Portable Fluid Analyzer

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ABSTRACT

A portable fluid analyzer that combines LaserNet Fines for debris analysis, Fluid Scan for oil condition analysis and a COTS viscometer is described. Examples of instrument operation and results of application to shipboard equipment are given.

1.0 INTRODUCTION

We describe a portable, comprehensive, oil analysis instrument, called the Portable Fluid Analyzer, that provides immediate analysis of the physical properties of the oil and analysis of debris for the presence of mechanical wear and its source or for particulate contamination. The instrument combines the LaserNet Fines oil debris monitor, the Fluidscan oil condition monitor and a commercial viscometer into a single portable instrument controlled by a notebook computer. It was developed to address the need of fleet support personnel for immediate, actionable information during shipboard maintenance operations.

Comprehensive oil analysis, including both fluid condition and lube oil debris, is an important part of machinery maintenance. In combination with other diagnostics such as vibration analysis it is an important troubleshooting tool for fault diagnostics and machinery health assessment. Several major fault modes for diesel engines can be identified from effective oil analysis, including faults in fuel injectors, governors, and turbochargers, and bearing wear. Currently, analysis of lube oil from shipboard engines is done by drawing a sample and sending it to a shore based lab. There can be significant delays in getting the analysis results to the user. In addition, the routine tests used by the Navy for debris analysis are often inadequate for reliable identification of impending catastrophic problems.

ONR has conducted aggressive programs to address these limitations. The result has been the development of advanced technologies for analysis of oil fluid condition and debris. These technologies are the Foster Miller Fluid Scan oil condition monitor and the LaserNet Fines oil debris monitor.

The Fluidscan (FS) oil condition monitor has been developed by Foster Miller under ONR support for on-line applications. It measures the infrared transmission of the oil sample at several wavelengths that have been associated with important chemical species in the oil. From these measurements, quantitative determination of total water, soot, total base number (TBN), byproducts of chemical reactions by the oil additives such as sulfation, nitration and oxidation, contaminants such as glycol, and antiwear additive depletion are made. Infrared spectral analysis can replace standard lab analysis tests and allows immediate determination of oil properties on site.

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The LaserNet Fines (LNF) wear particle analyzer was originated at Naval Research Laboratory (NRL) and developed into a commercial instrument by Lockheed Martin under a patent license. This instrument analyzes debris particles in the lube oil and identifies directly the mechanical wear processes present in the engines from quantitative analysis of several aspects of the debris, including size distributions and shape characteristics of individual particles. In addition, it identifies the presence of other particle types such as sand contaminants, filter fiber and free water. This analysis allows identification of fault conditions due to mechanical wear, filter deterioration, particulate contamination and excess free water. This technology is an extension of effective laboratory microscope analysis and was developed specifically to address the shortfalls of monitors that measure only particle size or elemental concentrations.

LNF is currently available as a benchtop sample unit that can be used for on site analysis of lube oil debris. It operates with "dark" oils, e. g. diesel lube oil, allowing analysis to be made without the need for dilution. It provides immediate results for the sample analyzed, as well as trending for individual pieces of equipment and performance comparison between different engines. LNF has been used to analyze debris from main propulsion diesel engines (MPDE), ship service diesel generators (SSDG), emergency diesel generators (EDG), turbine engines, as well as line shaft bearings, HPAC, controllable pitch propellers, and flight control, aircraft elevator and submarine hydraulics.

LNF has demonstrated the capability to find and identify severe wear in Navy diesel engines that was not found by standard Navy SOAP tests. LNF has also demonstrated the ability to detect the presence of excess wear well in advance (up to 14 months) of component failure. LNF is a unique instrument that offers the ability to detect and identify the presence and severity of mechanical wear from quantitative assessment of several aspects of the debris.

A separate viscometer in the PFA measures the oil kinematic viscosity at 100 degrees Celsius, and temperature compensates that measurement to 40 degrees Celsius, the reference temperature used for the US Navy limits.

2.0 PORTABLE FLUID ANALYZER

The Portable Fluid Analyzer (PFA) combines the FS, LNF and viscometer into a single instrument on a Windows 2000 platform. It provides the operator with graphical and numerical analysis of an oil sample as well as trending data for any of the quantities measured. A typical analysis summary screen is shown in Fig. 1a. More detailed analysis of fluid condition and debris, including images of all particles larger than 20 micrometers and trending, are available on additional screens. Summary debris screen and fluid condition screen are shown in Fig. 1b and 1c.

3.0 RESULTS

PFA instruments have been made available to diesel inspectors for trial testing. Under this program over 50 samples have been processed through the PFA. Oil samples from shipboard Main Propulsion diesel engines and Ship Service and Emergency Diesels generators and a start air compressor were examined.

For the FluidScan and viscometer measurements the sample analysis interpretation is fairly straightforward, as there are limits or guidelines established by either Naval authorities or by commercial best practice. The LNF assessments are based on NRL's experience with oil samples from other types of equipment that were operating normally and a few that were distressed. Additional information can be obtained from class survey comparisons among similar equipment to look for anomalies. The distressed equipment samples that have been examined using the LNF instrument contained elevated concentrations of total particles and of wear particles with distributions that peaked for particle sizes above 25 microns in size, rather than decreasing with increasing particle size. These criteria serve as a basis for our evaluation of whether a sample is normal or possibly abnormal.

Of the samples processed in the trial program, none failed based on Navy limits or the commercial best practice limits for fluid properties other than viscosity. Several failed due to low viscosity readings.

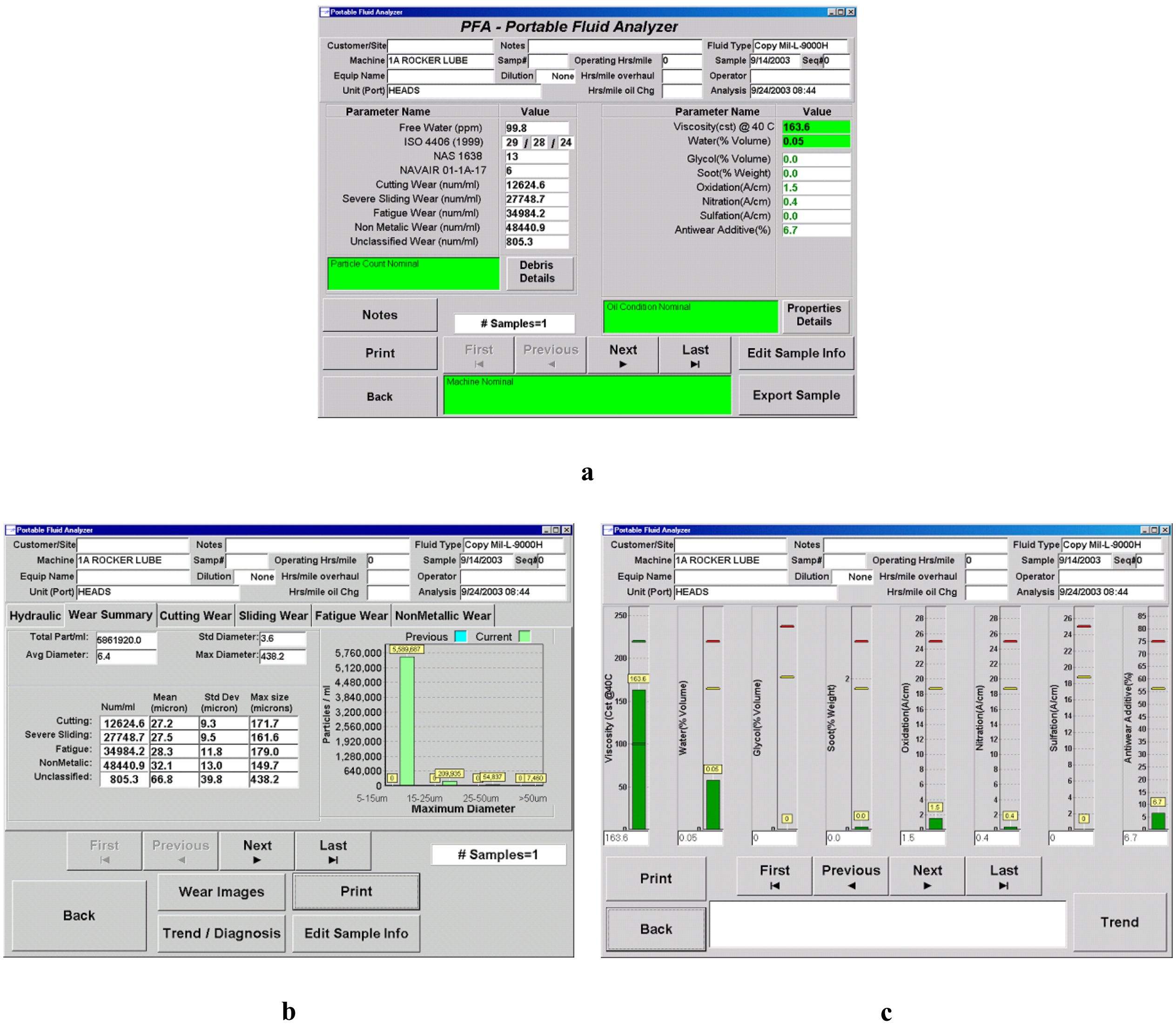

Figure 1. a. Top level summary screen; b. summary debris screen; c. fluid condition screen.

Wear debris analysis showed problems or potential problems in five pieces of equipment. These are: a rocker arm, the start air compressor, a SDDG , a MPDE and MPDE transmission. The first two pieces of equipment were sampled after failure and the other three may have indications of progressing problems. The wear debris analyses of the remaining systems were within normal ranges as determined by previous experience of LNF analyses of other systems and with class surveys of equipment covered in the trial program. The sample analysis from the two pieces of failed equipment is described below.

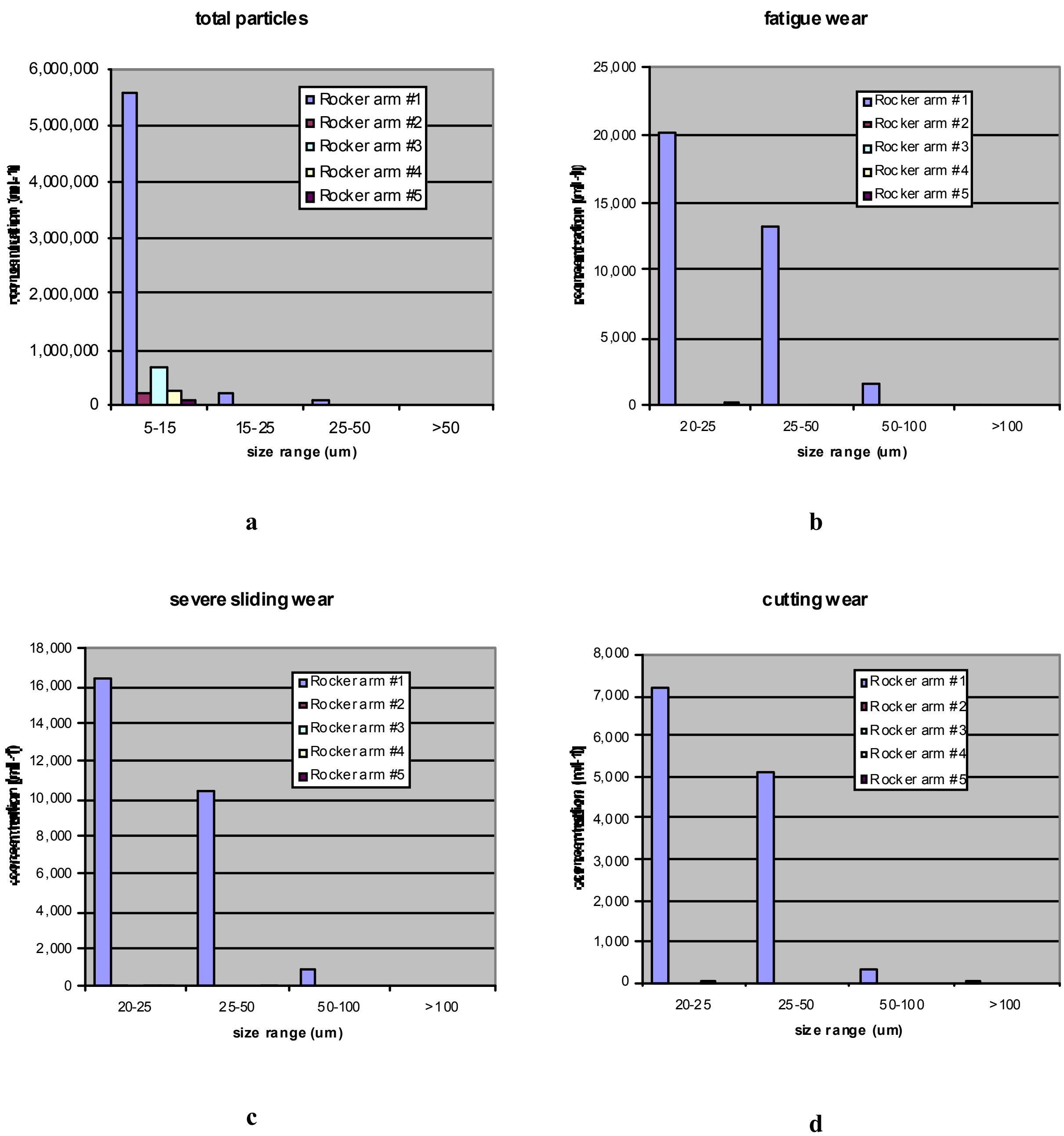

Figure. 2. Particle concentrations for a failed rocker arm and normally running rocker arms a. total particles, b. fatigue particles, c. severe sliding particles, d. cutting wear particles.

3.1 Rocker Arm Analysis

The wear debris analysis measured particle concentrations in the oil sample from the failed rocker arm sample that were substantially higher than those in other rocker arm samples. The increase in total particle concentration as compared to samples from normally running engines was at least 10 times, and the increase in the particle wear mode classifications for particles larger than 20 microns ranged from 50 to 200 times. These results are shown in Fig. 2.

The dominating feature of the sample from the failed rocker arm as compared to other rocker arm samples is the large concentration of wear particles. Since this sample was taken after a failure the high concentration of particles is not surprising. It is unknown what the wear debris concentrations were prior to the failure. However, the large differences in measured debris concentrations between the normal and failed rocker arm samples suggest that there may be substantial ability to see increased particle generation as the fault develops, allowing actions to be made prior to the failure. Continued sampling of normal and distressed rocker arms in various stages of failure can provide quantification of particle increase and allow alarm levels to be set.

3.2 Start Air Compressor

The oil sample from the start air compressor failure had classed particle concentrations that were a factor of 10 higher than any sample analyzed by the PFA from operating equipment. Although no air compressor samples were analyzed prior to failure, the large differences between particle concentrations and other samples indicate a strong potential to set alarms for early warnings of pending equipment failures. That sample also had substantial non-metallic debris. The distribution of non metallic debris particles along with a representative image map of the individual particles is shown in Fig. 3. The non-metallic debris shouldn't be created in the failure and may suggest external contamination as the root cause of the failure.

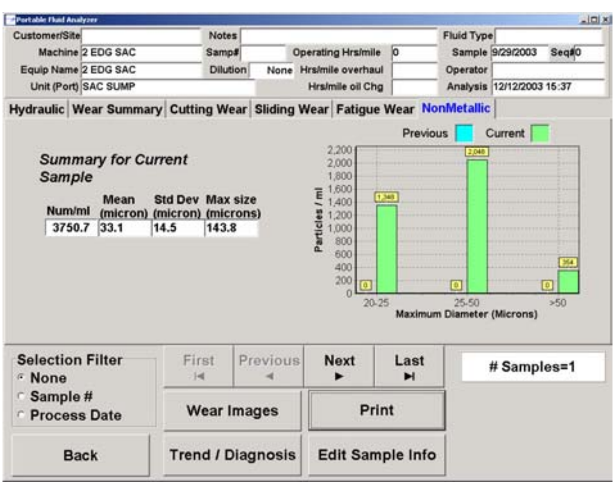

Figure 3a: Non-metallic debris size distribution from a failed rocker arm.

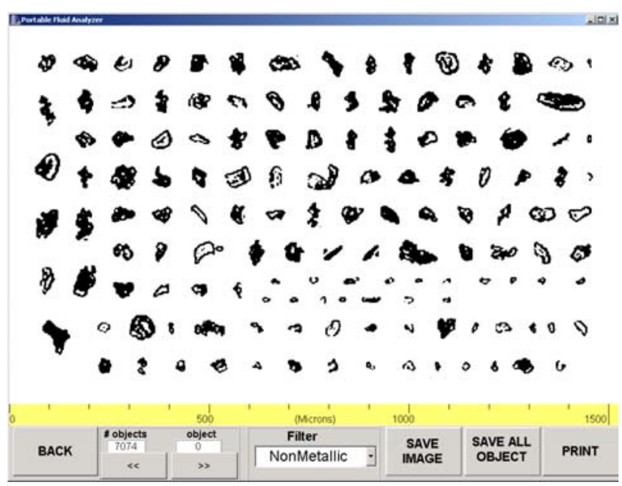

Figure 3b: Non-metallic debris particle map (one page of approximately 20) from a failed rocker arm.

3.3 Trending

An example of trending capability in the PFA is shown in Fig. 4. The samples were taken from a diesel engine during a break in run following overhaul. The trend for fluid properties show constant values throughout. The trend for wear particles shows the typical run-in period at the beginning with a relatively high particle concentration that decreases over time as engine components wear in together, followed by a period of relatively low constant particle concentration.

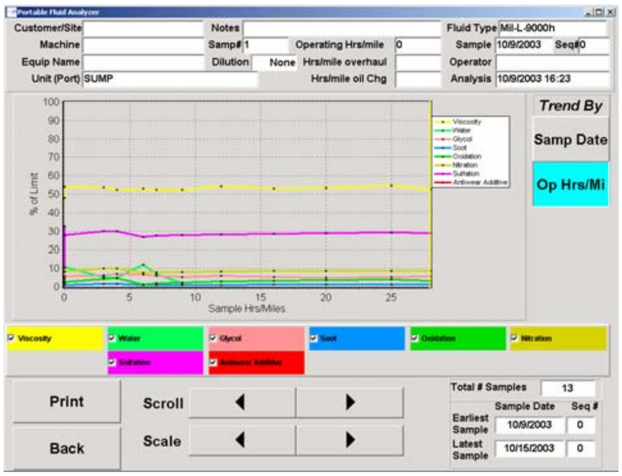

Figure 4a: Fluid properties trend screen for SSDG break-in run.

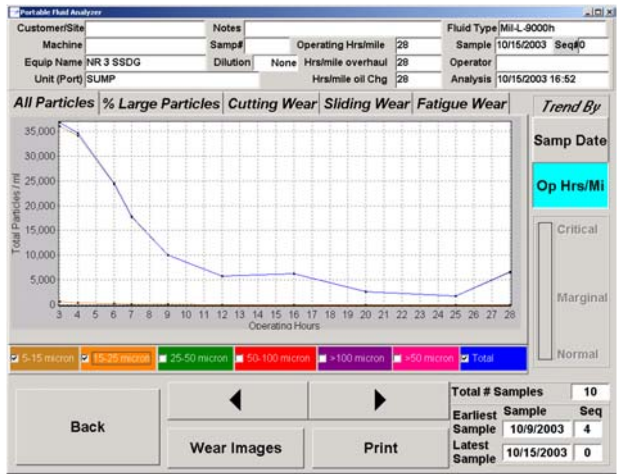

Figure 4b Total particle trend screen for SSDG break-in run.