Wear Debris Analysis - A Meaningful Condition Monitoring Technique for Industrial Drives

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Abstract

Wear debris analysis has recently become a more widely applied technology in machinery health monitoring. This paper describes what it is, where it's application is relevant and the kind of successes that have been achieved in it's use.

1. Introduction

Wear is the primary mechanism by which industrial plant deteriorates. By observing the amount and mechanism of wear periodically one is able to monitor the deterioration of plant. Traditionally this has been done by SOAP (spectrometric) analysis of used oil. In industrial drives this has a major deficiency, the most important size fraction, that is the particles above 10 microns are ignored. In a "normal" industrial drive as shown in Fig. 1 the average particle size is 15-25 microns. In most cases in a distress situation the size of these particles increases and traditional techniques have not been able to effectively detect this. Wear debris analysis overcomes the particle size limitation and gives additional information on the mechanism, location and extent of wear as well as the state of the Lubricant and contaminant content.

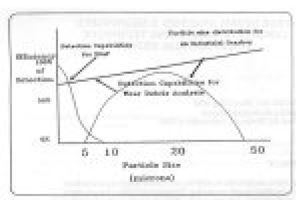


Fig. 1 Showing the particles size effects of SOAP vs Wear Debris analysis.

To some extent wear debris analysis has taken over the major role of condition monitoring within the mining industry within the UK even though it is a relatively newcomer on the condition monitoring scene.

2. Wear Debris Analysis

The basic principle of operation is simple. A representative sample of oil is tested through the following cycle.

1. Obtain an oil sample from a machine.
2. In the laboratory take a measured amount of the fluid and deposit into a clean beaker. The sample is then diluted with a solvent
3. Draw the sample through a membrane filter or use a magnetic separation technique such as the rotary particle depositor to separate the solids from the fluid.
4. The amount of ferrous wear is quantified by means of a debris analyser such as the PQ2000 manufactured by Swansea Tribology Centre.
5. Visually analyse the debris at 100x magnification under a reflected light microscope quantifying the following parameters:

- Type of particle (relating to the mechanism of removal)
- Average particles size
- Maximum particle size
- Contamination index

These parameters are then trended in a custom designed software package and the diagnostician awards the unit a Health Status. The health status is a single parameter which gives the unit a level of threat. (Health status is a parameter between 1 -5 with 1 being a healthy machine and 5 being a machine which is imminently threatened with failure.)

6. Repeat the procedure at a decided time interval.

Wear debris analysis is a relatively simple procedure not requiring a high skills level to perform. Even so the results give a direct indication as to the level of threat and damage within industrial drives absent from some of the more sophisticated techniques.

3. Visual and Microscopic Examination of the Debris Samples

Visual and microscopic examination of the sample is as important a source of information as the regular testing of the debris samples.

Prior to filtering the sample, examination of the sample visually within the sample bottle gives useful information. Water present within the oil sample can clearly be seen either in the form of emulsification or as a distinct water layer. The general cleanliness level of the oil may also be determined.

Once filtered the debris should be visually examined prior to microscopic examination. The presence of water within the lubricant can be detected from the filter paper. This is seen in the form of light circular areas on the filterpaper. Water also sometimes oxidises the ferrous material, and the presence of rust indicates the ingress of water. Water effects the viscosity of the lubricant, considerably reducing the effect of the lubricant, increasing wear rates and should be avoided.

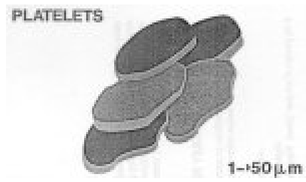
Frequently gearboxes become contaminated with mineral particles such as silica, coal and shale. These produce fine abrasive wear particles normally only observed under the microscope. The unchecked presence of mineral particles specifically quartzite with it's high hardness should be avoided. The mineral particles in suspension act as a grinding medium and produces excessive bearing wear which leads to loss of gear and shaft location which further accelerates the wearing process.

The various debris testers available do not respond to non magnetic materials such as:

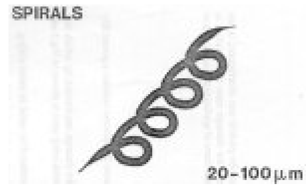
Chromium	Brass	Coal
Tin	Bronze	Copper Minerals
Antimony	Phosphor bronze	Aluminium
Aluminium bronze		Molybdenum disulphate

These are often clearly visible on the filter paper, and should be carefully looked for because even though they may be present in quantities no indication would be given by the debris tester.

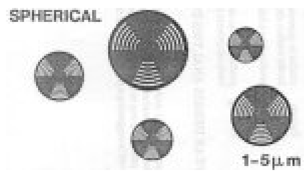
Fig. 2: Diagramatic Illustration of Particle Types



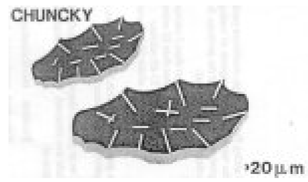
1. "Normal" Rubbing Wear



2. Cutting Wear



3. Bearing Fatigue, Overheating



4. Gear Fatigue

The sizing (both average, maximum particle size and the particle size distribution) is one of the more important aspects of testing. In general the damage state of a gearbox is proportional to the size of the particles. In it's simplist form of application four classes of size classification are used:

Fine	less than 5 microns
Small	less than 25 microns
Medium	25-60 microns
Large	above 60 microns

As a general rule, which has exceptions, particles over 25 microns indicate a potentially dangerous damage state for the unit.

The wear particle shape gives an indication as to the damage mechanism by which that particle was removed. The wear shape characterisation being used is shown in Fig.2 and consists of:

Platelets	two dimensional particles produced by metal to metal sliding.
Spherical	produced by bearing fatigue or by lubrication failure resulting in local overheating.
Spirals	similar in appearance to machining swarf, and are produced by a harder surface abrading into a softer
Chunky	produced by a fatigue mechanism
Fretting	produced by an oxidation mechanism where small intense cyclic loads are present in the presence, of oxygen in a close tolerance fit.

4. Wear Debris Analysis in South Africa:

The gearboxes in underground coal mining equipment have long been a maintenance problem. Traditional techniques of failure analysis, quality assurance and control have only gone part of the way to solving this problem. In 1986 Condition Monitoring Services was involved in suggesting a predictive rather than a reactive maintenance philosophy for these units.

To date a number of wear debris analysis mini laboratories have been installed and have monitored underground coal mining equipment with considerable success.

No other technique could have served this purpose due:

*** firstly** to the large debris size and quantity naturally generated in these units.

*** secondly** to the problems associated with taking conventional condition y monitoring tools into fiery mines.

*** thirdly** to the logistical problems of monitoring large numbers of gearboxes within a very hostile environment.

Since the early days of 1986 debris analysis has become a widespread and generally accepted technique of condition monitoring. Examples of some of the successes achieved with debris analysis are:

- failure prevention in diesel engines used in haul trucks.
- failure prevention in long wall mining and continuous miner gearboxes.
- failure prediction on a large selection of both surface and underground mining equipment used in the gold mining industry.
- contamination control in surface gold mining process equipment.
- grease and oil selection through comparative lubricant trials.
- condition monitoring of critical coal milling gearboxes in the power generation industry.
- failure investigations of critical bearings in ball mills used in the gold mining industry.

5. New Developments in Debris Analysis

There have been two innovative local developments of debris monitoring. These are

Contamination Control.

A simple technique for monitoring and reporting on levels of solid contamination within a system has been developed. Previously monitoring of contamination to the accepted codes has either been time consuming or required an expensive investment in equipment. Now users are able to set contamination limits for their equipment and simply monitor whether they are within these limits.

Grease Analysis

A program for the routine monitoring of greases using debris analysis has been going on for over a year now. Ale major problem concerning grease is separating the wear debris from the solids occurring within the grease's additive assembly. As no generally accepted standard method existed, this had to be developed and refined into a meaningful technique. There has now been a buildup of data showing that not only can debris analysis be performed on greases but the technique is sensitive to mechanical health.

6. Data Management Processing and Reporting

Today more and more importance is being placed on the collection, control and effective use of information as a management tool. This is particularly appropriate in the field of maintenance management where so much can be gained or lost through effective action at the appropriate point in time. To facilitate using information as a powerful management resource, the CMS machinery health monitoring system has been developed.

The system is designed to be as adaptable as possible so as to allow future expansion as the users needs grow and also allow specific customised needs to be integrated as and when required.

Fig 3 The Wear index and Si level plotted against time of sampling for an industrial gearbox.

In addition the program has the ability to record maintenance details and costs, previous performance histories and has the facility to build in intelligence such as threshold values and acceptance limits. From the data stored within the computer it will be capable of producing management reports such as:

- Plant status summary reports
- Plant status exception reports
- Problem follow up reports
- Cumulative machine history reports
- Specific machine history reports
- Cumulative fault summary reports
- Cumulative equipment summary report

These additional new sources of information which in most cases were not previously available are an important in allowing management to optimise the availability of equipment.

7. Side Benefits of Instituting Wear Debris Monitoring Programs:

Beyond the main concern to prevent unexpected failures which most users of such systems have, there are a number of side benefits that have been experienced. These side benefits are easily overlooked but all contribute to instigating better use of machinery and reducing the running costs for users. Some of the hidden benefits are:

- regular sampling ensures that there is lubricant in the gearbox
- the oil is in a state whereby it will serve the required function
- reduction or elimination of unexpected failures allows better use of manpower
- extension of the life of mature machines
- allowing slightly degraded machines to be run until they can be conveniently rectified, whereas previously this machine may have been immediately taken out of service with resultant loss of availability.
- due to the reduction in failures, the high costs of transport, storage and handling of spares and sub assemblies is greatly reduced. In the UK coal mining industry this figure is estimated to be as high as 22% of the life cycle costs of machines.
- by sampling a unit immediately prior or after entering service an indication of the quality and workmanship during maintenance is obtained. At one mine this has led to an improved standard of maintenance both within the mine and by external contractors.

8. Conclusions:

Several methods exist for the monitoring of machine health. Present experience indicates the simple method of extracting oil samples periodically and monitoring the rate of wear are particularly appropriate to industrial applications.

Qualitative analyses of the particle morphology, is seen as an important factor in deciding what action to take once a problem has been identified, because it assists in identifying the source, severity and mechanism of wear.

As important as the physical testing of the sample is the method of communicating results to management. The computer plays a vital part in this role and as such has become an important part of the condition monitoring instrumentation required.

The benefits of obtaining better intelligence on the health of equipment from correct testing, interpretation and data processing, provide management with important information for strategic machine maintenance.

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