WEAR DEBRIS ANALYSIS USING FERROGRAPHY

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Abstract: Ferrography is a technique for analyzing the particles present in fluids that indicate mechanical wear. Ferrography provides Microscopic Examination and Analysis of Debris (particles) found in lubricating oils. These particles consist of metallic and non-metallic matter. The metallic particle in a wear condition that separates different size and shapes of metallic dust from components like all type of bearings, gears or coupling (if lubricated in path). Non-metallic particle consists of dirt, sand or corroded metallic particle. Analytical ferrography is among the most powerful diagnostic tools in oil analysis in tribology. When implemented correctly it provides tremendous information on machine under operation. Yet, it is frequently excluded from oil analysis programs because of its comparatively high cost and a general misunderstanding of its value. Performance may be improved through proper filtration of oil. Clean oil lubrication is always more effective. Adopting approach of oil replacement is expensive. A rapid centrifuged and/or magnetic separator cleaning system helps cost cutting and disposal of used oil, as well. Ferrography also helps improving filtration efficiency and frequency for oil cleaning systems.

The objective of this paper is to present the ferrographic analysis of wear particles contained in used lubricant oil samples that collected from the engine of dumper, A heavy vehicle that normally used in coal mines. The study showed that the application of wear particle analysis and ferrography in particular is an effective means to identify and respond to maintenance needs of Engines and machineries.

Keywords: Ferrography, Bichromatic microscope, Lubricant Oil, Debris.

I. INTRODUCTION

Continuous, in-site monitoring of lubricating oil quality is currently of major importance to modern military, manufacturing and transportation industries. The maintenance costs associated with rotating machinery represent a major part of total operating costs of all manufacturing and production plants. Depending on the specific industry, maintenance costs can represent between 15 and 60 percent of the overall cost of goods produced. For this reason traditional maintenance strategies are becoming increasingly unacceptable for many manufacturing industries. This has led to the need for research and development into more efficient maintenance technologies and methodologies.

During abnormal operating conditions the degradation of lubricating oil is typically brought about by the accumulation of wear debris particles and deterioration in physical properties of the oil. Over time the volume of wear debris and the deterioration of the oil properties will increase, leading to the catastrophic failure of the machine or system. In an effort to prevent this from occurring, detailed machine health condition monitoring techniques are sought to reduce machine downtime and greatly extend the effective life of machines.

A number of existing condition monitoring techniques consist of off-line oil sampling used for laboratory analysis. These types of methods include spectrography, ferrography, viscosity and acid content tests.

In this thesis, a condition monitoring measurement system is discussed that is capable of separating wear debris particles from oil sample and analysing their images. It is known as ferrography. Among
many monitoring methods, oil analysis is considered as an accurate and effective approach due to its capability of being able to reveal the wear condition of the machinery through the analysis of oil properties and wear particles. In addition to detecting and distinguishing faults, the key purpose of machine condition monitoring using wear debris analysis techniques is to fully understand wear mechanisms, to effectively assess the real wear stage of machinery, and to develop strategies to eliminate or decrease wear. When a machine is in operation, wear particles generated by the interaction of two moving surfaces or carried in from outside may cause abrasive wear if these particles have a relatively high hardness. Abrasive wear of engineering machine components caused by the abrasive particles is a major industrial problem, especially for mining and port machines. The significance of abrasive wear has received considerable attention over the last decades. Wear caused by the presence of abrasive particles is influenced by their size, concentration, shape, hardness, and sliding velocity, etc.

II. RESEARCH OBJECTIVES
The main objective of this research is to develop a methodology of monitoring that is capable of the detection and analysis of wear debris particles. It will help in assessing the problems in the machine at early stage and avoiding their catastrophic failure.

III. LITERATURE REVIEW
Jiaoyi Wu, Junhong Mao, Wei Cao, You-Bai Xie, [2014]: In this article, image projection transformation was utilized for extracting the overall characteristics of the wear-debris chains according to the fundamental feature of wear-debris arraying along the horizontal direction.

M.C. Isaa, N.H.N. Yusoffa, Hasril Naina, Mohd Subhi Din Yatia, M.M. Muhammada, Irwan Mohd Nora, [2013]: The objective of this paper is to present the ferrographic analysis of wear particles contained in used lubricant oil samples that collected from the engines, generators and gearboxes of a commercial marine ship. Flash point, viscosity measurement, ferrography analysis and energy dispersive X-ray analysis (EDX) have been employed to extract the relevant information about the physical aspects of used oil and the wear condition of the parts from generator, gearbox and main engine.

R.K. Upadhyay, [2013]: In this present work, used CH4 15W40 engine oil were monitored under bichromatic microscope to observe the contamination and surfaces wear micrograph. According to the observation, rubbing, cutting, fatigue, corrosion, abrasive and scuffing wear modes were observed.

N.K. Myshkin, L.V. Markova, M.S. Semenyuk, H. Kong, H.-G. Han, E.-S. Yoon [2003]: In the presented paper, the principle of operation of the optical ferroanalyzer (OF) jointly developed by V.A. Belyi Metal-Polymer Research Institute of Belarus National Academy of Sciences and Korea Institute of Science and Technology is presented. The results of bench tests of the analyzer are described and example of its application for condition monitoring of engine is shown.

B. J. Roylance, J. A. Williams, R Dwyer-Joyce, [2000]: Commencing with a brief description of some wear-related failures of critical components, such as bearings and gears, the different manifestations of wear debris are reviewed with particular regard to the methods employed to measure or capture the debris and how their characteristics are determined.

IV. ANALYTICAL FERROGRAPHY METHODOLOGY
In analytical ferrography, a ferrogram (i.e. microscope slide with deposit of captured particles) is prepared by pumping a fluid sample (e.g. oil or diluted grease) that contains wear particles through Teflon tubing.
Fig. 5.1- Engine oil sample

The sampling procedure in the field has significant effect on the validity of the results. The ideal sample (Fig. 5.1) is taken immediately downstream from the lubricated surfaces. The pumping is onto a specially prepared glass substrate, which has a non wetting barrier painted on one surface to centrally channel the liquid.

Fig. 5.2- Ferrogram (slide)
The ferrogram (Fig.5.2) is slightly tilted, with the entry end elevated, so that the fluid flows downward within the barrier toward a waste bottle. The tilted ferrogram is mounted above two permanent magnets. The magnets are separated with their magnetic poles counter posed, so that a strong magnetic field gradient is created in the vertical direction above an Al strip. Ferrous particles in the fluid experience a strong downward force. These particles migrate through the fluid down to the glass surface, where they are deposited in strings perpendicular to the direction of fluid flow. Because the distance from the magnet to the substrate is slightly greater at the entry side than at the exit side, the magnetic field strength is weaker at the entry side, causing only the largest (magnetically affected) particles to deposit. Farther down the ferrogram, the progressively stronger magnetic field deposits progressively smaller particles. For the same particle shape, motion downwards through the fluid as a function of size is governed by the ratio of the particle diameter cubed to the particle diameter squared. Nonferrous particles and contaminants travel downfield in a random distribution pattern, not being oriented by the magnetic field. They often appear between the strings of ferrous particles. Contaminants, such as sand and dirt, fibers and friction polymers, are also distributed in an irregular fashion throughout the length of the slide. After all the fluid in a given sample has been run across the ferrogram, a fixer solution is run to remove residual fluid. After the fixer dries, the ferrogram is ready for observation under the microscope. This is often a special microscope (Fig.5.3), equipped with both filtered reflected and filtered-green transmitted light sources that may be used simultaneously. This lighting scheme, called bichromatic illumination, will show a metal as red and a non-metal as green. Chemical analysis of wear particles can be carried out by various analytical techniques. Heat treatment of the particles on the ferrogram is another quick, inexpensive method of identification. By quantifying the ferrographic patterns (i.e. number, shape, size and texture) and determining the composition of different particles on the ferrogram, the origin, mechanism and level of wear can be determined. A Wear Particle Atlas was constructed, providing information for the identification of various wear particle types, the description of wear modes that generate these particles, and as a guide to the prediction of machine operating condition based on the identified modes. Since then, several new atlases have been published, some of which in electronic format. Machine maintenance records should suggest a proper sampling frequency. Once a possible problem is detected, the sampling frequency must be increased, until a positive determination is made on machine condition and the action to be taken. For each lubricant parameter that is measured, a control record is built that, after a period of time, will reveal normal operating ranges for a given type of machine/lubricant.

V. RESULT
This report is rated critical due to the presence of excessive sand and dirt particles (Fig.6.1) in engine oil. null quantities of white non ferrous particles have found during test.
Excessive sliding stress on the ferrous components (gears, cams, cam rollers, etc.) is indicated by the presence of marginal quantities of low alloy steel sliding wear particles (Fig.6.1). Inspection of internals can be planned at the earliest possible maintenance schedule for severe wear out of piston and related components. Resampling may also be considered before inspection. Large quantities of rubbing wear particles (Fig.6.3) are also found in sample during test, which can create excess rubbing of internals and can lead to the generation of secondary wear in the equipment.
On the other hand abnormal quantity of red oxide particles (Fig.6.4) found in the lubricant indicates excessive corrosion and need to cure. Presence of copper wear particles are normal but need some attention to minimise it. Cleaning the lubricant (centrifuge to remove the existing wear particles and contaminants) is necessary to avoid the generation of secondary wear. Maintenance is immediately required on this equipment as the size and concentration of rubbing and sliding wear particles, red oxide particles, sand/dirt particles has increased as compared to normal.

VI. CONCLUSION
The wear debris monitoring method access the nature of the particles generated when components wear. They can indicate exact nature of the machine problem. The methods of wear debris analysis used as an indication of machine conditions are:
Indication from the debris present in the oil
Indication from the size distribution of debris
Indication from the physical form of debris
Application of chemical analysis of debris

Ferrography today has advanced as one of the premier predictive maintenance tools. This technique for wear particle analysis is becoming prominent in the pulp and paper industry, especially for new plants with automated operations. With minor financial outlay, ferrography offers a diagnostic tool that enables plant and maintenance managers to make decisions more effectively.

VII. SCOPE FOR FUTURE WORK
- With Engine oil, sample of gear oil may also collected and examine for complete monitoring of Engine.
- For better identification and visualisation of wear particles present in lubricant a high range microscope with (100X) to (1000X) can be used.
- Resampling after a period of time interval following ferrography test of each may give increment in size and concentration of specific wear particles, which can very useful for engine monitoring.
- Another method like spectrography, D R Ferrography etc. may also used for condition monitoring.
- Instead of mining dumper, other vehicles, ships or spacecraft may use for sampling and monitoring.
- Use of micro scale measuring microscope and capturing software may give more information about identification of wear debris present in lubricant.

REFERENCES
1. Jiaoyi Wu, Junhong Mao, Wei Cao, You-Bai Xie, (Sep. 2014) - Characterization of wear-debris group in on-line visual ferrographic images.