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StandardGuide for
Practical Lubricant Condition Data Trend Analysis[1]

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INTRODUCTION

Maximum reliability of in-service machine components and fluids requires a program of condition monitoring to provide timely indications of performance and remaining usable life. In order to diagnose and predict machinery and fluid condition, the rate of change must be trended. Level alarms only state how much damage has occurred. The *predictive* or *forecasting* nature of condition monitoring is based on trending in order to determine the degree of damage and remaining useful life of the component or fluid.

Equipment maintainers expect condition-monitoring information to clearly and consistently indicate machinery condition, that is, the rate-of-change of component damage over time and the risk of failure. The data trending procedure must automatically adapt to equipment usage and sampling circumstances and provide numbers that *reflect equipment condition change in an incremental fashion*.

1. Scope

1.1 This guide covers practical techniques for condition data trend analysis.

1.2 The techniques may be utilized for all instrumentation that provides numerical test results. This guide is written specifically for data obtained from lubricant samples. Other data obtained and associated with the machine may also be used in determining the machine condition.

1.3 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *alarm limit, n*—set-point threshold used to determine the status of the magnitude or trend of parametric condition data.

3.1.2 *dead oil sampling, n*—oil sample taken that is not representative of the circulating or system oil due to one of several reasons, including the fluid in the system is static, the sample is taken from a non-flowing zone, and the sample point or tube within the oil was not flushed to remove the stagnant oil in the tube.

3.1.3 *lubricant 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 results to support decisions related to the operation and maintenance of the machine.

3.1.4 *machinery health, n*—qualitative expression of the operational status of a machine subcomponent, 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.

3.1.5 *optimum sample interval, n*—optimum (standard) sample interval is derived from failure profile data. It is a fraction of the time between initiation of a critical failure mode and equipment failure. In general, sample intervals should be

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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.

short enough to provide at least two samples prior to failure. The interval is established for the shortest critical failure mode.

3.1.6 *prognostics, n*—forecast of the condition or remaining usable life of a machine, fluid, or component part.

3.1.7 *remaining usable life, n*—subjective estimate based upon observations or average estimates of similar items, components, or systems, or a combination thereof, of the number of remaining time that an item, component, or system is estimated to be able to function in accordance with its intended purpose before replacement.

3.1.8 *sample population, n*—group of samples organized for statistical analysis.

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

3.2 *Symbols:*

Avg = average
C = current sample
H = usage metric (for example, hours)
OI = time on-oil interval
P = previous sample
PP = predicted prior sample
SSI = standard sample interval
T = trend

4. Summary of Guide

4.1 This guide provides practical methods for the trend analysis of condition data in the dynamic machinery operating environment. Various trending techniques and formulae are presented with their associated benefits and limitations.

5. Significance and Use

5.1 This guide is intended to provide machinery maintenance and monitoring personnel with a guideline for performing trend analysis to aid in the interpretation of machinery condition data.

6. Interferences

6.1 Sampling, maintenance, filter, and oil changes are rarely performed at precise intervals. These irregular, opportunistic intervals have a profound effect on measurement data and interfere with trending techniques.

6.2 *Machinery Operation*—Operational intensity can impact how quickly a component wears and how rapidly a fault progresses.[3,4] A relevant indicator of machine usage must be included in any calculations. The selected usage indicator must reflect actual machine usage, that is, life consumed (for example, stop/start cycles, megawatt hours, hours of use, or fuel consumption).

6.3 *Maintenance Events*—Component, filter, and oil changes impact the monitoring of machine performance, wear debris, contamination ingress and fluid condition. Maintenance events should always occur *after* a sample is taken (or condition test is performed). All maintenance events should be documented and taken into account during condition data interpretation. In all cases, maintenance events, if not reported, will reduce trending reliability.

6.4 *Sampling Procedures*—Improper or poor sampling techniques can profoundly impact condition test data (see Practices D4057 and D4177). A significant difference in the test data could trigger a false trend alarm. Examples of poor sampling techniques are:

6.4.1 Stagnant sampling,

6.4.2 Sampling after component change out,

6.4.3 Sampling after oil, or filter changes, or both,

6.4.4 Irregular sample intervals,

6.4.5 Sampling intermittent or standby equipment without circulating the oil and bringing the equipment to operating temperatures.

6.5 *Laboratory and Testing Practices*—The tools used to perform the condition monitoring tests impact the data.

6.5.1 Analytical instrument differences impact data reliability. Trending should only be performed on results from the same make and model of test instrument. For example, trending atomic emission inductively coupled plasma (ICP) results should be from ICPs with the same sample introduction configuration, same plasma energy, and preferably, the same manufacturer and model.

6.5.2 Analytical instruments with poor measurement repeatability and reproducibility will result in correspondingly poor trending. Testing repeatability should also be included with the trending studies.

6.5.3 Inappropriate analysis techniques can hide or distort interpretational conclusions. The condition-monitoring tool chosen must provide evidence of the critical failure modes under review.

6.6 *Machinery Wear Process*—Wear metal concentrations in oil are subject to variability.[4]

6.6.1 Filters remove the majority of debris particles greater than filter pore size. Thus an oil sample only captures new wear and small, suspended, old wear.

6.6.2 Wear particle release is event driven; increased load or speed can result in increased wear.

6.6.3 The rate of wear debris release is not linear with time. For many fault mechanisms, wear occurs in bursts.

6.6.4 Wear metal analysis methods can have particle size limitations that should be included in the evaluations. For example, ICP metal analyses are limited to those particles below nominally 8 microns.

6.7 *Reservoir/Sump Volumes*—Fluid and wear condition parameters are concentration measurements and are affected by reservoir/sump size. Varying the oil volumes in a reservoir can impact the trending analysis. For example, infrequent top ups allows the oil volume to decrease and thus concentrate the wear debris and contaminants. Alternatively, large volumes of make-up oil dilute the concentrations. Small, routine oil top-ups reduce this interference. The fluid make-up rate should be considered as apart of the evaluation practice.

[3] Forster, N., et.al., "Assessing the Potential of a Commercial Oil Debris Sensor as a Prognostic Device for Gas Turbine Engine Bearings," *ISHM*, August 2005.

[4] Toms, Larry A., and Toms, Allison M., *Machinery Oil Analysis - Methods, Automation & Benefits*, 3rd edition, STLE, Park Ridge, IL, 2008.