Improvements in pyrometry for low maintenance operation

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Abstract (max. one page)

The use of optical pyrometry to measure the surface temperature of high-speed turbine blades in gas turbine engines is well established. Radiation from the hot surface is measured with an optical detector and converted to temperature using calibration factors which depend on the properties of the pyrometer and on the surface emissivity. Uncertainty in the latter typically affects the measurement accuracy by approximately 1ºC per 1% error in emissivity, for a blade temperature of 950ºC. Furthermore, changes in the emissivity due to blade ageing, and contamination of the optics by the hostile engine environment, both lead to a drift in calibration accuracy. This paper reports on work to reduce the effects of both sources of error in a commercial pyrometer, to improve accuracy and enable longer service intervals, which is a prerequisite for engines for the civil market.

A method to measure blade emissivity at elevated temperature was developed, consisting of measuring the cooling profile of blades heated in a specialised furnace with a removeable aperture. The measurements were performed in two different infra-red wavelength regions using silicon (Si) and Indium Gallium Arsenide (InGaAs) detectors.

Results of emissivity measurements made both on brand new turbine blades and on used blades will be presented. It was found that the emissivity in the central region of used blades was similar to that of new blades in the same position. However, the emissivity in the trailing edge region of the blades was reduced by 8.1% compared to the same position on new blades for the Si photodiode and by about 7.5% for InGaAs. The calibration errors resulting from these emissivity changes correspond to a blade ageing error of about 8ºC for Si and about 10ºC for InGaAs. Therefore the effect of ageing is to cause the pyrometer to underestimate the blade temperature.

The *absolute* errors which would occur for a pyrometer calibrated against a perfect blackbody source depend on both the initial emissivity of the blades and also on the emissivity ageing. These errors are shown to be 12ºC and 17ºC for Si and InGaAs respectively. In order to reduce these errors, the ratio of the measured radiant signals from the two photodiodes was also computed and the equivalent temperature errors determined. It will be shown that the effect of blade ageing for the used blades is significantly reduced by the ratio method.

In addition, the dual-wavelength method is also able to compensate for lens contamination if the latter has no spectral effect on optical transmission. Electron microscope studies of the lens surface from several used pyrometers showed the presence of a variety of mineral and metallic particles. These were generally in the 20-30µm region. Our laboratory studies have shown that debris of this size attenuates both wavelengths equally whereas fine debris (<1µm) shows a spectral dependence. There was, however, found to be a complete absence of soot and fine debris on the lenses inspected from pyrometers removed from engines. This was attributed to the efficiency of the purge air system that was fitted to the pyrometer, preventing small particles from impacting the lens.

In summary, dual wavelength pyrometry, in combination with an effective purge air system, offers reduced sensitivity to emissivity, blade ageing and lens contamination, and makes the pyrometer suitable for use on civil aircraft.