Int. J. of Applied Mechanics and Engineering, 2006, vol.11, No.4, pp.751-754

This paper was prepared on the Fourth International Tribology Conference ITC 2006

FILTER DEBRIS ANALYSIS

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Due to normal friction, wear, corrosion, etc., it is not uncommon to find small amounts of debris in a used filter element. Ferrous metals may indicate wear of the steel parts. Principally, one can use a magnet to differentiate between ferrous and non-ferrous metals found in the used filter element. Further, the analyst should use microscopic examination of debris morphology characteristics such as shape, size, color, surface texture, thickness ratio and edge detail as their principal analysis technique. The wear debris morphological analysis technique has been applied for monitoring the condition of oil-lubricated machinery for quite sometimes. However, most the works reported to date have been focused on used oil debris analysis. In this particular work, systematic filter debris analysis is reported.

1. Introduction

Due to the finer (*25* micron) filtration of the lubrication systems, the SOAP (Spectrographic Oil Analysis Program) analysis proved to be inconclusive as a CM (Condition Monitoring) technique because all of the significant debris was removed from the oil. This particular work addresses this problem, the solving of which led to the development of the FDA (Filter Debris Analysis).

The technique involves removing system's filters at regular intervals for inspection (and subsequent wear trending). After cleaning the filters and gathering the filter debris on *0.8* micron Millipore membrane, the debris is analyzed under a microscope. The analysts will take note of the debris characteristics to determine the wear condition of the system and to track the system condition over time. An analyst is able to determine several important factors regarding a suspect system's wear condition from FDA. The type of wear metals present, e.g. copper based, may be apparent even though specific alloy compositions are difficult to determine through visual inspection with the naked eye or optical microscopes. Secondly, the general debris composition (i.e., mainly non-metallic paint chips) will help the analyst recognize the problem. An analyst may also be able to determine the type of wear occurring in a system by examining the morphology of large particular wear (e.g., cutting wear, spalls, or striations). These forms of information combine to give an experienced analyst an insight into the system failure modes before they occur (Roberge ***et al***., 1994; Rock ***et al***., 1992).

2. Fuel filter debris analysis

Many components within the rotary pump operate under hydrodynamic (or elastohydrodynamic) conditions, where a fluid film which provides adequate lubrication is maintained between the surfaces. Here viscosity is the key fluid property and, although these are not normally critical areas, a marked reduction in fluid viscosity may reduce the film thickness sufficiently to cause lubrication problems. Fuel specifications set a limit on minimum viscosity well above the critical level.

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The components where lubrication is more marginal operate under a “boundary lubrication” regime. In this regime the thickness of the fluid film between the moving surfaces is of the order of nanometers (typically 1 to $100\,nm$) and this is generally less than the dimension of the largest asperities (or irregularities) on the metal surfaces. Thus, under dynamic conditions, there will be collisions between these asperities resulting in local deformation of the surface and higher friction.

Wear Mechanisms – Fuels of low lubricity cause a breakdown in boundary lubrication resulting in excessive wear. To some extent a discussion of wear type hinges on the definitions used by different authors to describe what they have observed. However, three wear types of significance to fuel pump equipment can be identified (Tucker, 1994):

- Corrosive/oxidative wear, in which the surfaces are chemically attacked (and which can be important when fuels contain water)
- Adhesive (or sliding) wear, in which the contacting metal surfaces instantaneously weld together on a microscopic scale and are then forced apart. Scuffing is a severe form of adhesive wear.
- Fretting wear (or tribochemical wear), perhaps similar to adhesive wear but with a smaller amplitude of vibration such that the wear debris contributes to the surface damage.

The distinction between scuffing wear and mild adhesive wear is a matter of degree – in the former, more severe case the effected surfaces are roughened, whereas in the latter the surfaces can appear polished. The differences between adhesive wear and fretting wear can be cast in terms of the form of motion at the point of wear, with fretting being the case where the relative distance moved by the contacting surfaces is less than the dimension of the contact area, and sliding being the converse. A typical wear particle normally found both in fuel and lubricating oil filter are shown in Fig.1.

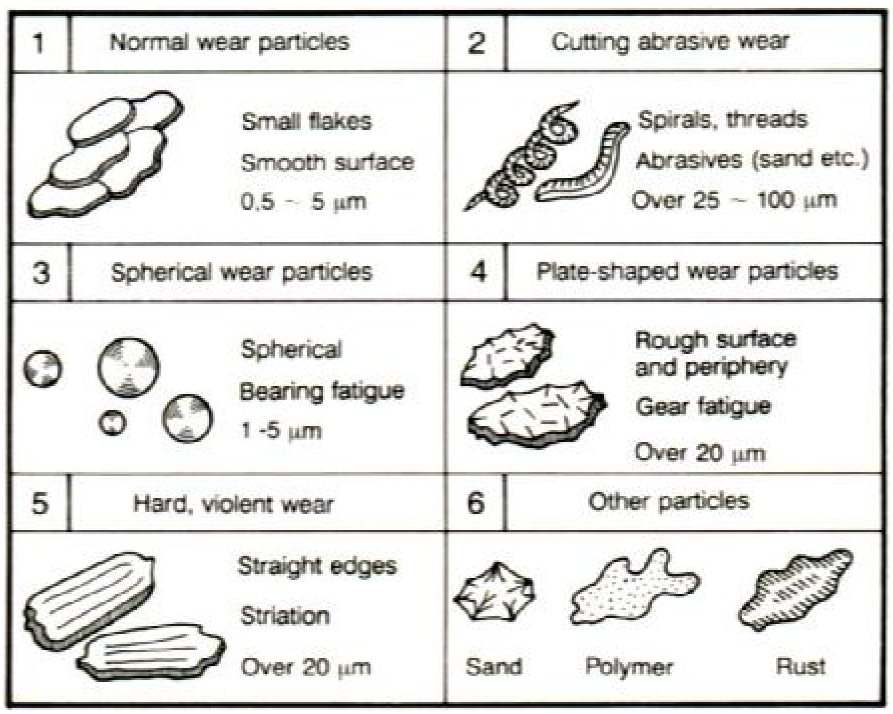

Fig.1. Typical wear particle morphology found in used fuel and oil filters.

In this particular part of the FDA work, the effects of Refined Palm Oil (RPO), as alternative fuel, on wear of diesel engine components are assessed. Fleet testing is carried for the qualifying candidates diesel fuel replacement, i.e., *100%* RPO fuel or *50%* RPO & *50%* conventional diesel fuel mixture. The base line of the fleet testing is using pure conventional petroleum diesel fuel as an energy source in one of the tested vehicles in the fleet.

The process for extraction of debris from fuel filter is shown in Fig.2. Analyses of used fuel filter, taken when the oil was changed in the vehicles, were compared. A typical debris from the used filer is shown in Fig.3.

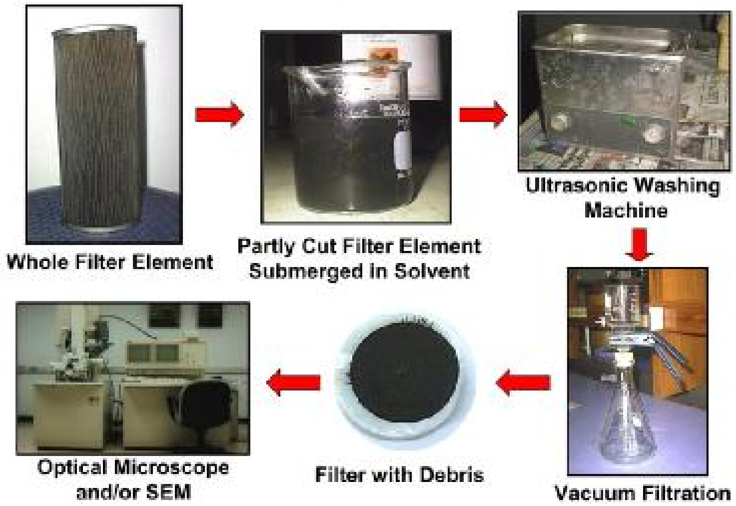

Fig.2. Fiter debris extraction procedures.

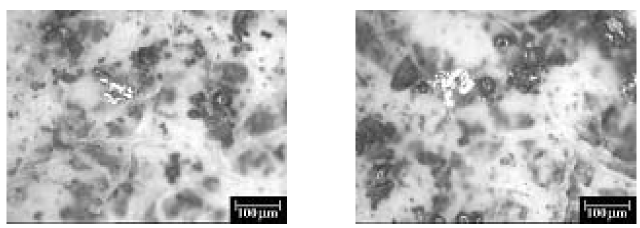

Fig.3a. *100%* Diesel

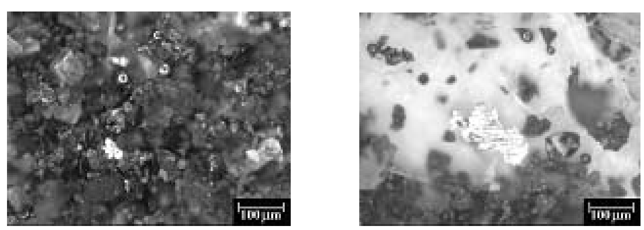

Fig.3b. *50:50* (Diesel: RPO)

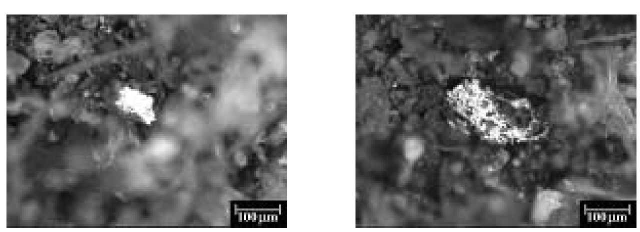

Fig.3c. *100%* RPO

Fig.3. Typical debris from used fuel filters.

3. Lubricating oil filter debris analysis

As it has long been recognized that wear debris and contaminant trapped by the oil filter are invaluable to condition monitoring analysts. Filters of lube oil of earth moving vehicles were collected and consequently contaminants and wear debris were extracted and assessed visually under conventional microscope and, in some cases, scanning electron microscope (SEM). Two sets of oil filters from different engine operating modes, namely, run-in and overhaul period, were assessed to demonstrate the distinction between debris characteristics. The filters to be analyzed are cut by a special tool to prevent additional metallic particles from its housing. Debris is separated from the oil filter media by submerging the oil filter in proprietary solvent and applying ultrasonic cleaning for *15* minutes. The debris is then captured on a $0.4\mu m$ absolute, polycarbonate Millipore filter using vacuum to expedite the filtration process. Figures 4 and 5 show typical debris characteristics found on the Millipore filters. Elongated wear particles are generally found in the filter collected from run-in period. On the other hand, chunky and/or spherical type wear particles are normally present in those collected from overhaul period (Raadnui, 1999).

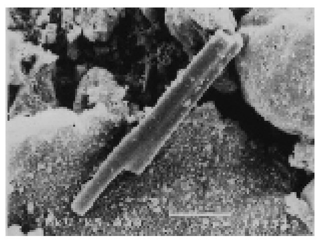

Fig.4. Elongated wear particle.

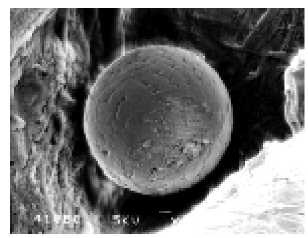

Fig.5. Spherical wear particle.

4. Conclusion

In a world that continually seeks out better, more efficient and cost effective ways of maintaining oil-wetted systems, CM has proven itself as the method of choice. The FDA being developed will provide a working example of how an analyst can aid condition monitoring technique in determining both the system state and consequent corrective action.

Acknowledgment

The Thailand Research Fund (TRF) has supported this work financially.

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Received: May 19, 2006

Revised: September 11, 2006