FIRST OPERATION OF A ROTATING TEST RIG FOR TRANSIENT THERMOCHROMIC LIQUID CRYSTAL HEAT TRANSFER EXPERIMENTS

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ABSTRACT

In an effort to increase the overall efficiency of turbojet engines, the turbine blade cooling air consumption of modern engines is being constantly reduced. However, with decreasing cooling air mass flow rates, the influence of rotation on the flow and thus the heat transfer distribution inside rotating cooling channels increases. Future cooling system designs will be more and more dependent on the understanding of these rotational effects.

INTRODUCTION

A test rig for the investigation of rotating turbine blade internal cooling channel configurations is presented. The heat transfer is measured using the transient thermochromic liquid crystal (TLC) technique. The rig can be operated at rotational speeds of up to 900rpm, mass flow rates between 5g/s and 30g/s, a fluid temperature between -100°C and +80°C and a pressure of up to 10bar. This allows for a broad range of possible test conditions. The investigated cooling channel model is a two-pass leading edge configuration. It consists of a first pass with a trapezoidal cross-section and radial outward flow, a 180-degree bend, and a second pass with a rectangular cross-section and radial inward flow. The suction side and pressure side surfaces are ribbed.

The evaluation method is based on the measurement of TLC indication times. A fluid temperature change is applied to induce a colorplay on the TLC-coated heat transfer surfaces. This colorplay is captured using cameras that are rotating with the test model. A remote controlled camera unit with integrated batteries, LED lighting and a signal-LED for synchronization purposes has been developed and is presented in this paper.

In order to reproduce the correct sense of the buoyancy forces, the heat flux needs to be in the correct direction, i.e. from a warm channel wall to a colder cooling fluid. Therefore, liquid nitrogen cooled air is used as cooling fluid with the test model at ambient temperature. Precooling of the air supply pipes inside the rotor prevents the test air to heat up excessively before reaching the test model. This is essential especially for low mass flow rates. A radio telemetry system collects temperature and pressure data from inside the rotating model housing and allows real time monitoring.

RESULTS AND DISCUSSION

The results of a typical experiment are presented. Heat transfer data are shown in contour plots of the Nusselt number distribution. Data reduction methods yielding area-averaged (e.g. rib segments) and line-averaged values are described. A direct comparison between rotating and non-rotating experiments is presented. An example is given in fig. 1 which shows the ratio of the local Nusselt numbers between a rotating (400rpm; Ro=0.14) and a corresponding non-rotating experiment.

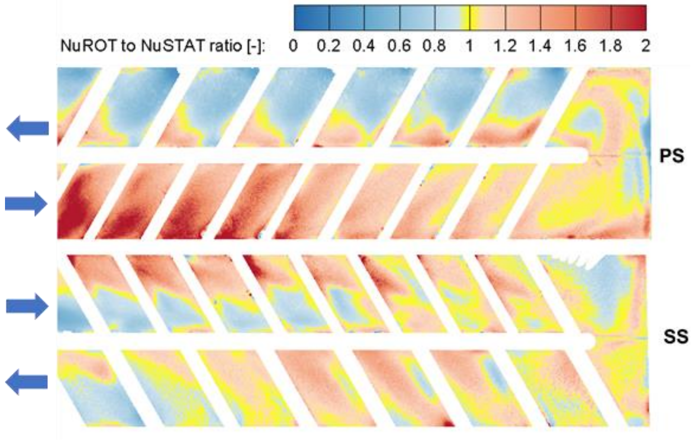

Figure 1. Ratio of Nusselt numbers (rotating to stationary)