Graphical Abstract

Long Wavelength Infrared Radiation Thermometry for the Measurement of Ceramic Thermal Barrier Coatings

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Abstract

Long Wavelength Infrared Radiation Thermometry for the Measurement of Ceramic Thermal Barrier Coatings

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Stationary gas turbines provide an essential contribution to the energy supply in Europe. The efficiency of such turbines can be significantly increased by increasing the temperature of the hot combustion gas. For a technical realization of higher gas temperatures thermal barrier coatings (TBCs), which can withstand these temperatures, are applied onto the turbine blades in order to reduce the heat transfer into the substrate.

Furthermore the operating parameters of the turbines are improved in such a manner that the gas turbines are operating under optimal conditions. This means that the maximum feasible gas temperature is exactly adjusted to reach the high efficiency without provoking material damages by exceeding the acceptable temperatures. For this purpose the knowledge of the surface temperatures of the turbine components (e.g. the TBCs) which are occurring during operation is of essential importance in order to operate the turbine with optimal parameters.

At high temperatures the non-contact measurement of surface temperatures using radiation thermometers which are sensitive in the near or short wavelength infrared is state-of-the-art for opaque surfaces. However, this is not possible for TBCs which are based on oxide ceramics (e.g. partially yttria stabilized zirconia) as such materials are semi-transparent in the near and short wavelength infrared spectral region [1]. As these materials are non-transparent in the long wavelength infrared (LWIR), and at the same time provide a high emittance in this wavelength region, LWIR radiation thermometry can be used to overcome the limitation of existing techniques. Therefore, one work package within the EU-project STARGATE (Sensors Towards Advanced Monitoring and Control of Gas Turbine Engines) is dedicated to the development of an LWIR radiation thermometer for the contactless measurement of the surface temperature of TBCs during the operation of gas turbine engines.

Within this work the infrared-optical characterization of the used TBCs in the wavelength range from 2 μm to 20 μm at high temperatures up to 1600 K is presented, which includes the emittance of the applied TBCs as well as the transmittance of free-standing TBCs. Based on the derived data the optimal wavelength for the non-contact temperature measurement is determined. Additionally the wavelength of the LWIR pyrometer is chosen in accordance with the transmission bands of the hot combustion gas. The infrared-optical characterization of this gas is described in detail in an additional publication as it is beyond the scope of this work. Furthermore the STARGATE project is briefly introduced and an overview of the LWIR radiation thermometer and its testing facility is given.

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