PROGRESS ON LUMINESCENCE COATINGS FOR TEMPERATURE MAPPING ON TURBINE ENGINES

Dr Chris Pilgrim, Sensor Coating Systems
c.pilgrim@sensorcoatings.com

As the operating temperature of thermal barrier coatings (TBCs) increase to accommodate the higher firing temperatures of new gas turbine developments, the need for accurate temperature measurements is becoming increasing critical. Furthermore, the increasingly aggressive operating conditions also limit the number of suitable temperature measurement methods.

Thermocouples are practically very challenging to implement to measure TBC temperature, therefore, are not widely used. While infrared cameras enable the measurement of temperature profiles over the surface of components, the transparency of TBCs in the infrared range lead to significant errors. The technique is also susceptible to emissivity changes, which can occur during testing, and stray radiation from combustion can cause further errors. To overcome some of these limitations, there has been significant research and development interest in a relatively new technique called phosphor thermometry. In this technique a phosphor material is deposited on the surface of interest and the temperature dependent luminescence characteristics are used to measure the temperature during operation through interrogation by laser induced phosphorescence. This technique promises accurate temperature measurements in real-time and is under investigation by several research institutions.

The first implementation of this technique on an operating gas turbine demonstrated some of the capability of this method. The precision of the measurements was comparable to commercial thermocouples (~±5K) and transient temperatures were tracked at 8Hz, which is fast enough to follow a typical power generation gas turbine. More recent work has demonstrated the accuracy of the technique compared to commercial pyrometers and thermocouples on a burner rig. The effect of thermal gradients on the temperature measurements were also investigated through modelling and experimental testing. The research has indicated the possible capability of phosphor thermometry in gas turbine development.

While phosphor thermometry has great potential, the optical access required to make measurements during operation poses a significant practical challenge for implementation on commercial engines. The same restriction applies to infrared cameras.

To overcome this challenge, offline temperature measurement techniques are used to record peak temperature information. Thermochromic paint, the most widely used of these techniques, changes colour at predefined temperatures and is read-out afterwards by a trained expert. They are, however, not commonly used on TBCs because it can penetrate into the porous TBC material, causing ambiguous readings and potentially damaging the TBC system. In addition, the maximum temperature limit is restrictive for new engine developments. An alternative technique is thermal crystals, whereby silicon carbide crystals are embedded in the drilled holes in the surface. The crystals can be installed in TBCs but only give point measurements and have limited durability. A new technique is being developed at Sensor Coating Systems, which uses luminescence materials, similar to those used for phosphor thermometry but to record past peak temperatures. In this technique, the luminescence material is deposited as a paint or coating and on thermal exposure the microstructure permanently changes. The material can be deposited by atmospheric plasma spray making it very durable and compatible with TBC architectures. In one field test, the coatings survived 4,500 operating hours with less degradation than a standard TBC. Recent lab testing has demonstrated a measurement capability up to 1400°C and this presentation will discuss new development work taking the capability to higher temperatures. The research will provide a new and unique measurement capability at the upper temperature limit of current and future TBC systems, which will be critical for the development of new generation engines.