THE FUTURE OF JET FUEL THERMAL OXIDATION HEATER TUBE SCANNING

With jet fuel thermal oxidation testing becoming more important to the aviation industry there's a growing need for more reliable methods to validate heater tube readings. Multi-wavelength ellipsometry offers accurate results that are proven to be the most precise.

Jet fuel thermal oxidation testing has become significantly relevant as aviation kerosene undergoes significant heating within the fuel system of an aviation gas turbine. Jet fuel experiences high heat and contact to metal surfaces, since:

- Fuel is used as a coolant for the engine lubricating oil and for other heat exchange systems
- Certain regions have a high intrinsic temperature (e.g. injector feed-arms)

The feed-arms, which pass fuel directly into the combustor, represent a severe fuel system environment. The combination of high fuel inlet temperatures and very hot metal surfaces can promote a high degree of thermal degradation (oxidation) leading to deposit (and/or particulate) formation. In this event, the small apertures within the fuel atomizers can become obstructed, causing flow restriction or fuel spray pattern distortion, ultimately leading to engine malfunction. The deposit formation would also deteriorate the heat transfer efficiency of the heat exchangers where the jet fuel is used as a coolant. Hence, thermal stability of aviation fuels is crucial for the safe operation of gas turbine engines.

The jet fuel thermal oxidation test method is a well recognized test method by ASTM and other standard bodies to determine jet fuel thermal stability. The test measures the high temperature stability of gas turbine fuel using an instrument that subjects a heater tube to a fuel flow around it under well-defined temperature, pressure differential and time duration. At the end of this test the fuel is rated based on the deposit formation on the heater tube. The test results are indicative of fuel performance during gas turbine operation and can be used to assess the level of deposits that form when fuel contacts a heated surface at a specified temperature.

The most widely used apparatus to rate deposits on heater tubes is the Visual Tube Rater (VTR). The VTR determines the deposits thickness (resulting from thermal oxidation on ASTM-certified heater tubes) by comparing the color of the deposit with that of the arbitrary scale established for this test method, plus two additional YES/NO criteria that indicate the presence of an apparent large excess of deposits, an unusual deposit or both. While VTR is a well-accepted instrument, the industry is seeking a more stable and objective measurement technique that eliminates the human element to determine the results. Moreover, the growing need to learn the deposit characteristics and profile has further influenced the need of advanced metrological technology for this application.

Over the past few years, multiple technologies have been considered to replace VTR. Some of those technologies are: Interferometry, Single-wavelength Ellipsometry and Multi-wavelength Ellipsometry.

Ellipsometry Methods

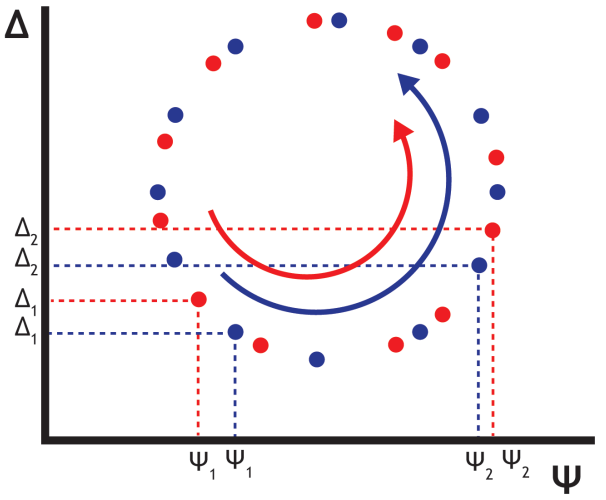
Ellipsometry uses polarized light to characterize thin film and bulk materials. The light undergoes a change in polarization and phase shift as it interacts with the sample structure, due to reflection, refraction and combinations thereof. The raw data comprises of two values: change in polarization (Psi - Ψ) and Phase Shift (Delta - Δ). The measured values (Ψ and Δ) are used to calculate the thickness of the deposit film on the heater tube surface.

With single wavelength ellipsometry, a laser is used to collect data only at a single wavelength. Incorrect results would occur if the film was absorbing, graded or rough. Even for the ideal case of a perfect transparent film, the cyclic nature of single-wavelength ellipsometry measurements produce multiple answers, as shown in the figure below. The possible thicknesses are separated by the thickness period and an educated guess is required to decipher the correct solution.

In this case, single-wavelength ellipsometry over-determines the film thickness. While the index of refraction will be wavelength-dependent, the thickness remains the same. The spectroscopic measurement quickly removes the "periodicity" problem by eliminating all except the correct answer. This is demonstrated for the first three possible solutions to the single-wavelength cycle from above. Note that while the data is identical at the single-wavelength of 500 nm, the spectral response is entirely unique.

One of the logical ways to improve the certainty of the predicted thickness from an ellipsometer is to increase the number of wavelengths used. Each new wavelength contains information about the sample property – which, in this case, is thickness.

With single wavelength ellipsometry, we are trying to solve unknown



variables (Ψ and Δ) with only one mathematical equation, which is practically impossible.

Thickness (nm) = f (Ψλ1, Δλ1)

With multi-wavelength ellipsometry, we are trying to solve the same unknown variables (Ψ and Δ), but with numerous mathematical equations that complement each other.

Thickness (nm) = f (Ψλn, Δλn)

As a result, multi-wavelength ellipsometry offers higher certainty over wide range of thickness measurements.

OptiReader

After taking into consideration all of these aspects of metrological mapping, PAC has developed OptiReader – a game changer in JFTOT heater tube fuel deposit quantification. It is a stand-alone, compact, revolutionary multi-wavelength ellipsometric heater tube scanner that can be used to measure deposit thickness and volume resulting from jet fuel thermal oxidation testing. With its blazing fast speed of scanning, OptiReader can scan a heater tube in less than 10 minutes. It provides a 2D and 3D thickness map along with pass/fail results with high precision. With its simple and user-friendly interface no technician training is required resulting in time and money savings. For more information got to paclp.com or contact sales@paclp.com

Author Details

Prashant Chandarana, Product Manager, PAC

Tel: 1.832.701.5092 • Email: Prashant.Chandarana@paclp.com

Web: www.paclp.com