“The case for understanding asset health of your critical gear reducers & geared motors”

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ABSTRACT

In the steel and aluminium processing industries, maintenance cost accounts for 10-15% of production cost. Poor or lack of progressive maintenance can affect the overall efficiency, quality and most importantly the profitability of the plant.

It as long been accepted that the implementation of Condition Based Monitoring as part of a RCM program can appreciably reduce maintenance costs and can improve equipment reliability and product quality.

In a great number of metal producing mills throughout the world, failures of critical equipment frequently lead to loss of production, higher maintenance costs and an increase in operation costs. In today’s economic environment, the capital cost of large specialised modern machines is extremely high and it is inevitable that these assets will have to operate for prolonged periods.

This industry sector has been quick to acknowledge Whole-life cost, or Life-cycle cost (LCC), which refers to the total cost of ownership over the life of an asset. Typical areas of expenditure which are included in calculating the whole-life cost include, planning, design, construction and acquisition, operations, maintenance, renewal and rehabilitation, depreciation and cost of finance and replacement or disposal.

The principles and case for Condition Based Monitoring has long been established. However, there remains a need to continuously prove the case financially; this paper will attempt, to show a means to do so and refers to formal training as a key factor in this debate. It will also be shown that CBM if utilised pragmatically will be a true holistic program considering various complementary monitoring techniques available, which must all be considered.

“For want of a nail, a shoe was lost. For want of a shoe, a horse was lost. For want of a horse, a message was lost. For want of a message, a battle was lost. For want of a battle, a war was lost. All for want of a horse shoe nail”. - Extract from Reliability-centred Maintenance, by John Moubray. (Derivative of an original quote assigned to Benjamin Franklin).

A strange way to begin a paper, but it summarises the whole case for Reliability Centred Maintenance (RCM), Root Causes of Failure Analysis, Failure Modes and Effects Analysis (FMEA) and Condition Monitoring as well as others techniques to be discussed.

In the modern world the nail could be a screw or bolt, the shoe a small but vital cog, the battle could be a machine driving the production line and the war - a lost contract or even the liquidation of the company.

John Moubray also rightly points out that drilling down too far to find the root cause of any failure, could prove less productive than necessary, as one could go on forever beyond the control of the organisation concerned. At the risk of doing just that, I would like to drill down one step further below the loose nail or screw and say that the root cause could have been the lack of regular monitoring, which if it had been carried out properly would have detected this loose nail or screw and saved the war or contract. What price RCM?

It is not the intention in this paper to explain RCM, or indeed any type of Condition Monitoring program. It is however, to show among other topics, one way Condition Monitoring programmes can be justified in the work place to those who must sign up to it as an acceptable expense, such as the Financial Director or the people who control the finances within an organisation.

BACKGROUND

A conventional integrated steel plant has a vast array of high tech equipment. The steel plant is then made up of small self contained business units, such as, Coke Ovens, Sinter Plants, Blast Furnaces, Steel Melting Shops, Continuous Casting, Basic Oxygen Steel-Making, Plate Mills, Hot Strip Mills, Cold Rolling Mills, other secondary mills, power plants and various other facility departments.

In all these process plants, there are a large amount of machines involved, with the majority being rotating equipment, and although electric motors will be the predominant asset in any metal producing plant, gear reducers are a more expensive and complex asset.
Electric motors although expensive when considering high motor powers and / or high voltage supplies, generally have a far lower cost and shorter lead time, as they are manufactured to a limited number of standard sizes.
Gear reducers generally found in metal producing plants, by comparison, are generally unique special design units with a high capital outlay and inevitably a long lead time / delivery.
Therefore, when considering the CRITICALITY process as part of the RCM program it is imperative that these critical assets (industrial gear reducers) are assessed correctly and monitored inline with the findings of the study.

As previously explained, the competiveness of the modern steel maker is one of the major, if not thee major priority.
Effective maintenance management and true asset management has now been accepted as a corporate strategy for reducing costs.
Additionally, the industry also accepts that maintenance management can cost between 35 & 40% of revenues and therefore, most companies are considering improved maintenance technologies that deliver reduced costs and improved profitability.

During the life of any asset, decisions about how to maintain and operate the asset need to be taken in context with the effect these activities might have on the residual life of the asset.

If by investing 10% more per annum on maintenance costs the asset life can be doubled, this might be then considered as a worthwhile investment.

Other issues which influence the lifecycle costs of an asset include:

- Site conditions.
- Historic performance of assets or materials.
- Effective monitoring techniques.
- Appropriate intervention strategies.

Although the general approach to determining whole-life costs is common to most types of asset. Each asset will have specific issues to be considered and the detail of the assessment needs to be tailored to the importance and value of that asset.

High cost assets (and asset systems) will likely have more detail, as will critical assets and asset systems.

Maintenance expenditure can account for many times the initial cost of the asset. Although an asset may be constructed with a design life of 30 years, in reality it will possibly perform well beyond this design life.

For assets like these a balanced view between maintenance strategies and renewal/rehabilitation is required. The appropriateness of the maintenance strategy must be questioned and the point of intervention for renewal must be challenged.

The process requires proactive assessment which must be based on, the performance expected of the asset, the consequences and probabilities of failure occurring and the level of expenditure in maintenance to keep the service available to avert disaster.

Hence, why condition based monitoring is deemed as a necessary function for large, special and critical industrial gear reducers.

MONITORING GEAR REDUCERS

As with any asset, there are a number of machinery conditions and parameters that can be measured, trended and analysed to detect equipment deterioration and potential imminent failures.
Standard common monitoring techniques are as follows:-

- Vibration (velocity, acceleration, FFT, etc)
- Lubrication / oil analysis (wear debris and overall oil analysis)
- Thermal imaging
- Ultrasonics
- Motor analysis (Current, Meg test, impedance, inductance, etc)
- Shock pulse

All the above techniques have a value and not one alone is the best technique for all applications, therefore, it is imperative that the technique selected suits the application in question.

Gear reducers by their design are complex assets consisting of various rotating components, such as shafts, bearings and various gear pinions and gear wheels.

Based on selecting the most suitable technique for monitoring equipment, the following methods are generally regarded as the most suited for monitoring gear reducers and in particular those found in metal process plants.

VIBRATION

The first step in monitoring gear reducers by vibration is to determine whether or not the asset criticality justifies a continuous monitoring system or periodic scheduled monitoring.

Fixed continuous monitoring systems are generally installed on equipment where the criticality is deemed important enough to require continuous data being recorded.

These are a number of systems in the market place today that continuously monitor plant, but the majority of these monitor overall vibration (some monitor true RMS), which gives an indication of a problem occurring on the gearbox in question.

This indication then enables the engineer to make a decision on what action to take next. He can undertake a more detailed vibration inspection and also take an oil sample to help with the decision making process.

Periodic scheduled monitoring is undertaken on a pre-determined schedule, daily, weekly, bi-weekly, monthly, etc. However, should a change in condition be identified during one of the inspections, then this frequency should be increased to determine how serious this change is in condition and what the cause of the change is.

Using hand held data-collectors with FFT (fast fourier transform) analysis is ideal in identifying the cause of the change in condition.

When analysing gear reducers it is imperative that the engineer know the shaft speeds, gear and bearing particulars, so they can identify the individual gear mesh frequencies and bearing defect frequencies.

These gear mesh frequencies are always present regardless of gear condition and amplitudes may increase due to load or gear condition.

People regularly talk about noisy gear reducers and pull them out of service based on their sound.

Please note that “noisy gearboxes” are not always a good indication of gear condition. It is not uncommon for gear mesh frequencies or other component frequencies to be excited by resonances of a gearbox cover, which causes radiated airborne noise to increase notably.

It is also imperative that we consider the associated transmission equipment, which may have a direct effect on the gear reducer; such as couplings, brakes, auxiliary drives, etc.

The measurement direction when using accelerometers is also important and must be installed inline with the gear type / design in mind.

An example below is of a ball mill gear reducer and drive application on a critical plant.

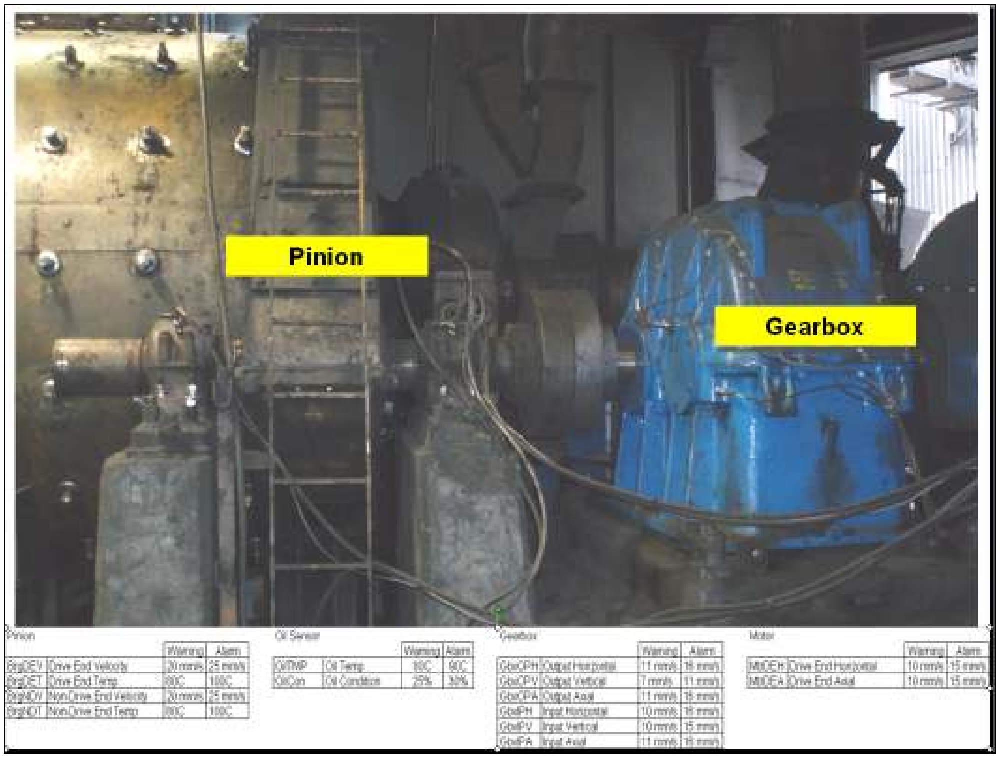
A continuous monitoring system had been installed on this equipment for a number of years and in March 2011 the client saw a dramatic increase in all readings, on both of the pinion support shaft pedestal bearings. (on both the drive end and non drive end, see below)

<u>Pinion DE Support Shaft Pedestal Bearing</u>

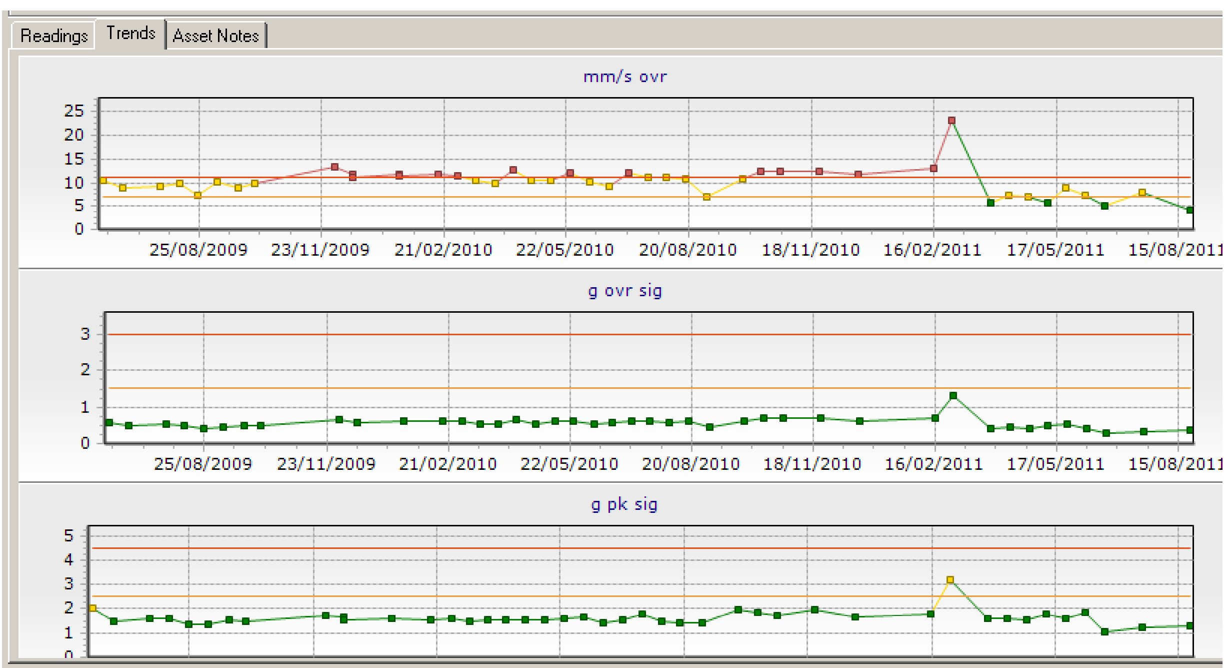
Taken		mm/s ovr		g ovr sig		g pk sig
15/02/2011 11:10		13.10326		0.6948975		1.78247929
01/03/2011 10:18		23.312294		1.30130672		3.19856644

<u>Pinion NDE Support Shaft Pedestal Bearing</u>

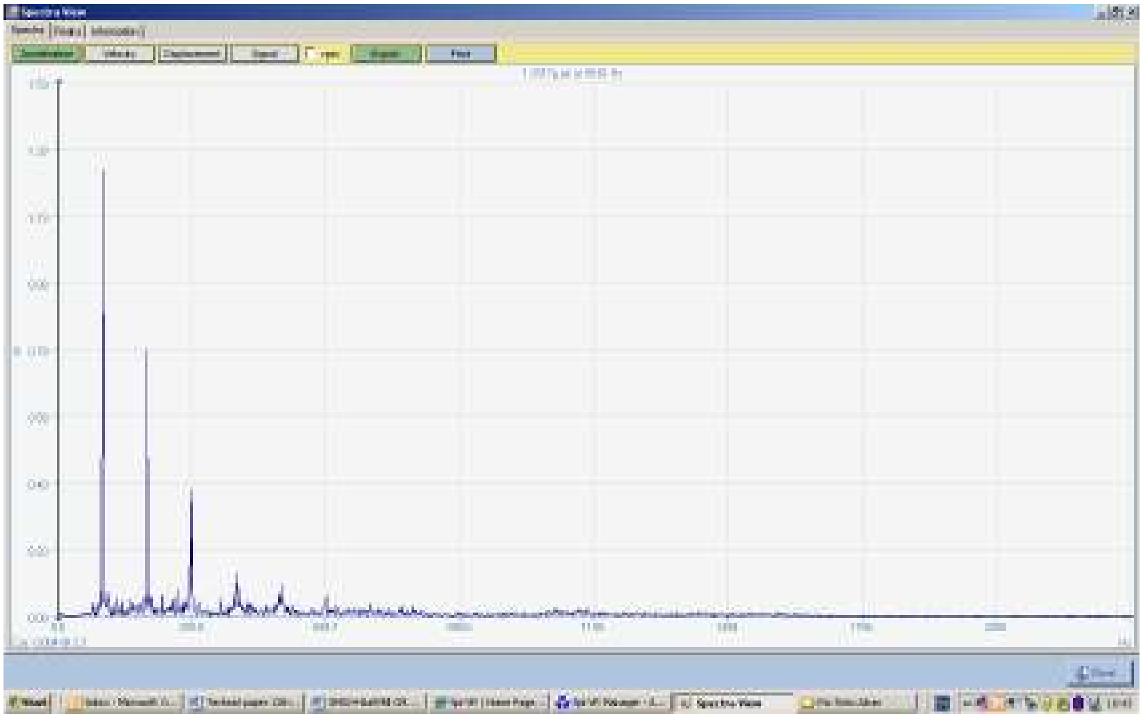
Taken		mm/s ovr		g ovr sig		g pk sig
15/02/2011 11:10		13.51091		0.7281186		2.3333
01/03/2011 10:19		17.319746		1.49950993		5.995941

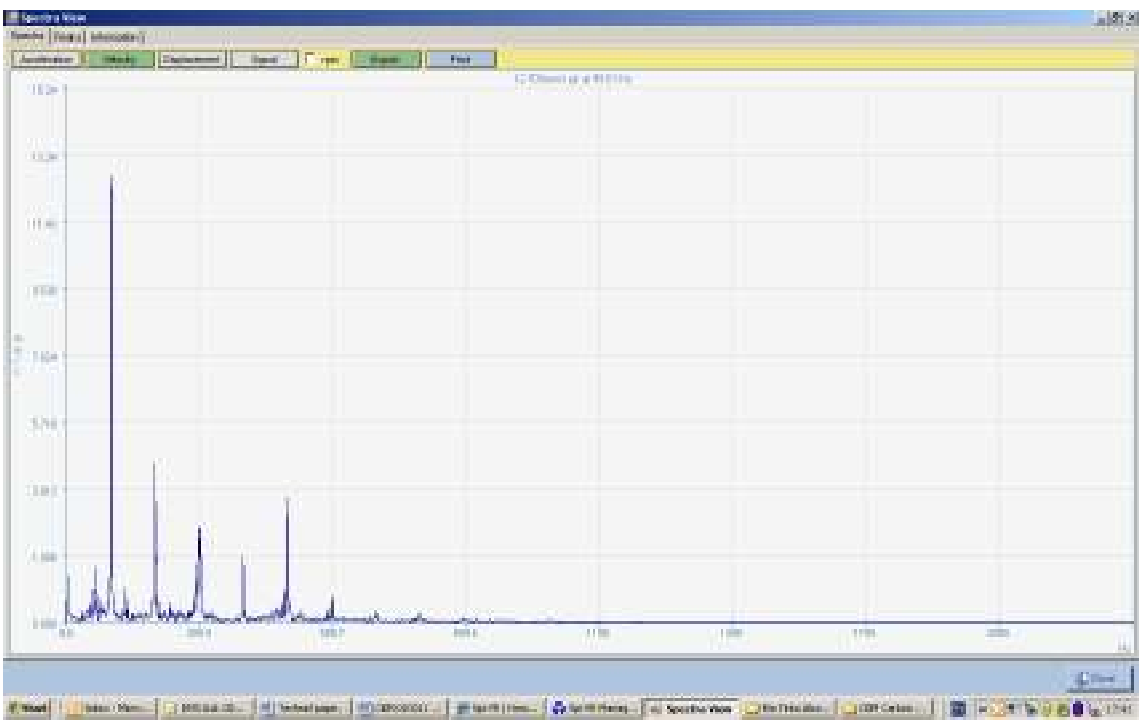


The system detected this increase in vibration (see trends below) and then a detailed FFT vibration analysis inspection was undertaken.



On completion of the FFT analysis, it was found that on both bearings there was a dominant frequency at 99.62Hz with subsequent harmonics, which corresponded to the Pinion/Wheel Gear tooth meshing frequency (Pinion 34T @ 176rpm) and was characteristic of excessive loading or more probably gear tooth wear or misalignment.





The client then planned an inspection of the gear pinion and gear wheel, to find that the girth wheel was badly worn and was becoming misaligned due to the wear. A new replacement girth wheel was sourced and a change over was planned for the forthcoming weekend, in a maintenance window.

Once the guarding was removed during the planned maintenance window, it became apparent on the reasons for the badly worn gear wheel. In the bottom of the guard was a large mass of carbon dust that had not been cleaned over a long period. This dust had been picked up by the open gearing lubricant and became a “honing paste” over the period leading up to the detection.

OIL ANALYSIS

Another complimentary monitoring technique suited to industrial gear reducers is oil analysis.

In the metal processing industry they have been using oil sampling and oil analysis since the 1970's.

All critical gear reducers should be included in a regular scheduled oil analysis program. However, oil analysis is just like any other condition monitoring technique in that consistent procedures and principles must be followed.

Theoretically, the sample should be taken when the oil has reached its operating temperature and is agitated. This is fine in principle but in reality it is generally unsafe and potentially dangerous. Therefore, the best guideline is to ensure the oil sample is taken from the same location, using the same method, whilst ensuring the samples are taken at a scheduled interval.

The oil analysis report from the laboratory will inform the engineer of the overall oil condition, identifying viscosity, appearance, water contamination, TBN (total base number), TAN (total acid number), additive analysis and wear particle analysis.

This analysis is essential to understand the condition of your gear reducer.

The viscosity, water, TBN and TAN determine the lubricant condition and allow you to plan oil changes accordingly. The analysis of the additives also indicates the breakdown of the EP (extreme pressure) lubricant, which are generally used in modern day gear reducers.

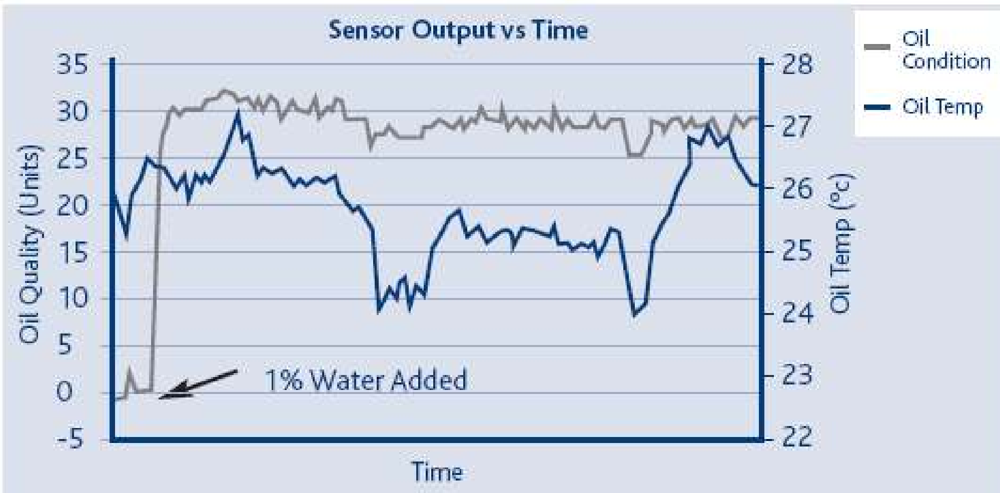
The wear particle analysis reports in ppm (parts-per-million) and identifies iron, chromium, nickel, molybdenum, copper, aluminium and others which are elements consistent with the metallurgical composition of gears and bearings.

ON-BOARD OIL SENSORS

Whichever technique is used in industry for the purpose of RCM, there is the risk that the condition of the machine or lubricant could become seriously contaminated or otherwise affected at a point just after or at least between sampling times.
To reduce this problem a risk assessment programme is usually carried out to establish the ideal frequency of monitoring any given equipment.
However, this ideal frequency of monitoring could prove difficult to justify both financially and practically in cases where safety of sampling is an issue or the equipment is in remote locations, such as isolated pumping stations, a windmill or landfill sites.

To overcome this problem and reduce the risk further it follows that an on-board monitoring device would prove advantageous in such cases.
The problem is that such devices are only just being developed, remain expensive and somewhat unreliable owing to the technologies they employ, the type of conditions they must operate in and the parameters they must be able to detect.
One such device believed to meet most of these requirements (and as discussed in other technical papers at various tribology conferences) is an on-board oil sensor based on a variant of the dielectric properties of the oil.
This oil sensor uses patented technology based on dielectric loss factor (Tan-delta), which is a more sensitive indicator of oil condition than permittivity (often known as dielectric constant).
For most oils, the loss factor will vary from perhaps 0.002 (fresh oil) to 0.1 when contaminated, a dynamic range of 60:1.
This is compared with just 0.8:1 for dielectric constant (which changes typically from 2.3 to 2.9), and therefore it is evident that a Tan-delta measurement system, is many times more sensitive than the traditionally understood and used dielectric constant.

Fig 1 Shows data produced in a client's workshop, from an EP220 gear oil filled in a 11.0kW helical inline geared motor.
A measurement of 1% of water was poured into the industrial geared motor, running a static pump on a test rig and monitored by a continuous monitoring system.
As you can see from the results the "Tan Delta" oil conditions sensor immediately identified the water problem, whilst the oil temperature remained stable.



Nevertheless it must be stressed that this oil sensor, like all oil sensors, remains a "blunt" instrument, showing only that "something" is wrong, but not exactly which parameter is in an abnormal state. However, the engineer will have the advantage of a continuous real time early warning system and the added advantage that when the amber sign is alerted an oil change is recommended.
The engineer is also advised to send a sample to the appropriate laboratory for confirmation of the oil and machine condition.

It is also often claimed that any oil sensor is required to identify exactly what the problem is, such as water or soot etc.
This idea is unjustified and not really a problem, as even if such a sensor could distinguish between each parameter and one day such an oil sensor will be designed to do so; it would still be necessary to send a sample of oil to an oil testing laboratory to identify what damage, if any, has been caused to the machinery.
Suggesting an investment in such technology may not prove any more advantageous, but a lot more expensive.

DMS believe that continuous oil monitoring systems have now become simple, cost effective and complimentary to an existing laboratory oil-sampling programme.
With the ever-escalating price of crude oil, it assists engineers on large expensive gear reducers to make informed decisions when it comes to replacing the oil.
With this Tan Delta monitoring system the guesswork is taken out of the process!

CONCLUSION

RCM is the future for industrial maintenance programmes in the metal and aluminium processing industries and condition based monitoring is an integral part of that future.
It has been shown how and why all maintenance staff should adopt an RCM policy.
Maintenance should not be considered as a necessary cost but as a strategic asset.

Maintenance influences the entire operation, from product quality to on-time delivery.
Predictive maintenance is designed to help organizations get the most effective use of their assets and equipment.

In the metal processing industries modern industrial gear reducers are a major critical and high capital outlay assets. These assets need careful monitoring and a combination of complimentary monitoring techniques should be utilised, to get the best overall picture of their ongoing performance.
In doing so they should first carryout a risk assessment on all assets, prove by calculation the savings possible with RCM, carry out the appropriate RCM programme, and determine whether continuous or periodic schedule monitoring is required.

Industrial gear reducers are complex special design units and not one monitoring technique is perfect and a combination of vibration and oil analysis has been proven to be a successful combination.

Newly developed continuous monitoring on-board oil sensors can now be fitted easily to critical gear reducers to monitor the overall oil quality, condition and temperature, especially in hostile or remote environments, on such applications as cranes.
An on-board oil sensor will fill a vital role in the continual strives to reduce downtime and improve profits.
Ideally, a Tan-Delta type oil condition sensor used in combination with regular oil condition monitoring (sampling) will prove to be the most effective force in the struggle to protect remote and vital oil lubricated equipment.

ACKNOWLEDGEMENTS

Mr. Chris Collister – Inventor of the Tandelta Oil Condition Sensor
Wearcheck UK Laboratories (ALcontrol UK Ltd)
Tan Delta Systems Ltd. Owners of the Tan Delta patent’s.
Drive Managements Services Ltd.
British Institute of Non-Destructive Testing (BINDT)

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