UNSTEADY CONJUGATE HEAT TRANSFER MEASUREMENTS IN THE PRESENCE OF LATERAL CONDUCTION

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ABSTRACT

Decades of development in turbine blade cooling have led to complex cooling systems composed of cooling techniques like channel cooling with turbulence promoters, impingement cooling, pin-fin cooling or film cooling [1, 2]. In general, the applied cooling techniques are designed and optimized with the aid of time-independent heat transfer experiments.

Instead, during operation the cooling system is exposed to time varying boundary conditions as a result of varying operation points, the extraction of cooling air from the compressor or combustion instabilities. In the mainly turbulent flow regimes of turbine blade cooling the quasi-steady assumption is commonly accepted and experimentally confirmed which enables the usage of the time-independent results [3]. However, numerous experimental and numerical publications showed, that depending on the cooling technique, the quasi-steady assumption is not valid for all conditions [3, 4, 5, 6, 7, 8, 9, 10, 11, 12].

Within the scope of this publication, an experimental setup, the measurement techniques and the evaluation techniques to investigate the unsteady conjugate heat transfer in a channel with turbulence promoters are presented.

The experimental setup, sketched in Figure 1, provides the possibility to control the flow speed and the flow temperature independently. For this purpose, adjustable vanes and a controllable mesh heater are applied. A constant temperature hot wire probe and constant current hot wire probe measure the reference fluid speed and the fluid temperature in the inlet region of the channel. An infrared camera in combination with a surface thermocouple for in situ calibration delivers spatially and temporally resolved surface temperature data. Fine wire thermocouples are used to measure the fluid temperature. A previous calibration according to Park et al. [13] allows to correct the influence of thermal inertia on the measured signal.

The object of interest for this study is a vortex generator and the unsteady heat transfer in its wake region. For steady situations, the induced longitudinal vortex system enhances the heat transfer in the wake region locally and leads to areas with strong lateral conduction effects. The induced effects are discussed in detail by Henze et al. [14]. Changes for unsteady situations are presented.

The applied evaluation method calculates the spatially and temporally resolved heating rate with the aid of the measured surface temperature history. It was presented by Estorf [15] and is valid for a semi-infinite (z direction) cuboid with adiabatic side walls and a time-varying heating rate on the top wall. Lateral conduction effects are considered by transforming the surface temperature data into Fourier space (xy plane).

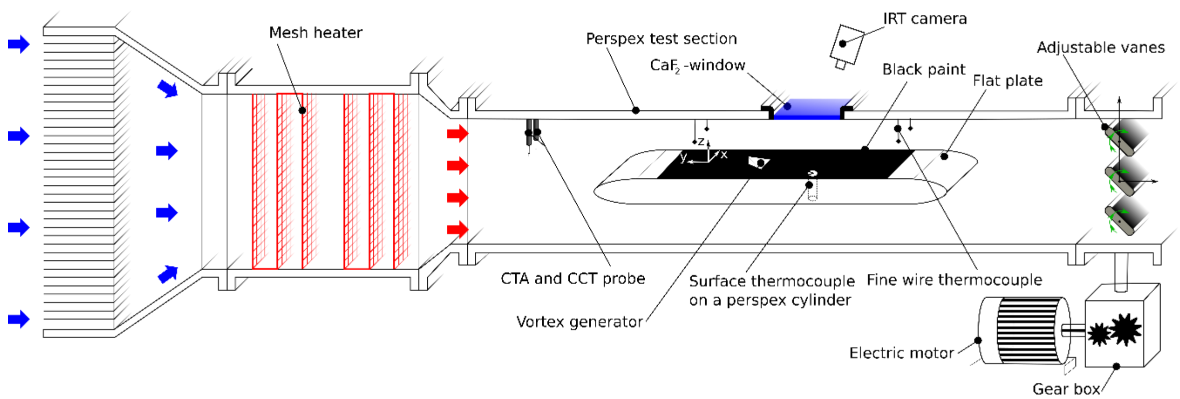

Figure 1. Experimental setup

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