equipment should be treated on its own merits with regard to the application of the most suitable type of maintenance philosophy.

BREAKDOWN MAINTENANCE

This involves rectification only after the failure of an item of equipment. Although no longer viable for large, costly and critical items of equipment, breakdown maintenance can still be appropriate for small, non-critical items, e.g. light bulbs.

PREVENTIVE MAINTENANCE

This involves the servicing, overhaul and replacement of items based on intervals of operating time or other unit, or on an elapsed time basis, the most familiar example is probably the servicing of your car. The downside to this philosophy is that units of equipment which are possibly operating completely satisfactorily can be unnecessarily disturbed, and there can be wastage involved when items are prematurely scrapped.

PREDICTIVE MAINTENANCE

This is where the use of CM first came into its own when maintenance was carried out on items based on predicted needs rather than on a regularised basis.

PROACTIVE MAINTENANCE

This system developed from the previous three philosophies and is concerned with the analysis of all maintenance and CM techniques to determine the causes of failures, and their prevention.
As could be expected, these differing maintenance philosophies result in differing failure modes.
These are summarised below in order of decreasing seriousness:

CATASTROPHIC FAILURE

As the name implies, this is the sudden and complete failure of a piece of equipment, and is associated with the 'Breakdown Maintenance' approach.

PREVENTIVE FAILURE

A state of deteriorating performance leading to a gradual loss of efficiency and/or a progressive shortening of working life of some, but not necessarily all, components.

PREDICTIVE FAILURE

The situation where loss of machine performance has not yet become apparent to the operator, but where detective measures such as lubricant CM begin to predict a deteriorating situation.

PROACTIVE FAILURE

The most 'early-warning' situation which can alert an operator to potential deteriorating performance or even complete failure even though no adverse effects are readily apparent.
It can be seen that CM has an important role to play both in the Proactive and the Predictive categories of failure mode.
There are also several differing levels of CM, i.e.

DETECTION

To determine whether a problem exists, and if so, the criticality of the situation

DIAGNOSIS

To determine the exact nature of the problem, and also to determine what, if any, additional CM techniques are required.

PROGNOSIS

To determine the overall seriousness of the problem and the use of the experience for future reference

LUBRICANT CONDITION MONITORING

Of the various approaches to CM outlined above, lubricant CM is one of the most useful, and can play an important complementary role in both Predictive and Proactive maintenance philosophies. However, it must be stressed at this point that lubricant CM should not be viewed as the complete answer to every potential failure situation. Even with a lubricant CM programme, catastrophic failures can still occur in a number of situations. These include:

EXTREME SHOCK LOADING

Examples are driver abuse and overloading in the case of vehicles

METAL FATIGUE

Lubricant CM will not identify the progressive breakdown in the crystalline structure of metal components, which could lead to their eventual breakdown.

SHORTAGE OF LUBRICANT

If a piece of equipment, such as an engine, runs short of oil, irreversible damage will occur, which will not be rectified by subsequently topping-up the oil level.
Failure to properly rectify a previous breakdown situation
An earlier failure can result in the generation of wear debris, which, if not completely removed, can result in further failures of other components in the same piece of equipment.
Also, generally speaking lubricant CM should not be used in isolation, but in conjunction with other monitoring programmes including filter debris inspection.
The lubricant CM programme should also be planned such that sampling frequency is adequate, and that sampling is carried out in such a way so as to ensure that samples are properly representative and free from contamination.

IDENTIFICATION OF AN APPROPRIATE LUBRICANT CM PROGRAMME

Lubricant CM programmes are developed according to the type of equipment using the lubricant.
Programmes generally fall into the following broad classes:

- Engines
- Gear Systems (including automotive manual gearboxes and differentials, also industrial gearboxes
- Automatic Transmissions
- Hydraulics
- Compressors and turbines

A number of further but more minor categories include e.g. aircraft engines, refrigeration compressors, etc.
A normal test programme would include

- Elemental analysis
- Particulate analysis (normally quantification only)
- Viscosity measurement
- Water content

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TABLE 1. COMMON ELEMENTS DETECTED BY ICP AND THEIR RESPECTIVE SOURCE

Element	Symbol	Found in
Iron	Fe	Gears, rolling bearings, cylinder liners, shafts
Chromium	Cr	Rolling bearings, piston rings
Nickel	Ni	Rolling bearings, camshafts and followers, thrust washers, valve stems, valve guides
Molybdenum	Mo	Piston rings, soluble additives, solid additive
Aluminium	Al	Pistons, journal bearings, dirt
Copper	Cu	Brass/bronze bushes, gears, thrust washers, oil cooler cores, internal coolant leaks
Tin	Sn	Bronze bushes, washers and gears
Lead	Pb	Journal bearings, grease, contamination from leaded petrol
Silver	Ag	Silver solder
Silicon	Si	Dirt, grease, additives
Sodium	Na	Internal coolant leaks, additives, sea-water contamination
Lithium	Li	Grease
Magnesium	Mg	Additives, sea-water contamination
Zinc	Zn	Additives
Phosphorus	P	Additives
Boron	Bo	Additives, internal coolant leaks, brake fluid contamination
Sulphur	S	Mineral oils, additives

TABLE 2. COMMON WEAR SITUATIONS AND THEIR IDENTIFICATION USING ICP

Situation	Elemental analytical results by ICP
Dirt entry	Si and Al present, usually in the ratio between 2 and 10 to 1. Monitor trends for increases and also for increases in associated wear elements
Piston torching	Al and Si present in ratio 2 to 1. Since failure is rapid, this type of failure is rarely detected in time by CM.
High Fe (alone)	Varied sources commonly include valve gear, oil pump wear, and rust
High Si (alone)	From anti-foam additives, grease and silicone sealants
Top-end wear (engines)	Increases in Fe, Al and Cr. Presence of Ni also indicates camshaft/cam follower wear
Bottom-end wear (engines)	Increases in Fe, Pb, Cu, Sn
Overheating	Increases in Mg, Ca, Zn, P, S (all from additives) and viscosity due to loss of volatile oil components
Bronze bush wear	Increase in Cu and Sn normally in ratio of 20 to 1
Bronzegear/thrust bearing wear	Increase in Cu and Sn normally in ratio of 20 to 1
Internal coolant leaks	Increases in Na, B, Cu, Si, Al and Fe (not necessarily all) and possibly Pb, Cu and Sn
Rolling bearing wear	Increases in Fe, Cr and Ni, possibly also Cu from brass/bronze cages
Hydraulic ram wear	Increases in Fe, Cr and Ni

TABLE 3. IRON AND PQI RELATIONSHIP

Situation	ICP Fe content (ppm)	PQI	Inference	Wear Profile
1	Low	Low	Few wear particles	Normal wear profile
2	High	Low to medium	Lots of small particles, few large particles	Accelerated wear. Wet brake systems Dirt entry
3	Low	High	Few small particles, many large particles	Metal fatigue
4	High	High	Lots of particles of all sizes	Serious wear indication with possibility of catastrophic failure

TABLE 4. INTERPRETATION OF CHANGES IN VISCOSITY

Component	Viscosity Change	Cause
Engine	Increase	Overheating Sludging Fuel dilution (Heavy fuel oil-powered marine engines only
Engine	Decrease	Fuel dilution
		Viscosity Index Improver breakdown in multigrade oils
Other Components	Increase	Overheating Grease contamination Severe water contamination Breakdown of the oil Mixture of oils
Other components	Decrease	Contamination by volatile substance Viscosity Index Improver breakdown in multigrade oils Breakdown of the oil

TABLE 5. TYPICAL WATER LIMITS

Component	Limit (%)
Engine	0.0
Drivetrain	1.0
Transmission	0.5
Hydraulics	0.5
Compressors	According to type

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1. ELEMENTAL ANALYSIS

This aspect of the CM monitoring programme yields the most information and is carried out using spectroscopic examination, normally Inductively Coupled Plasma Spectroscopy (ICP). The technique does have its limitations, however. The method is limited to detecting elements or which are in solution or in very fine particulate form only, i.e. less than 5-8µ. In practice, this is a very real limitation, since components which are undergoing the initial stages of failure through metal fatigue will generate particulate matter from spalling which is larger than can be detected by ICP.
Also, because the technique only measures elemental concentrations, and not the nature of the compound containing the element, the technique will not necessarily assess the extent of additive depletion in a lubricant. Examination of an engine oil containing a calcium-based detergent, for example, will show unchanged levels of calcium concentrations even though the calcium-based additive has undergone a change from an active form to an inactive form.
The elements determined are grouped into three main categories, i.e.

- Wear Metals
- Contaminants
- Lubricant Additives

See Tables 1 and 2.

2. PARTICULATE QUANTIFICATION

This analysis can take many forms, from a simple quantification of the total amount of magnetic material present (Particulate Quantification Index - PQI) to a full assessment of the numbers of particles present, their sizes and even their shapes.
Application of the more sophisticated techniques of particle counting and sizing is not normally necessary for conventional lubricant CM, however, where generally a measurement by magnetic sensor indicating the total amount of Fe present is all that is required, since this information can also be used in conjunction with the ICP Fe measurement to provide further information on the distribution of wear particles.

See Table 3.

3. VISCOSITY

Kinematic viscosity checks (normally at 40°C but sometimes also at 100°C) can yield some useful information in that fuel dilution can lower viscosity whereas over-heating can result in elevated viscosities. Con-current occurrences of these two conditions could conceivably have little effect upon overall viscosity levels, so it is important that other information from e.g. ICP is also taken into account.

See Table 4.

4. WATER

Again, there are a number of methods for the determination of water contents, ranging from the simple crackle test to more sophisticated titrimetric or conductivity methods.
Water is one of the more common contaminants, and can arise from internal coolant leaks, high-pressure hose cleaning techniques or from simple condensation. Adverse effects arising from water contamination include rusting, reduction in the load-carrying capacity of the oil, and the flashing-off into steam at elevated temperatures.

See Table 5.

SUMMARY

This article provides a broad overview of the role of lubricant condition monitoring in maintenance programmes, together with some practical details.
For more information on this subject, readers are recommended to visit the excellent Wearcheck website at from which much of the information for this article was obtained.

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LINK
www.wearcheck.com

WHAT THE UK'S NATIONAL MEASUREMENT SYSTEM (NMS) CAN DO FOR YOUR BUSINESS

Over **80%** of the world's trade in manufactured goods involve measurement at some point the manufacturing process.

Quote from a Multi-national car manufacturer in the UK, **"If you can't measure it you can't manage it."**

Improving the accuracy of measurements of sulphur in fuel is expected to cut production costs by about **£4m** per annum.

In the UK alone it is estimated that there are 10 million blocks and length bars in use, all of which need calibrating to establish their true size.

Measurement in the UK contributes significantly to the UK economy, directly and indirectly underpinning and enabling about 0.8% of GDP per annum or $5 billion per annum.

NMS supports business in a whole variety of ways:

- raising productivity through improved process and quality control
- ensuring barrier-free trade through the concept of 'once measured, accepted everywhere', including overseas
- contributing to the development of existing and new products and processes
- confident compliance with statutory and regulatory requirements
- Improving quality of life of UK citizens by providing confidence in health and safety.

All of which improves UK competitiveness and impacts on your business's bottom line - through greater efficiencies, reduced wastage, compliance with regulation and increased profit margins. Measurement also underpins a wide range of other activities, including environmental controls, safe medical treatment and food safety regulation.

What is the NMS?
The National Measurement System (NMS) provides world-class measurement standards and calibration facilities. These enable UK businesses and public authorities to make accurate measurements, which are nationally and internationally accepted.

A WORLD WITHOUT MEASUREMENT

At the start of the 20th century 1,206 different combinations of nuts and bolts that were supposedly the same size were tested, but only 8% of them 'engaged sufficiently' to allow tightening with a spanner.

Such inconstancies are hard to imagine in today's cost-driven, competitive market.
Once measured, accepted everywhere

Certification and testing requirements vary from country to country. When certification and testing are statutory or regulatory requirements they can create barriers to trade. The NMS supports international mutual recognition arrangements - through the foundation of accredited certification, calibration and inspection - which reduces the need for UK suppliers to be assessed by each of their customers and so helps reduce trade costs.

LINK
www.dti.gov.uk/NMS

LUBE-TECH

GOVERNMENT ADVICE TO BUSINESS: ACTIONS TO TAKE BEFORE AND DURING A STRIKE IN THE FIRE SERVICE

This is a synopsis of the guidance advice on the practical implications for businesses and their employees and was issued by the Office of the Deputy Prime Minister.

The UK Fire Brigades Union (FBU) has announced that there will be strikes within the Fire Service, though at time of going to press latest negotiations have deferred some of the strike-days.

The owner or operator of a building (not the fire brigade) is responsible for safety on site and emergency evacuation arrangements. Employers should therefore check their preparedness and review their contingency arrangements accordingly.

During any strikes, the Ministry of Defence will provide emergency fire and rescue cover as part of national contingency arrangements. The 999 system will continue to operate with calls being diverted on a temporary basis to alternative operations centres. From there, emergency fire crews and other specialised teams will be mobilised from temporary fire stations. Military fire crews are trained and equipped to carry out basic fire-fighting and rescue operations. They will not have the same capability as your local fire brigade and they are more widely dispersed. Businesses and other organisations should consider what additional measures they can put in place to prevent fire and limit damage.

From a health and safety perspective, it is anticipated that the vast majority of businesses shall be able to continue their commercial activities unaffected by the dispute. However, during periods when the fire services are on strike, it is foreseeable that:

- Attendance times to some incidents will be increased.
- The emergency services attending will have fewer specialised capabilities.
- The emergency services attending will be familiar with neither the incident site concerned nor the local geography.

Accordingly, businesses should consider the implications of, and risks associated with, the potentially reduced emergency services response and where appropriate institute supplementary measures and arrangements to prevent incidents and minimise the consequences of reduced emergency response cover. Examples of such measures include, where possible, delaying certain activities if they have an increased risk of fire associated with them; rescheduling deliveries of flammable substances to coincide with periods when full emergency response cover is available when or lowering inventories of substanceslitems that are flammable or toxic. However, businesses should ensure that such measures do not increase the risks of an incident of another nature; for example, delaying the welding of a pipe decreases the risk of fire but might result in the collapse of the weakened pipework.

DIRECTORS AND MANAGERS RESPONSIBILITIES

The Health and Safety Commission's recent guidance on the responsibility of directors and the guidance on internal control issued following the Turnbull Report affirm the importance of risk management.

The responsibilities of directors and management boards will include the identification of any increase in risk to their core assets or business operations that may arise out of the dispute and taking appropriate steps to manage the risk.

Normal evaluation of the risk from fire is based on the presumption of an early and defined attendance by fully trained and equipped fire-fighters. This cannot be guaranteed for the duration of any strike action and there will be an increase in the level of risk. Briefings for senior staff, review of risk assessments and validation of emergency response information are key features in preparation and response during the dispute.

Directors' Checklist

- Have the risks from fire been properly assessed and prioritised? Do these include risks to assets and business as well as risks to safety?
- Is there an Incident Control Team to manage any emergency situation and limit damage?
- Is there a Business Recovery Plan in place and is it up to date?
- Are key records, emergency plans and contact details duplicated off site?
- Have all existing fire precautions been specifically checked to ensure readiness?
- Is there a detailed emergency fire procedure in place? Is this up to date and has this been brought to the attention of all staff?
- Are all key staff aware of their duties and have they been properly trained?
- Have steps been taken to increase security patrols or management inspections to deter fire raising and improve housekeeping?
- Are arrangements in place (during periods of strike action) to call the fire service by using the 999 system rather than placing reliance on automatic systems?

EMPLOYEES' RESPONSIBILITIES

- The best protection against such a risk remains, as ever, the vigilance of everybody who works in a building observing the usual health and safety precautions.
- Under the law, employers should not dismiss or discipline employees who remove themselves from a situation at work where there is "serious and imminent" danger. But it should not be assumed that the workplace is more dangerous simply because of the strike.
- If employees have any concerns about their own positions, or about safety in their workplaces more generally, they should be encouraged to talk to their managers. If they withdraw from work without the employer's permission, the law will not necessarily protect them from being penalised or, in certain circumstances, even dismissed.

ADDITIONAL FIRE SAFETY MEASURES FOR EMPLOYERS

Normal contingency planning is based on the presumption of early attendance by fully trained and equipped fire-fighting teams. This cannot be guaranteed for the duration of any action and accordingly there will be an increase in the level of risk from fire. Organisations are urged to check their preparedness and to review contingency arrangements. The main areas for this evaluation are as follows: -

- Ensure that business continuity and damage control plans are up to date:
- Check the effectiveness of existing fire precautions:
- Review arrangements for calling the emergency services in the event of fire:
- Lifts
- Workplace Fire Precautions
- Fire Warning and Detection
- Means of Escape in Case of Fire
- Means for Fighting Fire
- Maintenance and Testing
- Emergency Plans
- Fire Safety Checks at Shutdown

LINKS

Fire Industry Confederation at: www.the-fic.org.uk under 'news'

www.fire.org.uk provides a considerable amount of material on all fire issues.

The link General advice is offered at www.firekills.gov.uk.

The full text of this document can be obtained from:

http://www.safety.odpm.gov.uk/fire/firesafety/index.htm