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Standard Guide for Monitoring Failure Mode Progression in Industrial Applications with Rolling Element Ball Type Bearings[1]

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INTRODUCTION

Oil analysis is a part of condition based maintenance programs. Despite being widely used for several decades, there is no systematic approach in selecting oil tests based on failure mode analysis. Most users select tests primarily based on oil degradation criteria, minimizing the potential for detecting surface damage and limiting the potential benefits of the oil analysis program. This guide provides justification for oil analysis in industrial applications from a failure standpoint to include both rolling element bearing wear and fluid deterioration.

1. Scope*

1.1 This guide approaches oil analysis from a failure standpoint and includes both the rolling element ball type bearing wear and fluid deterioration in industrial application.

1.2 This guide pertains to improving equipment reliability, reducing maintenance costs and enhancing the condition-based maintenance program primarily for industrial machinery by applying analytical methodology to oil analysis program for the purpose of detecting specific failure modes.

1.3 This guide reinforces requirements for appropriate assembly, operation within the original design envelope as well as the need for condition-based and time-based maintenance.

1.4 This guide covers the principles of Failure Mode and Effect Analysis (FMEA) as described in Guide D7874 and its relationship to rolling element ball type bearing wear in industrial application and its fluid deterioration.

1.5 *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.*

1.6 *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. Referenced Documents

2.1 *ASTM Standards:*[2]

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration

D1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration

D6595 Test Method for Determination of Wear Metals and Contaminants in Used Lubricating Oils or Used Hydraulic Fluids by Rotating Disc Electrode Atomic Emission Spectrometry

D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)

D7414 Test Method for Condition Monitoring of Oxidation in In-Service Petroleum and Hydrocarbon Based Lubricants by Trend Analysis Using Fourier Transform Infrared (FT-IR) Spectrometry

[1] This guide is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.96.04 on Guidelines for In-Services Lubricants Analysis.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

D7483 Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Oscillating Piston Viscometer

D7596 Test Method for Automatic Particle Counting and Particle Shape Classification of Oils Using a Direct Imaging Integrated Tester

D7685 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

D7690 Practice for Microscopic Characterization of Particles from In-Service Lubricants by Analytical Ferrography

D7874 Guide for Applying Failure Mode and Effect Analysis (FMEA) to In-Service Lubricant Testing

2.2 *ISO Standards:*[3]

ISO 4407 Hydraulic Fluid Power—Fluid contamination—Determination of particulate contamination by the counting method using an optical microscope

ISO 11500 Hydraulic Fluid Power—Determination of the particulate contamination level of a liquid sample by automatic particle counting using the light-extinction principle

ISO 15243 Rolling bearings – Damage and failures – Terms, characteristics and causes

ISO 16232-7 Road Vehicles—Cleanliness of components of fluid circuits—Part 7: Particle sizing and counting by microscopic analysis

ISO 16700 Microbeam analysis—Scanning electron microscopy—Guidelines for calibrating image magnification

ISO 24597 Microbeam analysis—Scanning electron microscopy—Methods of evaluating image sharpness

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions and terms relating to this guide, refer to Terminology D4175. Selected terms from these Terminology Standards are also included here for the benefit of readers.

3.1.2 *bearing failure, n*—the termination of the bearing's ability to perform its design function.

3.1.3 *bearing failure initiation, n*—the moment a bearing starts to perform outside of its design function measured by performance characteristics.

3.1.4 *causes of failure, n*—underlying source(s) for each potential failure mode that can be identified and described by analytical testing.

3.1.5 *design function, n*—function or task that the system or components should perform.

3.1.6 *detection ability number [D], n*—ranking number that describes the ability of a specific fluid test to successfully detect a failure mode's cause or effects. A scale is used to grade detection ability numbers.

3.1.7 *dynamic viscosity [η], n*—ratio of applied shear stress and the resulting rate of shear.

3.1.7.1 *Discussion*—It is also sometimes called absolute viscosity. Dynamic viscosity is a measure of the resistance to flow of the liquid at a given temperature. In SI, the unit of dynamic viscosity is the Pascal·second (Pa·s), often conveniently expressed as milliPascal·second (mPa·s), which is the equivalent of the centipoise (cP) in the centimetre gram second system of units (CGS).

3.1.8 *effects of failure, n*—potential outcome(s) of each failure mode on the system or component.

3.1.9 *elastohydrodynamic lubrication (EHD), n*—a condition where extremely high fluid interface pressure developed in concentrated rolling element contact causes the viscosity of the lubricant to increase by several orders of magnitude and for the surfaces to deform them appreciably in proportion to the thickness of a fluid film between the surfaces.

3.1.10 *failure developing period, FDP, n*—period from component's incipient failure to functional failure.

3.1.11 *failure mode, n*—the physical description of the manner in which failure occurs.

3.1.12 *failure mode and effect analysis (FMEA), n*—analytical approach to determine and address methodically all possible system or component failure modes and their associated causes and effects on system performance.

3.1.12.1 *Discussion*—This approach can be used to evaluate design and track risk-reducing improvements to equipment reliability.

3.1.13 *hydrodynamic lubrication (HD), n*—lubrication regime where the load carrying surfaces are separated by a relatively thick film of lubricant formed by a combination of surface geometry, surface relative motion, and fluid viscosity.

3.1.14 *kinematic viscosity [v], n*—the ratio of the dynamic viscosity (η) to the density of the fluid (ρ).

3.1.14.1 *Discussion*—In SI, the unit of kinematic viscosity is the metre squared per second (m^2/s), often conveniently expressed as millimetre squared per second (mm^2/s), which is equivalent of the centistoke (cSt) in the centimetre gram second system of units (CGS).

3.1.15 *severity number [S], n*—ranking number that describes the seriousness of the consequences of each failure's modes, causes and effects on potential injury, component or equipment damage, and system availability.

4. Summary of Guide

4.1 This guide is designed to assist users in the condition assessment of rolling element ball type bearing applications by selecting oil tests associated with specific failure modes, causes or effects for the purpose of detecting the earliest stage of failure development.

4.2 There are a number of different industrial systems with rolling element bearings. A simple horizontal bearing housing utilizing rolling element ball type bearings lubricated by oil splash will be discussed. This is a typical arrangement for many industrial overhang pump applications.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.