Developing Turbine Oils

Technical Topic

Beyond RPVOT

Introduction

The selection of a turbine oil that performs under the most demanding conditions of peak and base load applications has a direct impact on the reliability and profitability of a power generation operation. Unplanned outages from lubrication failures result in costly downtime and possible equipment damage. However, it is difficult to evaluate accurately the performance of turbine oil in-service from basic laboratory test results.

Modern turbine oils are asked to deal with higher temperatures; provide long service lives and ensure long-term keep-clean performance. To develop turbine oils with these features, product developers often use a broad suite of accelerated aging tests to approximate the long-term performance of these lubricants in service. ASTM D2272 "Standard Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel", more commonly known as RPVOT (Rotary Pressure Vessel Oxidation Test) is one of these accelerated aging tests commonly quoted on product data sheets. However, the RPVOT test was never intended for the comparison of the performance between different oil formulations. Despite this, many users erroneously assume that oil with high RPVOT is an indication of turbine oil quality and can be used to assess the relative longevity of different turbine oil formulations.

ASTM D2272 Description

The RPVOT is conducted by placing the subject lubricant, water, and a copper catalyst in a pressure vessel fitted with a pressure gauge. The vessel is then pressurized with oxygen, to 620 kPa (90 psi), placed in an oil bath at 150°C and rotated at 100 rpm. The result reported is the time taken for a pressure drop of 175 kPa (25.4 psi) below the max pressure. The drop in oxygen pressure indicates that oxygen has been consumed by reacting with the oil's components. The number of minutes required to meet the required pressure drop is used to infer the oxidation stability of the lubricant. The method specifically advises against the use of this test to compare oils of different compositions: "The estimate of oxidation stability <from this test> is useful in controlling the continuity of this property for batch acceptance of production lots of the same operation. It is not intended that this test method be a substitute for Test method ASTM D943, or be used to compare the service lives of new oils from different compositions. This test method is also used to assess the remaining oxidation test life of in-service oils." While RPVOT has some limitations, it is still a useful test for quality control and in–service oil condition monitoring. The following summarizes some of the advantages and limitations of this test.

Advantages

- It generates fast results - within minutes instead of months/years required for other glassware tests such as the Turbine Oil Stability Test (ASTM D943).
- It allows for quality comparison of batches of the same product or can be used as part of an overall analysis program for in-service oils of the same formulation.

Disadvantages

- RPVOT does not measure the formation of oxidation by-products such as lacquers, sludges, varnishes, and acids that can cause lubrication and control system failures.
- The RPVOT test reproducibility is +/- 22 percent. A product with 1000 minute life may have RPVOT results between 780-1220 minutes.
- The RPVOT test runs at much higher bulk oil temperatures than those found in most turbine applications in order to accelerate the oxidation process. As a result, it does not mimic operating conditions or the chemical kinetics of the in-service oil. It also has limited contaminants, very high levels of water and high levels of oxygen not normally found in turbine applications.

In summary, RPVOT can be used as a batch quality test or as a measurement for in-service estimation of remaining life in conjunction with other tests (see ASTM D4378 – In Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines). RPVOT should not be used as a single means to compare oxidation performance, oil life or deposit resistance of different formulations in an application.

Mobil™

Introduction

ExxonMobil's philosophy is to develop products that have balanced formulations that address the multiple needs of an application. With respect to turbine oils, three items are of critical importance.

- Maximize the life of the lubricant in service.
- Reduce the formation of detrimental oxidation by-products (sludge, lacquers and acids).
- And when oxidation by-products do form, (which is inevitable), manage these byproducts in the lubricant so they do not interfere with turbine operation.

Mobil Turbine oils are developed using multiple oxidation tests, including several standard industry tests as well as proprietary bench tests to ensure balanced performance is achieved. However, these bench tests are not completely sufficient to develop the highest quality oils. To better simulate conditions seen in turbine operation, ExxonMobil has also developed dynamic rig tests that more accurately represent operating conditions than is possible with the RPVOT test or other glassware tests.

Dynamic Rig Test Results

ExxonMobil's proprietary dynamic rig test evaluates the overall balanced performance of turbine oil in a system that mimics actual operating conditions. Specifically, the key criteria measured in this test are 1) RPVOT Retention, 2) Ultra Centrifuge Rating, and 3) Filter and Reservoir Cleanliness.

RPVOT Retention

While the RPVOT value of new oil typically does not correlate to the longevity of the oil in service it can be used to monitor depletion of oil antioxidancy over time. The typical limiting value of used oil is 25 percent of the new oil value per ASTM and many builder guidelines.

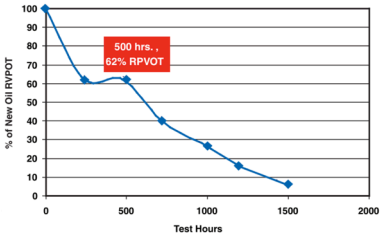
Ultra Centrifuge Rating

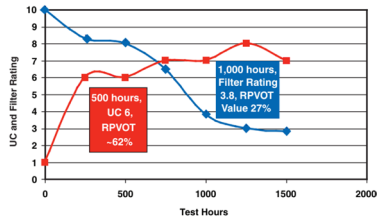
The ultra centrifuge test is designed to measure the concentration of oxidation by-products and insolubles in the oil. Tracking Ultra Centrifuge ratings provides a measure of the tendency of the oil to form oxidation by-products that lead to varnish and sludge. The test is measured on a scale of 1 to 8, where 1 is the best rating and 8 is the worst.

Filter and Reservoir Cleanliness

Cleanliness of the filters and reservoirs during the course of the rig test measures ability of the oil to resist the tendency to lay down deposits in the lubrication and control systems of the turbine. Maintaining clean performance allows more trouble free operation of the turbine and reduced unplanned outages. While all of these factors are important, the key to successfully managing long term turbine oil performance is to ensure that an oil maintains its RPVOT value while also providing keep clean performance. Some oils may show relatively little change in RPVOT value, yet still have significant deposit formation potential. Examples of this are shown in the following photographs and charts.

These graphs show an example of an oil that is generating deposits at 62 percent of new oil RPVOT value





Product A
New Oil RVPOT = 1,800
Clean filter after 2,000 hours

Product B
New Oil RPVOT = 3,000
Filter Blocked after 1,000

Filters from the Mobil circulating system test used to evaluate deposit formation. The oil with the highest new oil RPVOT value, lasted 1,000 fewer hours and had the lowest filter rating of the oils tested

Summary

- Control of detrimental oxidation products and the deposits that may result is critical to long term performance of modern turbine oils.
- Care needs to be taken when interpreting RPVOT test results, as this test is not intended for comparison of lubricants of different compositions from different oil companies.
- Use of a suite of standard oxidation tests provides important indications of in-use oxidation performance of turbine oils. However, it is important to include product development tests that address the formation and control of the detrimental by-products of oxidation and aging.
- In order to develop balanced high performance turbine oil, Mobil uses standard industry test methods plus other tests that simulate turbine operating conditions, which evaluate the impact of the by-products of turbine oil oxidation and can impact modern turbine performance.

Reference:

- ASTM D2272 – Standard Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel
- ASTM D4378 – In Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines