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NEW RECOGNITION TECHNOLOGY FOR FLUID SYSTEMS CONTAMINATION

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Summary: *Monitoring of technical condition of machines (e.g. engines) based on used oil analysis is an urgent practice to optimize control and maintenance. Both perfect wear products knowledge and used oil contamination is of crucial importance in order to make inspection, corrections or maintenance. The LaserNet Fines (LNF) technology [1] combines the technique of standard oil analysis, i.e., identification of number of wear and debris particles, automatic wear particle shape classification and trending tool to assist users in the field of ferrography. The LNF unit is a bench-top automated oil debris analysis unit which is a particle counter and shape classifier identifying sizes and trends wear particles and debris in all types of lubricants and hydraulic fluids.*

1. Introduction

The LaserNet Fines is a bench-top instrument that analyzes hydraulic and lubricating oil samples from varies types of equipment and machinery that are a part of condition monitoring program. The monitoring is based primarily on the morphological analysis of the abnormal wear particles that are created from the internal components of the machine. As a secondary application, the LNF is also an excellent particle counter. The operator is presented with an assessment of particles found in the fluid sample and history of previous results for the same equipment. The LNF consists of two maid components, see Figure 1, a bench-top instrument in which the sample is processed, and a PC to operate the instrument and manage the analytical data. Guiding principle of particle laser analyzer can be seen in Figure 2.
In the LaserNet Fines, oil samples are processed individually, one after the other. In the default processing time, a sample run takes approximately 3 minutes after shaking and degassing; 1 minute to draw the sample into the flow cell and 2 minutes for the actual analysis. For most samples, the new sample will adequately flush the old sample from the flow cell during the initialization period. Highly viscous or highly contaminated samples may require a flash to eliminate cross-contamination before another sample is run through the instrument. The different stages of the wear cycle depicted by both Ferrographic analysis and the LNF wear trending screen can be seen in Figure 3.
The new equipment LaserNet Fines (LNF) utilized to run the samples for the purpose of this article is a bench-top automated oil debris analysis unit which is a particle counter and shape classifier that identifies, sizes and trends wear debris in all types of lubricants and hydraulic fluids. The instrument does not require any special preparation prior to analysis, nor does it

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require any special type of gases or fluids. Its main components are: Collimated Laser Diode, Progressive Scan Camera, Flow Cell, Computer with Frame Grabber, Imaging Optics and Operating and Data Analysis Software [1].

Figure 1: LaserNet Fines Particle counter and Shape Classifier

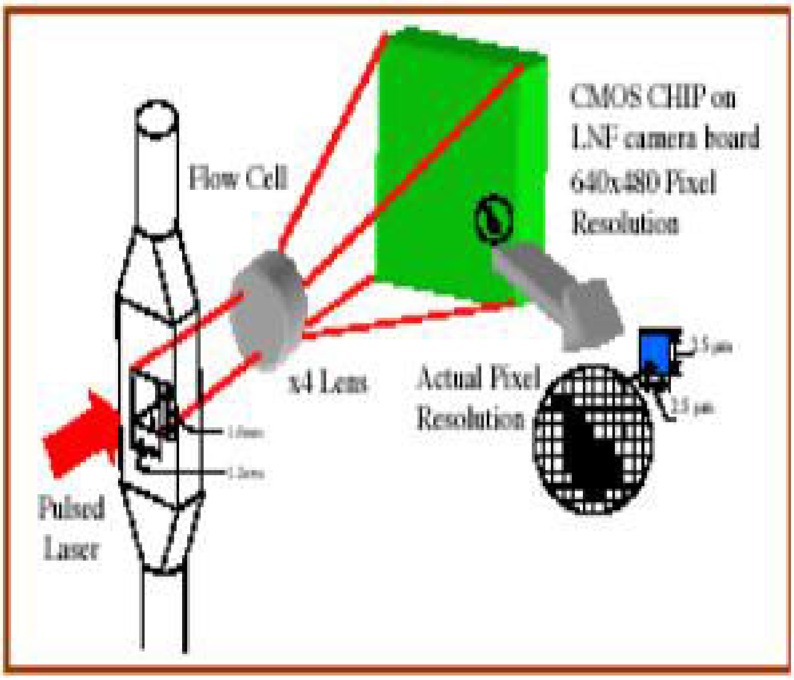


Figure 2: Guiding principle of particles laser analyzer LNF

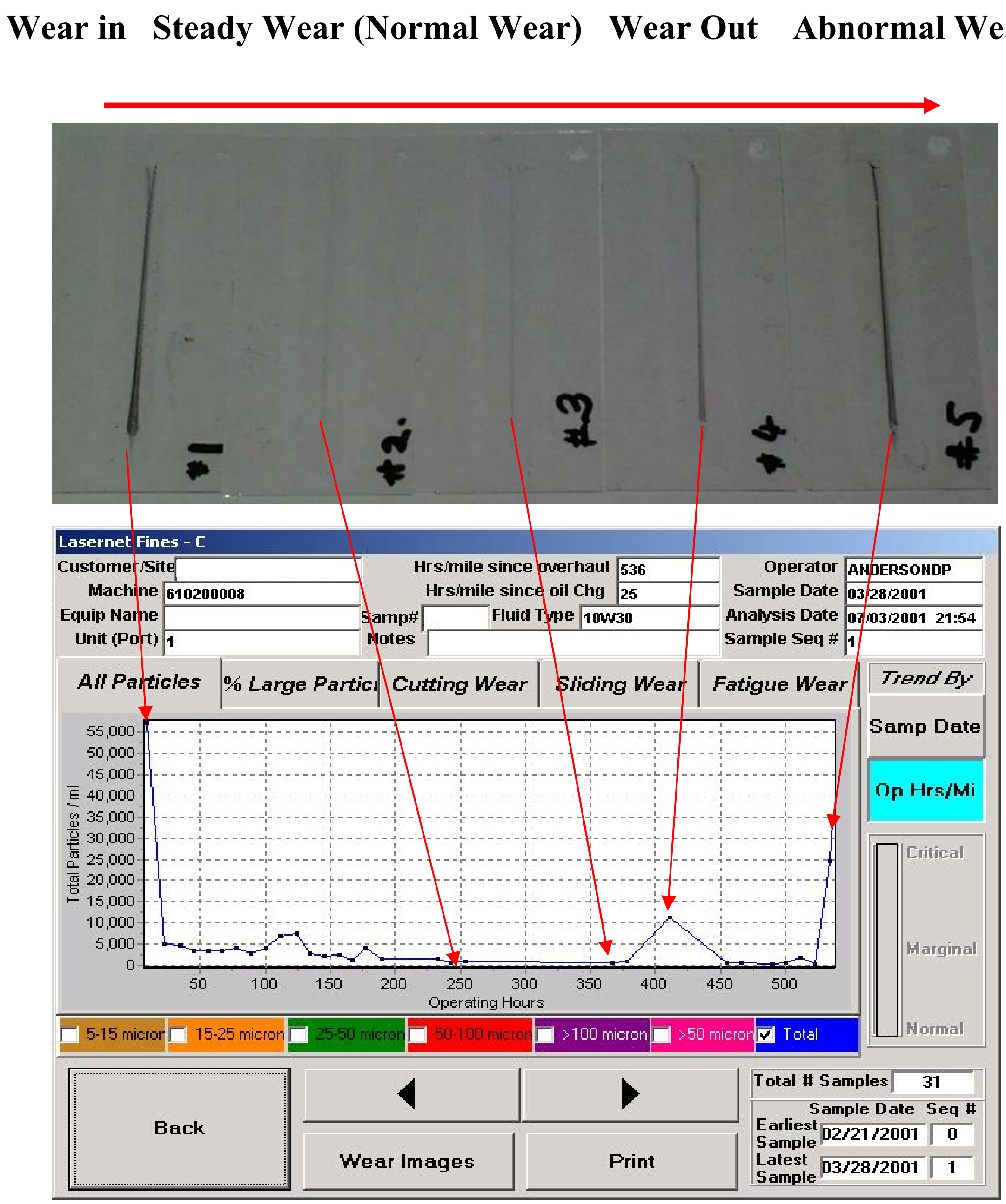


Figure 3: The different stages of the wear cycle depicted by both Ferrographic analysis and the LNF wear trending screen

The test dust size distribution was measured using a sieve and optical microscope resulting in a size distribution based on maximum diameter. There is a significant difference between the two distributions and this can be shown; an automatic counter calibrates with Fine Test Dust (FTD) measures an ISO [11] as measured with a scanning electron microscope, see Figure 4. The equivalent circular diameter used by NIST regulation [11] for the same particle distribution is smaller than the maximum diameter used in the FTD, see Figure 5. A particle counter is calibrated using the new ISO regulation; the size of any solid particulate sensed will be over estimated because it will be blocking more light than a particle of the some diameter with transparent areas which it was calibrated with, see Figure 6.

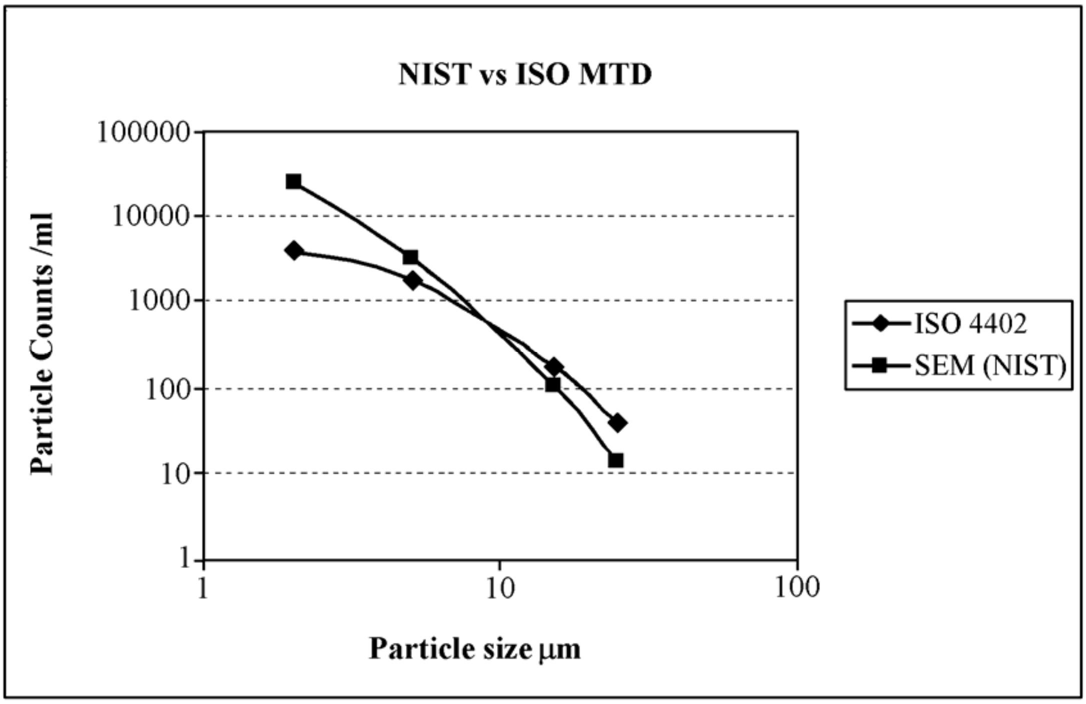


Figure 4: Significant difference between the two distributions when an automatic particle counter is calibrated with two measures

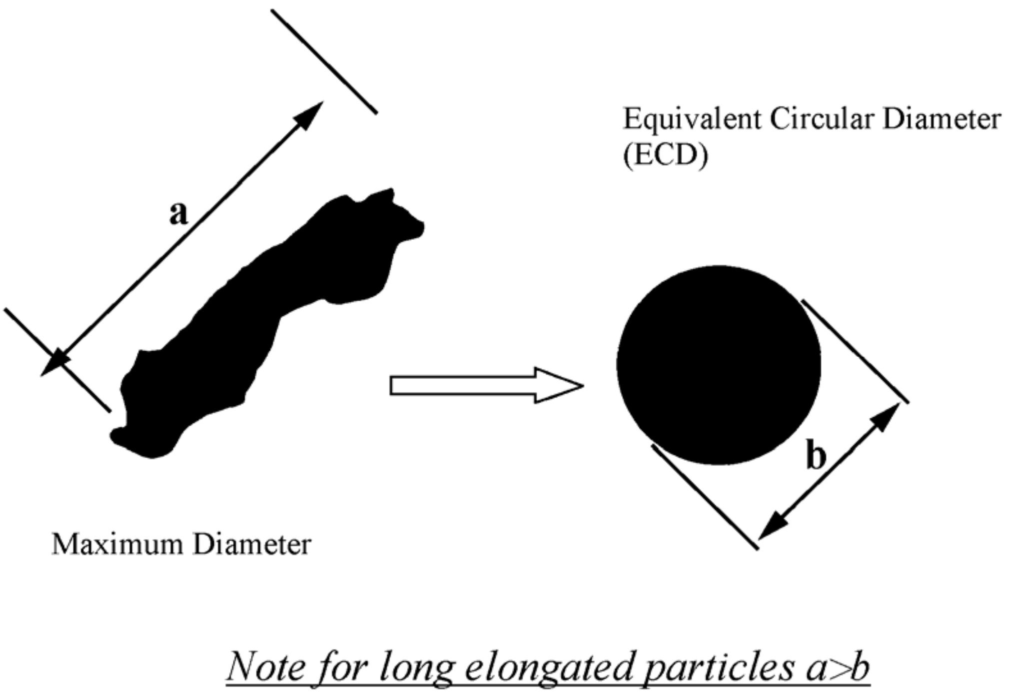


Figure 5: Equivalent circular diameter used for particle distribution

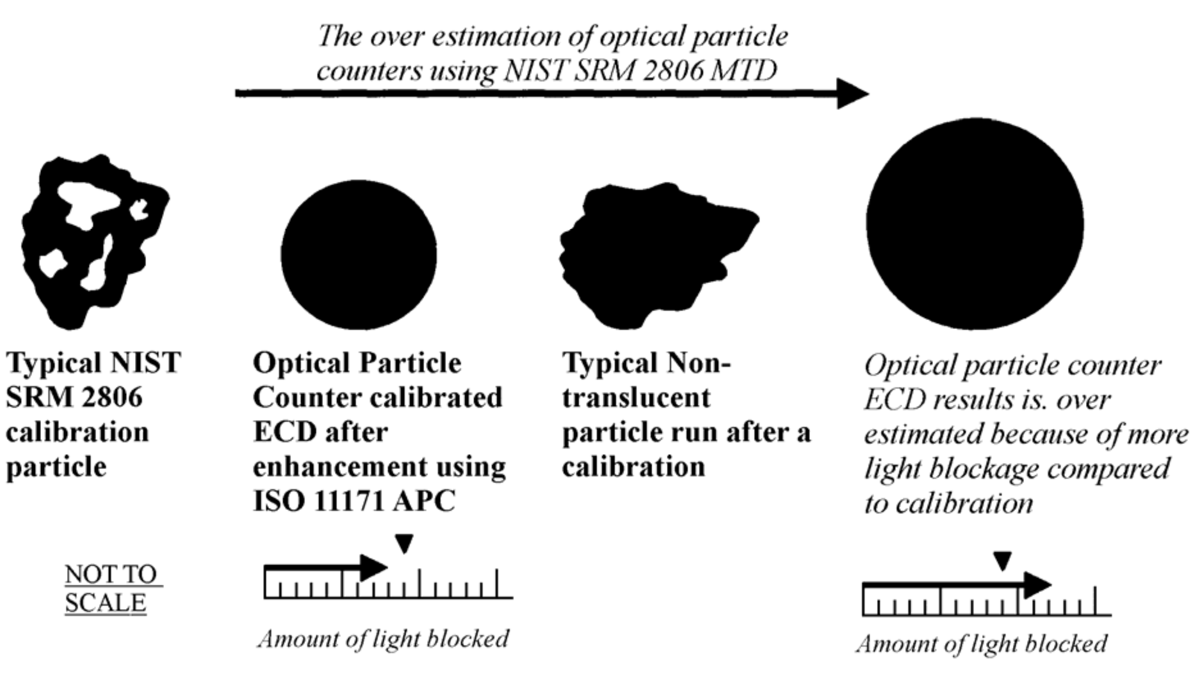


Figure 6: Scanning and calculation the equivalent circular diameter

2. Example of analysis

Complete case histories of samples were analyzed using the LNF. The samples were also run on an optical emission Spectrometer to check for any abnormal wear metal concentrations. From the LNF results specific samples from the set were chosen for a more in depth morphological analysis using the Ferrogram maker and the optical microscope [2]. The main purpose of the test program was to evaluate the shape recognition features of the LNF and compare them to the more conventional morphological analysis technique using the Ferrogram Maker and the optical microscope. The LNF can handle various lubricants with viscosities up to 350.10^{-3} m^2s^{-1} and with varying fluid darkness [3]. The oils which were analyzed, see Table 1, and presented in this article are from different applications and vary from hydraulic fluid to diesel crankcase oils. The different types of application attributed to each oil are listed below together with some comments which were observed from other used oil analysis techniques.

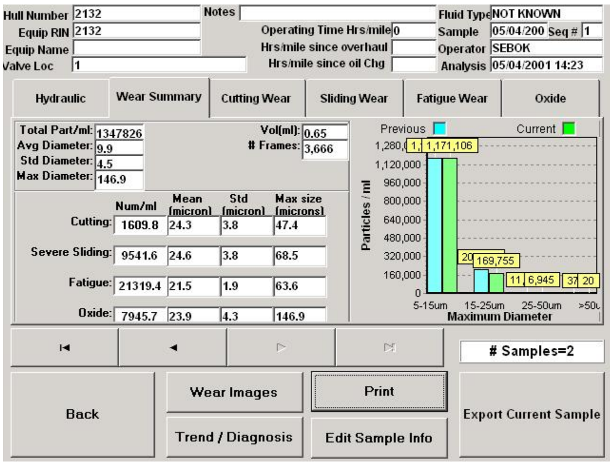
Table 1

Sample Nr	Application	Comments
1	Oil from an engine compressor	High Cu content
2	Oil from a hydraulic system	Fe and Cu increased
3	Oil from a car automatic transmission	Cu, Pb and Ag
4	Oil from a manual transmission	Failed shortly after
5	Oil from the Tatra 930 engine	No abnormal findings

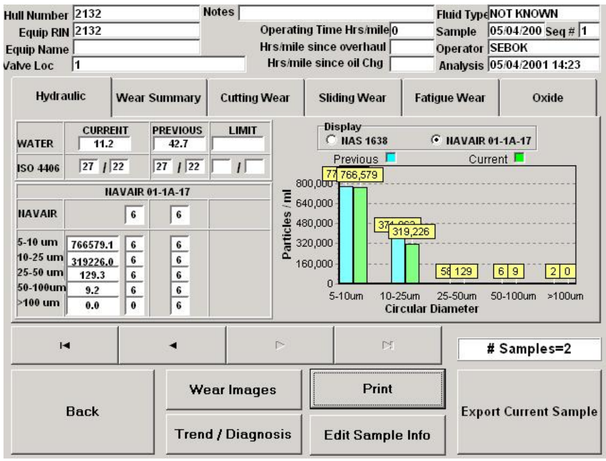
Visual inspection of the samples showed that they were not heavily sooted and therefore did not require a dilution with base oil the samples were first shaken using an automatic shaker. Before the analysis was undertaken the samples were shaken for a further 30 seconds and then placed in an external ultrasonic bath to remove air bubbles. Each sample took approximately 2mins 30 seconds to be initialized and analyzed on the LNF bench top unit. All the size resolutions and shape classifications are presented in a spreadsheet format in this article. This format is identical to the results which would be output from the LNF to a LIMS or other data information management station. This article also contains some individual screen shots of some of the different result screens. The Wear Summary screen shows particle concentrations based on maximum diameter compared to the Hydraulic screen which can present the results in either NAS 1638 or a NAVAIR [11] code format based on circular diameter [4]. The ISO particle counting codes and free water concentration are also presented in each of these screens. The graphical results page also shows a composite image map together with some enlarged particle type examples. The magnified particles are viewed by clicking on any particle within the samples composite image map [5]. Once the particle of interest has been selected it is shown in another window with its size statistics. It can then be zoomed in or out using the zoom buttons.

Sample Nr 1

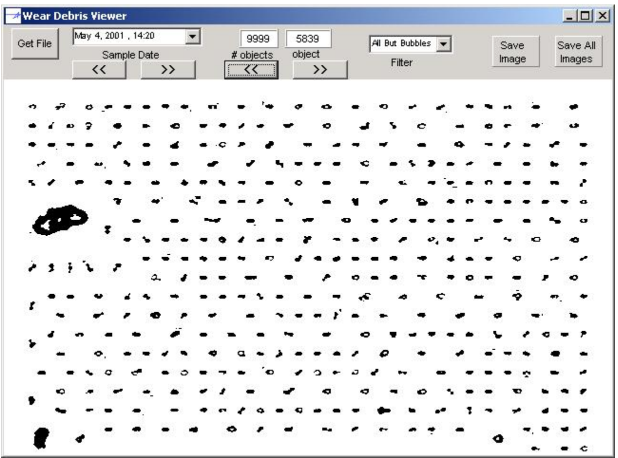
Wear Summary (Max diameter)



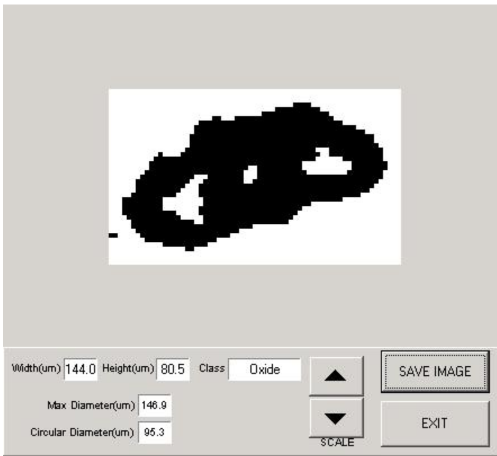
Hydraulic Screen



Composite Image Map



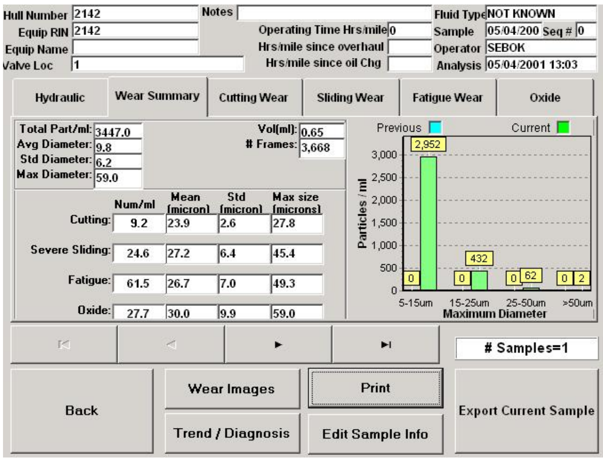
Zoomed Oxide Particle



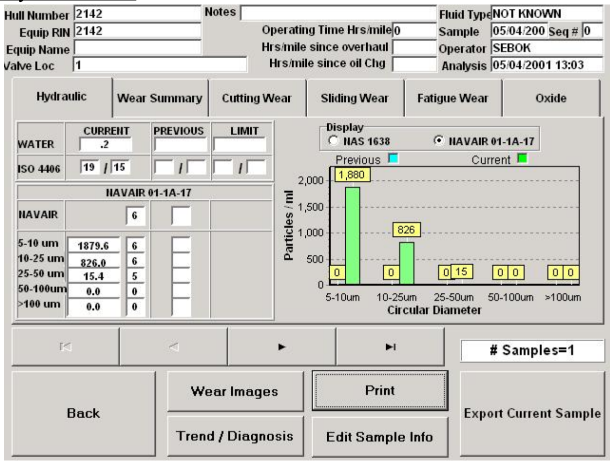
The sample showed a considerably high count of fine debris below 15µm. Abnormal wear (>15microns) was also present in high quantities in each of the severe wear classes. A large number of oxidative particles above 50 microns were also seen on this sample (see zoomed oxide particle) which may well have been caused by the high water concentration (42.7ppm- see above) also observed in this test [6].

Sample Nr 2

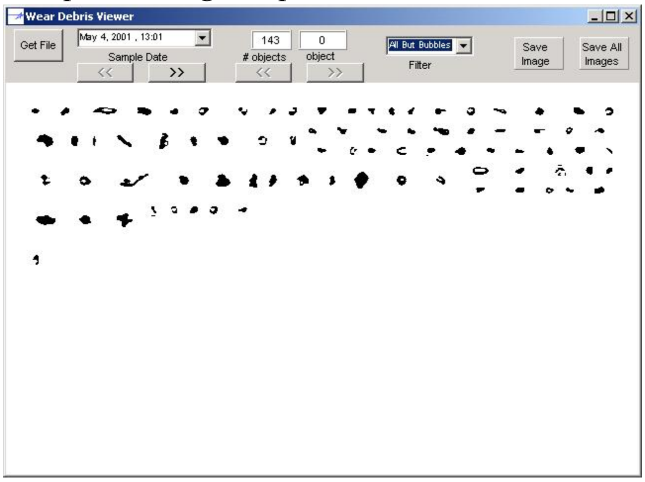
Wear Summary (Max diameter)



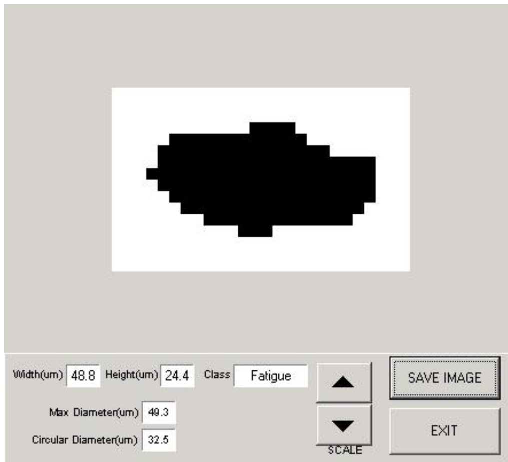
Hydraulic



Composite Image Map



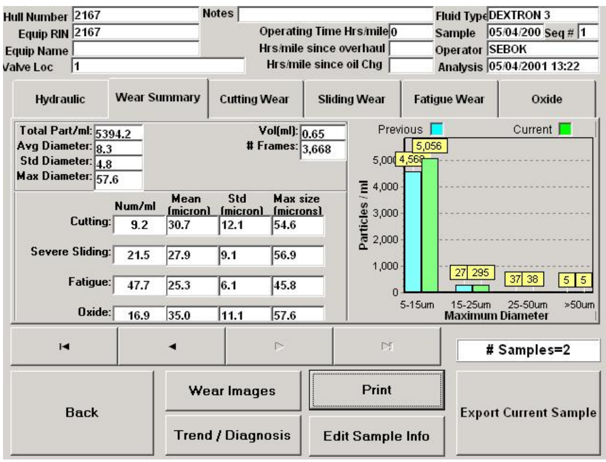
Zoomed Fatigue Particle



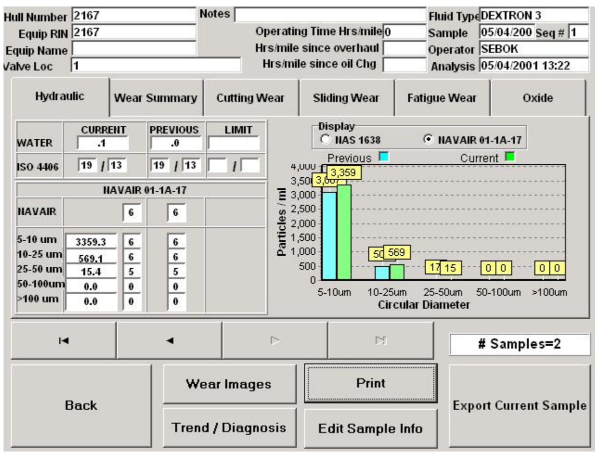
This sample showed a relatively high (abnormal) cleanliness code for a hydraulic fluid. The abnormal wear particle counts were found to be highest in the fatigue category (see zoomed fatigue particle) which may account for the high copper and iron levels established in previous tests.

Sample Nr 3

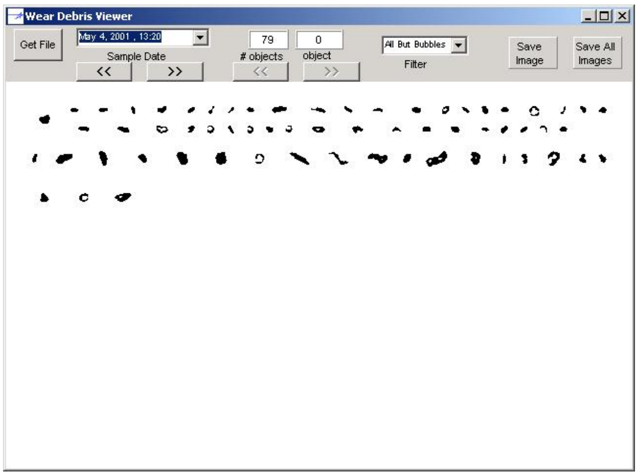
Wear Summary (Max Diameter)



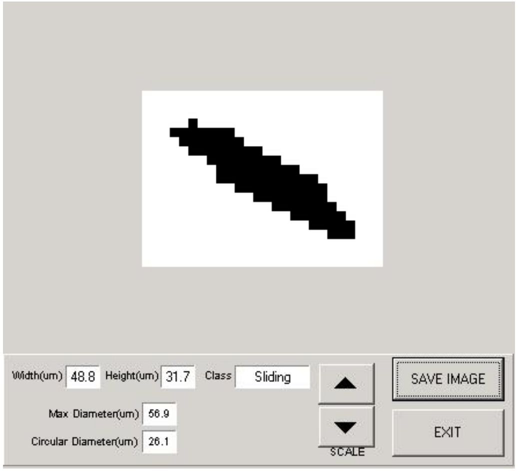
Hydraulic Screen



Composite Image Map



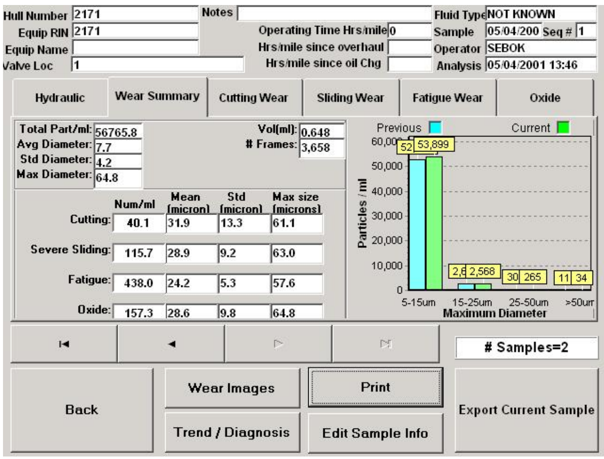
Zoomed Sliding particle



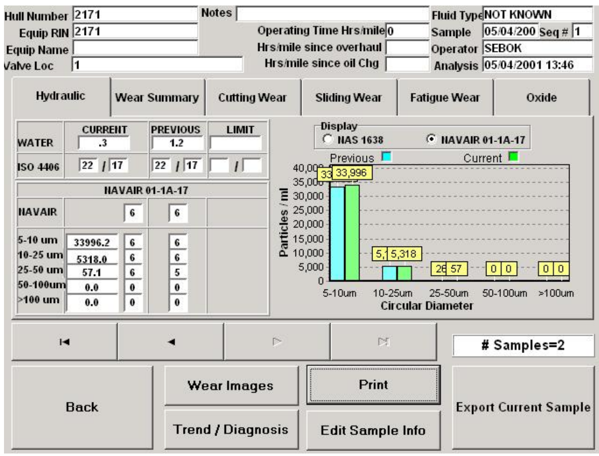
The earlier findings of Copper and lead may account for the abnormal wear counts which were prevalent in the Fatigue and Sliding categories.

Sample Nr 4

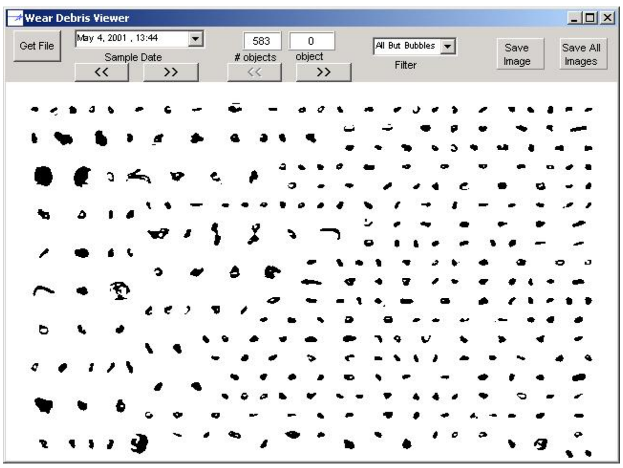
Wear Summary (Max Diameter)



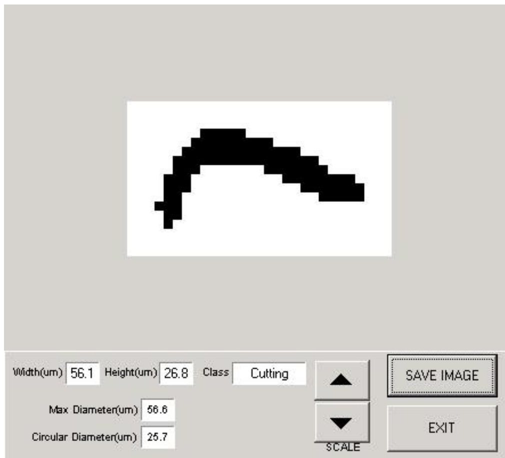
Hydraulic Screen



Composite Image Map



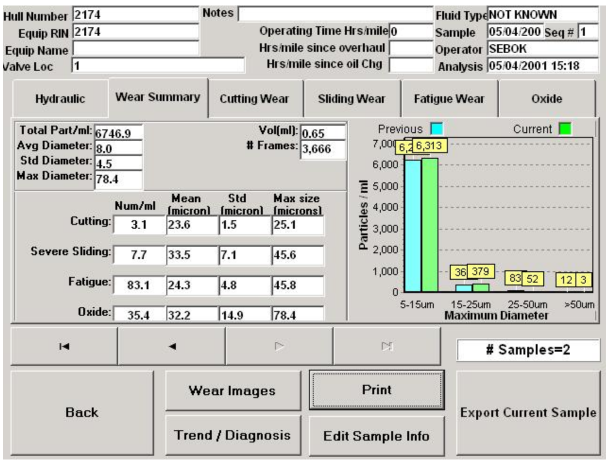
Zoomed Cutting wear particle



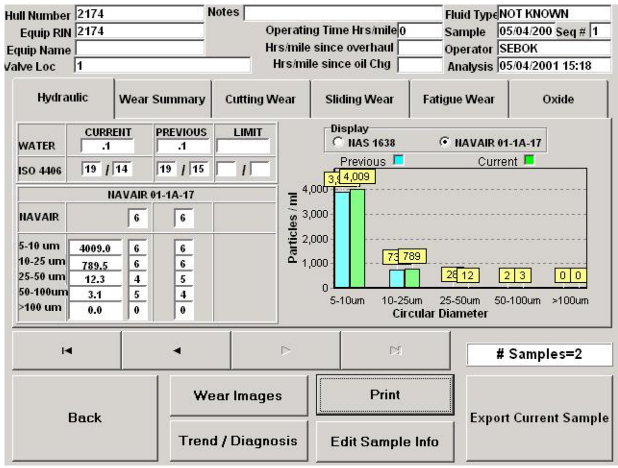
The particle counts showed a high ISO code together with high counts in all the severe wear categories (see composite image map). The Fatigue category showed the highest count but what is also of concern is the relatively high cutting wear counts which show classical cutting wear particle morphology (see zoomed cutting wear particle) [7]. The quantity and severity of the wear particles would indicate that the equipment was undergoing a severe wear mode. This was seen to be the case when the transmission failed soon after.

Sample Nr 5

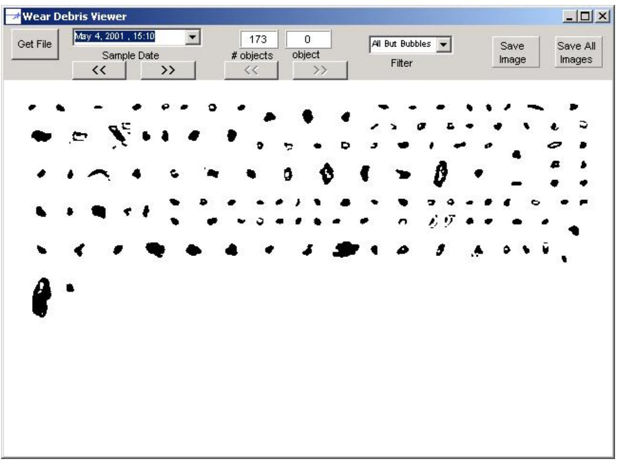
Wear Summary (Max Diameter)



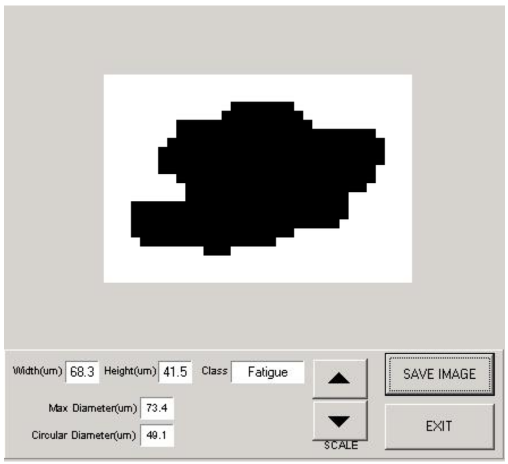
Hydraulic Screen



Composite Image Map



Zoomed Sliding Wear Particle



The ISO particle counts would not suggest anything too abnormal. However, the counts in the Fatigue category >20µm are high and would indicate a possible rolling contact wear mechanism [8]. The previous analysis tests found no abnormal findings within the engine of this piece of equipment. The LNF found some evidence of an abnormal wear mode in the form of fatigue particles which should warrant some concern and possibly further ferrographic analysis. In Figures 7 – 12 there can be seen results of ferrographic analysis of some choice samples we analyzed as our example (Table 1) [9].

Figure 7: Severe sliding wear particle, approximately 75 µm

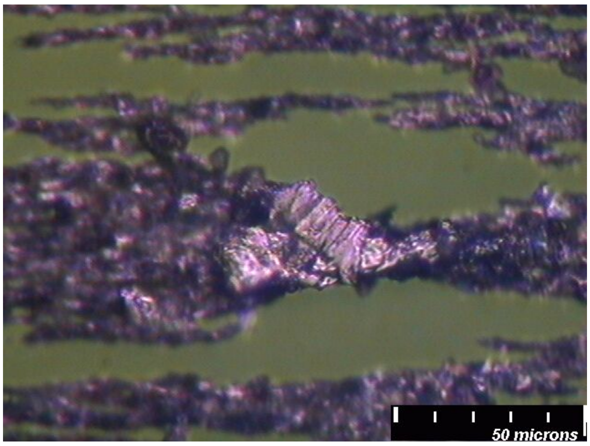


Figure 8: Two large particle 30 µm, generated during break-in

Figure 9: Chunky, 70 µm, during break-in wear

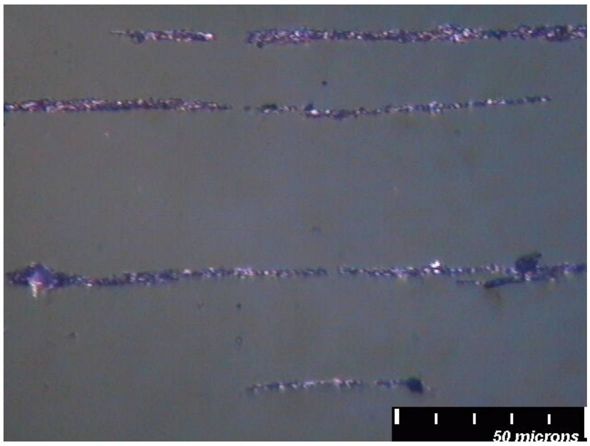


Figure 10: Fine rubbing wears debris, < 20 µm

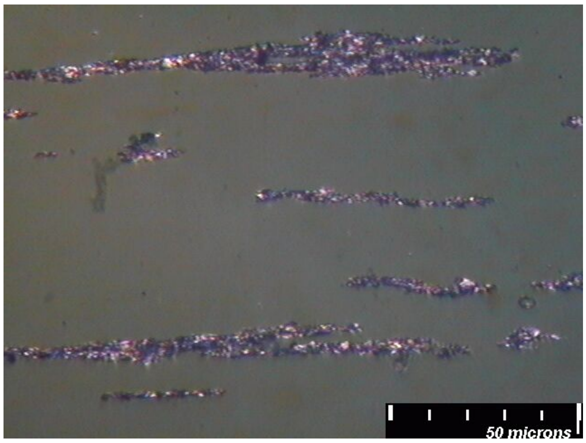


Figure11: Fine rubbing wears debris, < 20 µm

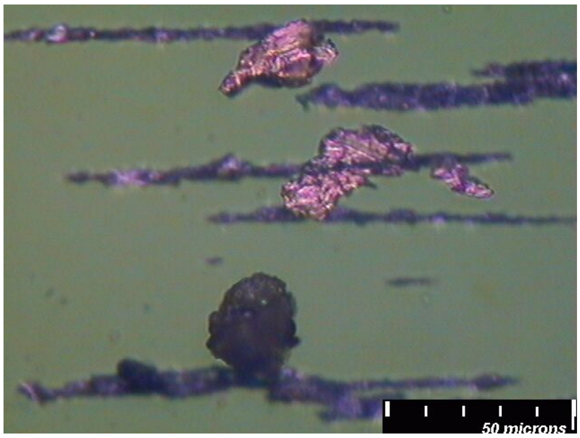


Figure 12: Severe rubbing debris, 40 µm

3. Conclusion

1. The sample results were found to be repeatable by running each sample for every application twice, except for sample 2 for which there was insufficient volume to run twice

2. The LNF was able to account for the high oxide particle counts in sample 2 because of the elevated water content it also detected and quantified.

3. The elements of copper and lead, which were found in earlier tests, are commonly found on their own or as alloying elements in journal (plain) bearings. The high fatigue counts may be bearing material.

4. The LNF was able to detect a severe wear mode by identifying and quantifying the morphology of severe wear particle types. (sample 4) This was further backed up when the transmission failed shortly after being filled with this oil.

5. The LNF is still able to detect abnormal wear which is undetectable by other instruments (sample 5). Analysis of a ferrogram would be able to back this analysis up if the LNF was used as a form of screening device.

The LNF-C results were found to be extremely consistent in terms of both the quantitative and qualitative aspects of more traditional techniques, namely Ferrography and Spectrometric analysis. The limitations of atomic emission spectroscopy have always been its inability to accurately quantify wear metal concentrations above 10 microns. However, it seems that in this particular failure mode enough small sub 10 micron aluminum debris was able to be detected [10]. The LNF's shape recognition feature showed a substantial increase in both fatigue and severe sliding debris during the final hours and although it is impossible to ascertain the nature and source of the debris by this method it certainly would warrant a detailed Ferrography analysis by an expert analyst. The Ferrography analysis which was undertaken clearly shows how well both the overall particle counts and the more detailed particle types compare with the LNF results. The aluminum particles can easily be identified by ferrography because they are non ferrous which means that the larger particles will be randomly deposited down the length of the ferrogram and not necessarily with their longest edge leading across the width of the ferrogram, as is the case with ferrous metals. The particles also appear very bright in comparison with the other debris as can be seen by some of the particle images presented in this report. It is not feasible to make Ferrograms and analyze each and every sample because Ferrography is both time consuming and expensive. However, this article has shown how both the LNF and Atomic Emission Spectroscopy can be used in conjunction with each other and be used as screening tools before a Ferrography analysis needs to be undertaken. The LNF can complement Ferrography by taking away the subjectivity and automating it to a point when a more definite answer needs to be obtained.

4. Acknowledgments

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