

Next Generation Debris Analysis

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Abstract

Rolls-Royce Debris Analysis Systems are one of the defence industry's leading oil debris analysis capabilities.

In a step up from more traditional basic approaches to oil debris analysis, the system through an fully automated process analysis's oil system debris and then uses material type and risk algorithms to produce fast, accurate and timely warnings of potential oil-wetted component problems. In addition, the system will automatically trend the results for accurate and easy monitoring.

The Systems powerful analytical, data-interpretation, trending tools and networking capability are all housed in a self-contained, turnkey unit that is mobile, robust, easy to operate and deploy. The system can be used for Debris Analysis alone or as a complete EHM system Integrator. The system is supported by a 24/7 Help Desk where Customers have access to comprehensive technical support in any region or Time Zone 365 days a year.

The system delivers Value for Cost by significantly reducing bearing-related mishaps. As a direct result, the system can bring about increased aircraft availability, future maintenance planning assistance and an overall reduction of maintenance costs that military fleet operators are under constant pressure to deliver.

Given the high-risk nature of military flight operations, this unparalleled capability makes the Rolls-Royce systems a must-have tool for any air force or maintenance support facility.

A proven and trusted solution, these systems are used by the Air Forces of 16 countries around the world in support of many different engine types and engine manufactures.

Keywords: Desktop Scanning Electron Microscope (dSEM), Engine Health Monitoring (EHM), Scanning Electron Microscope (SEM), Engine Configuration File (ECF), Magnetic Chip Detectors (MCD), Original Equipment Manufacturer (OEM).

Introduction

Rolls-Royce is extremely proud they have partnered with a leading Scanning Electron Microscope manufacturer to create the next Generation Debris analysis capability for the Gas Turbine Industries. This new technology (dSEM) is a Light weight, self-contained, fully automated, and extremely deployable system capable of being utilized as the hub for all Engine Health Monitoring (EHM) tools. Slightly bigger than a desktop computer, the system has a fully functional Scanning Electron microscope (SEM) that rivals the much larger and more expensive current SEM solutions. This paper will describe the solution in its entirety along with a detailed vision of Through Life Support of the product and Customer.

dSEM Next Generation Debris Analysis

The dSEM was developed to provide an accurate and quick analysis of debris obtained from any wetted system. In addition, the system was required to incorporate a single source of storage/access of a customer's Engine Health Monitoring Systems EHMS.

A conventional SEM requires numerous hours of training and a strong background in the technical field of what is being analysed. Rolls-Royce has taken a proven system of debris analysis to the next level. Integrating the SEM capability with the EHMS host potential could provide a customer a single source of EHM data to be readily available. The debris analysis function provides the operator a choice of analysing sample/samples utilizing a data bank of known materials to provide a result that can be reviewed by the organizations Technical Engineering section. The second option and more desired option are to have sample/samples analysed utilizing an engine type model specific data base. In order to achieve this function an Engine Configuration File (ECF) will need creation utilizing Original Engine Manufacturer (OEM) specific engine model limitations and materials map per the maintenance manuals and any additional customer's requirements. Rolls-Royce has created a template of sorts to be utilized to establish the ECF. After the ECF is established the fully automated system will then provide the operator results based on a known parameter for engine specific limitations allowing them to make intelligent decisions on the health of the engine. Triggers can be set to recommend further maintenance requirements or specific steps to be followed to ensure they have a healthy engine. The system User Interface is setup for easy operation with minimal training. The developed step by step process will not allow an operator to move on to the next step without completing the previous steps requirements. A complete manual has been created to guide the operator through the process from start to finish including the sample preparation requirements and troubleshooting. Below is a description on the process the system utilizes along with the detailed system specifications.

Sample Preparation:

The key to accurate results starts with the sample preparation. Debris can be removed from Magnetic Chip Detectors (MCD) or from Filter assemblies. The 1st requirement from either source is to remove all oil residues from the sample. This can be done by utilizing a substance like Isopropyl Alcohol or any other material that removes the oily residues and dries the sample. After cleaned the sample is then transferred from a MCD to a 12mm carbon tab. (Note Carbon Tabs are used to create the perfect background for EDS Analysis) The carbon tab is coated with adhesive and the debris will bond to it. For the filter the debris they will require removal from the filter utilizing a flushing method and captured on a 25mm patch. Samples are then mounted to the custom tray for analysis.

How the system works:

The following material explains each element of the system including the product specifications. A single User Interface will control the fully automated system. The system will come standard with basic login controls and have the ability to customize the login features to comply with any customers security requirements.

Elemental Mapping and Line Scan

The Elemental Mapping functionality visualizes the distribution of elements throughout the sample. The selected elements can be mapped at a user specified pixel resolution and acquisition time. The real time mapping algorithm shows live buildup of the selected elements. For a user, it is simply click and go to work with the **Elemental Mapping and Line Scan** functionality of the desktop SEM. The Line Scan functionality shows the quantified element distribution in a line plot. This is especially useful for coatings, paints and other applications with multiple layers. All results of both the Elemental Mapping and Line Scan functionality can be easily exported in the customers required format by using an automated report template.

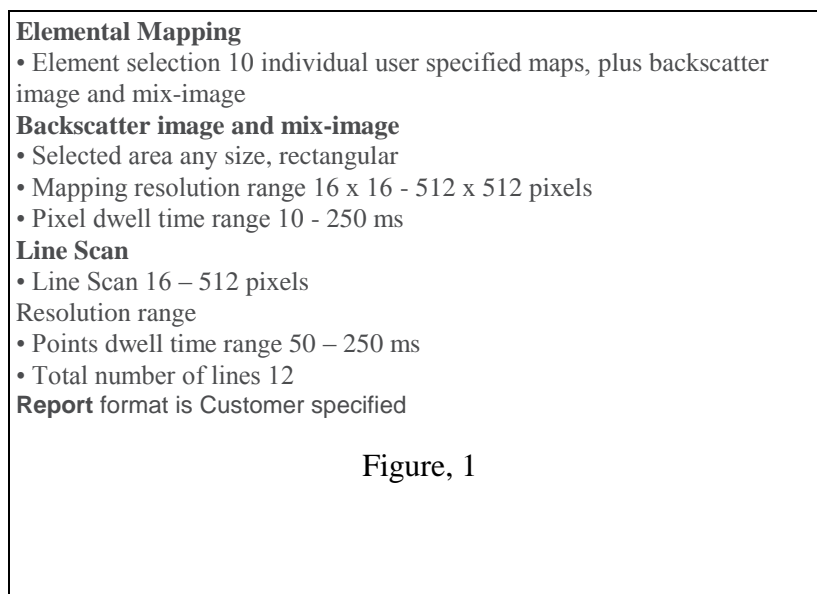


Fig. 1: Specs for dSEM System

Step by step data collection

A dedicated software package for Element Identification (EID) is used to control the fully integrated EDS detector. Analysis has become as easy as imaging, since there is no need to switch between external software packages or computers. The CeB6 electron source in the dSEM is used to generate the highest X-ray count rate in its market segment, allowing fast results. The EID software package allows the user to identify nearly all materials in the periodic table, starting from Boron (5) and ranging up to Americium (95). It is a perfect analysis tool for a wide range of samples and applications. Projects can be stored locally or on the network, where they can be analyzed at a later stage or offline. The EID software package runs smart algorithms with advanced peak analysis to optimize the auto-identification functionality, while still allowing for manual adjustments by the user at any time during the analysis process. The intuitive step by step process within the software helps the user to collect all X-ray results in an organized and structured way. Detailed chemical composition can be obtained from a micro volume via a spot analysis.

Detector type · Silicon Drift Detector (SDD)

- Thermoelectrically cooled (LN₂ free)
- Detector active area 25 mm²
- X-ray window Ultra-thin Silicon Nitride (Si₃N₄)

Window allowing detection of elements
B to Am

- Energy resolution Mn K α \leq 137 eV
- Processing capabilities Multi-channel analyzer with 2048 Channels at 10 eV/ch
- Max. Input count rate 300,000 cps
- Hardware integration fully embedded

Software · Integrated in Phenom ProSuite

- Integrated column and stage control
- Auto-peak ID
- Iterative strip peak deconvolution
- Confidence of analysis indicator
- Export functions: CSV, JPG, TIFF, ELID, EMSA

Report Docx format

Dimensions & weight

- Imaging module 316(w) x 587(d) x 625(h) mm, 75 kg
- Diaphragm 145(w) x 220(d) x 213(h) mm, 4.5 kg

Vacuum pump

- Power supply 156(w) x 300(d) x 74(h) mm, 3 kg
- Monitor 375(w) x 203(d) x 395(h) mm, 7.9 kg

ProSuite · Standard ProSuite System including:
19" monitor with PC and network
Router mounted

- 375(w) x 250(d) x 395(h) mm, 9 kg

Requirements

Ambient conditions

- Temperature 15°C ~ 30°C (59°F ~ 86°F)
- Humidity < 80% RH
- Power Single phase AC 110 - 240 Volt, 50/60 Hz, 300 W (max.)

Recommended 150 x 75 cm, load rating of 150 kg



Figure, 2

Fig. 2: Specs for dSEM EDS System

Engine Configuration File Creation:

Each and every Engine has unique Materials contained within it. Each OEM has dedicated identifiers for certain materials. I.E. M50 is bearing material, however it may have a different identifier for specific engine types. Basic Steps have been created for ECF establishment and some debris testing/evaluation is required to ensure accurate results will be provided every time an analysis is run. The following is a list of tasks (in order) that need to be undertaken to create an ECF. The Engine OEM and Customer inputs/outputs are required. RR is positioned to assist in the development of the ECF regardless of the Engine OEM with their support.

| Step 1 | Step 2 | Step 3 | Step 4 | |
|--|---|---|---|---|
| Engine ID | Materials Info | Analysis | Results | |
| Manufacturer | | | | |
| Aircraft Type | Materials name | Type of analysis: MCD, Filter, Semi- auto (AWD) | Rejection criteria | |
| Engine Name | Material Specification by composition % | Expected particle sizing | Algorithm Development | If different than rejection criteria |
| Engine Model Number | Element List | Excluded materials | Data capture for algorithm develop | |
| Engine Serial Number Format | | Sample tray needed | Trending needed | Specify trend details; i.e. materials, hours, specific hour windows (10, 20 etc) |
| Engine Status On wing, In test, Overhaul | | Desired measurements: microns, sq. thou | Expected reporting of analysis results | How do you want results grouped? Special reports etc |
| Engine Hours | | Required measurements | Exportable results | What data and formats |
| # of MCDs & names | | Morphology | Backup data | |
| # of filters & names | | | Data access requirements | Who/where |

Engine Health Monitoring Host:

The dSEM is not only a fully automated functioning SEM, it packs the power to store and distribute EHM data from any location. Whether your EHM system is Web based, Network based or downloadable, the system is capable of accessing and storing all the files. The system has a customizable storage capacity. We feel this unique capability brings the Next Generation EHM capabilities to the forefront.

Basic System Specification

Imaging modes

- Light optical Magnification range: 3 - 16x
- Electron optical · Magnification range: 80 - 100,000x
- Digital zoom max. 12x

Illumination

- Light optical Bright field / dark field modes
- Electron optical · Long lifetime thermionic source (CeB6)
- Multiple beam currents
- Acceleration voltages · Default: 5 kV, 10 kV and 15 kV
- Advanced mode: adjustable range
- Between 4, 8 kV and 20, 5 kV imaging
- And analysis mode
- Vacuum levels Low - medium - high
- Resolution ≤ 20 nm

Detector

- Standard Backscattered electron detector
- Optional Secondary electron detector

Digital image detection

- Light optical Proprietary high resolution color
- Navigation camera, single shot
- Electron optical High sensitivity backscattered electron
- Detector (compositional and
- Topographical modes)

Image formats JPEG, TIFF, and BMP

Image resolution 456 x 456, 684 x 684, 1024 x 1024

Options and 2048 x 2048 pixels

Data storage · USB flash drive

- Network
- ProSuite PC

Sample stage Computer-controlled motorized X and Y

Sample size · Max. 100 mm x 100 mm

(Up to 36 x 12 mm pin stubs)

· Max. 65 mm (h)

Scan area · 50 mm x 50 mm

· 100 mm x 100 mm (optional)

Sample loading time

- Light optical < 5 s
- Electron optical < 60 s

Figure 3

Fig. 3: Basic Specs for dSEM System

In conclusion, we look forward to discussing this next generation technology with each and every one of the attendees.