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Standard Practice for In-Line, Full Flow, Inductive Sensor for Ferromagnetic and Non-ferromagnetic Wear Debris Determination and Diagnostics for Aero-Derivative and Aircraft Gas Turbine Engine Bearings[1]

This standard is issued under the fixed designation D7685; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

In-line wear debris sensors have been in operation since the early 1990s. There are now thousands of these devices operating in a wide variety of machinery applications accruing millions of operational hours. Wear debris sensors provide early warning for the abnormal conditions that lead to failure. Improved machine reliability is possible due to the enhanced sensor data granularity, which provides better diagnostics and prognostics of tribological problems from the initiating event through failure.

1. Scope

1.1 This practice covers the minimum requirements for an in-line, non-intrusive, through-flow oil debris monitoring system that monitors ferromagnetic and non-ferromagnetic metallic wear debris from both industrial aero-derivative and aircraft gas turbine engine bearings. Gas turbine engines are rotating machines fitted with high-speed ball and roller bearings that can be the cause of failure modes with high secondary damage potential. (**1**)[2]

1.2 Metallic wear debris considered in this practice range in size from 120 µm (micron) and greater. Metallic wear debris over 1000 µm are sized as over 1000 µm.

1.3 This practice is suitable for use with the following lubricants: polyol esters, phosphate esters, petroleum industrial gear oils and petroleum crankcase oils.

1.4 This practice is for metallic wear debris detection, not cleanliness.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *condition monitoring, n*—field of technical activity in which selected physical parameters associated with an operating machine are periodically or continuously sensed, measured and recorded for the interim purpose of reducing, analyzing, comparing and displaying the data and information so obtained and for the ultimate purpose of using interim result to support decisions related to the operation and maintenance of the machine. (**2**)

2.1.2 *control unit, n*—electronic controller assembly, which processes the raw signal from the sensor and extracts information about the size and type of the metallic debris detected.

2.1.2.1 *Discussion*—A computer(s), accessories, and data link equipment that an operator uses to control, communicate and receive data and information.

2.1.3 *full flow sensor, n*—monitoring device that installs in-line with the lubrication system and is capable of allowing

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.96.07 on Integrated Testers, Instrumentation Techniques for In-Service Lubricants.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

the full flow of the lubrication fluid to travel through the sensor. Also referred to as a through-flow sensor.

2.1.4 *inductive debris sensor, n*—device that creates an electromagnetic field as a medium to permit the detection and measurement of metallic wear debris via permeability for ferromagnetic debris and eddy current effects for non-ferromagnetic debris.

2.1.4.1 *Discussion*—A device that detects metallic wear debris that cause fluctuations of the magnetic field. A device that generates a signal proportional to the size and presence of metallic wear debris with respect to time.

2.1.5 *machinery health, n*—qualitative expression of the operational status of a machine sub-component, component or entire machine, used to communicate maintenance and operational recommendations or requirements in order to continue operation, schedule maintenance or take immediate maintenance action.

2.1.6 *metallic wear debris, n—in tribology*, metallic particles that have become detached in a wear or erosion process.

2.1.7 *sensor cable, n*—specialized cable that connects the sensor output to the electronic control module.

2.1.8 *trend analysis, n*—monitoring of the level and rate of change over operating time of measured parameters.

3. Summary of Practice

3.1 A full flow sensor is fitted in the oil line to detect metallic wear debris. The system counts wear debris, sizes debris, and calculates debris mass estimates as a function of time. This diagnostic information is then used to assess machine health relative to cumulative debris count, or estimated cumulative debris mass warning and alarm limits, or a combination thereof. From this information, estimates of remaining useful life of the machine can also be made.

4. Significance and Use

4.1 This practice is intended for the application of in-line, full-flow inductive wear debris sensors. According to (**1**), passing the entire lubrication oil flow for aircraft and aero-derivative gas turbines through a debris-monitoring device is a preferred approach to ensure sufficient detection efficiency.

4.2 Periodic sampling and analysis of lubricants have long been used as a means to determine overall machinery health (**2**). The implementation of smaller oil filter pore sizes for machinery operating at higher rotational speeds and energies has reduced the effectiveness of sampled oil analysis for determining abnormal wear prior to severe damage. In addition, sampled oil analysis for equipment that is remote or otherwise difficult to monitor or access is not practical. For these machinery systems, in-line wear debris sensors can be very useful to provide real-time and near-real-time condition monitoring data.

4.3 In-line full-flow inductive debris sensors have demonstrated the capability to detect and quantify both ferromagnetic and non-ferromagnetic metallic wear debris. These sensors record metallic wear debris according to size, count, and type (ferromagnetic or non-ferromagnetic). Sensors are available for a variety of oil pipe sizes. The sensors are designed specifically for the protection of rolling element bearings and gears in critical machine applications. Bearings are key elements in machines since their failure often leads to significant secondary damage that can adversely affect safety, operational availability, or operational/maintenance costs, or a combination thereof.

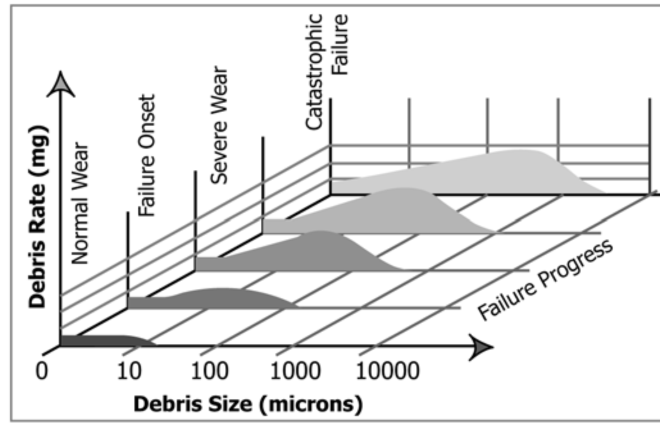

FIG. 1 Wear Debris Characterization

4.4 The main advantage of the sensor is the ability to detect early bearing damage and to quantify the severity of damage and rate of progression of failure towards some predefined bearing surface fatigue damage limiting wear scar. Sensor capabilities are summarized as follows:

4.4.1 In-line full flow non-intrusive inductive metal detector with no moving parts.

4.4.2 Detects both ferromagnetic and non-ferromagnetic metallic wear debris.

4.4.3 Detects 95 % or more of metallic wear debris above some minimum particle size threshold.

4.4.4 Counts and sizes wear debris detected.

4.5 Fig. 1 presents a widely used diagram (**2**) to describe the progress of metallic wear debris release from normal to catastrophic failure. It must be pointed out that this figure summarizes metallic wear debris observations from all the different wear modes that can range from polishing, rubbing, abrasion, adhesion, grinding, scoring, pitting, spalling, etc. As mentioned in numerous references (**1-11**), the predominant failure mode of rolling element bearings is spalling or macro pitting. When a bearing spalls, the contact stresses increase and cause more fatigue cracks to form within the bearing subsurface material. The propagation of existing subsurface cracks and creation of new subsurface cracks causes ongoing deterioration of the material that causes it to become a roughened contact surface as illustrated in Fig. 2. This deterioration process produces large numbers of metallic wear debris with a typical size range from 100 to 1000 microns or greater. Thus, rotating machines, such as gas turbines and transmissions, which contain rolling element bearings and gears made from hard steel tend to produce this kind of large metallic wear debris that eventually leads to failure of the machines.

4.6 In-line wear debris monitoring provides a more reliable and timely indication of bearing distress for a number of reasons: