Experimentally Determined Heat Transfer Coefficient of a Turbine Blade at Varying Incidence Angles

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Long Abstract

Introduction

Turbine engine designers rely more and more upon computer simulations as a design tool. It is often difficult to accurately predict the heat transfer coefficient of components with computational fluid dynamics (CFD) software. CFD results therefore still require validation through experimentation, especially for complex new blade designs, off-design conditions, or varying turbulence levels.The goal of this project was to experimentally measure the external, no-film cooling heat transfer coefficient (HTC) for a new turbine blade design by Pratt & Whitney at up to 10° off design conditions and with varying turbulence conditions to assist in validating CFD codes to be used in future engine design. This study seeks to document these effects in high-resolution with IR thermography. Considering past studies, see Hylton [1], Schultz [2], and Dunn [3] for examples of HTC measurements, Carullo et al. [4] for effects of turbulence on the heat transfer coefficient, Arts [5] and Camci and Arts [6] for incidence angle effects at low-resolution, and Giel et al. [7] for a recent validation with the liquid crystal technique on a new turbine blade at design and ±5° off design incidence angles.

1. Methods

Testing was completed at the Turbulence and Turbine Cooling Research Laboratory (TTCRL) at the University of Texas at Austin. The Experiments used a low-speed, recirculating wind tunnel with a 2 ½ blade linear cascade corner test section. The wind tunnel is capable of varying the inlet incidence angle as shown:

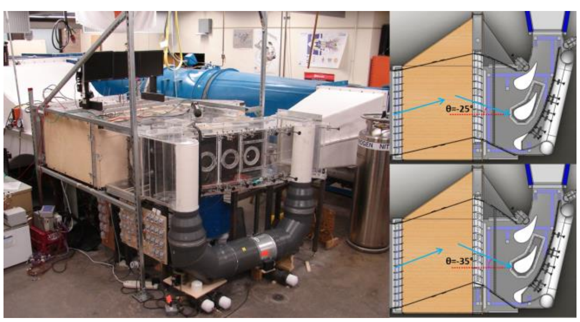

Figure 1. TTCRL Wind Tunnel

Two incidence angle regimes were tested (-25° and -35), and incidence angles in each test were verified by Particle Image Velocimetry. Reynolds number, stagnation line, and pressure distribution (C_p) as predicted by CFD were matched for each angle. Turbulence was generated by an array of vertical rods of diameter b, placed at an upstream location, $x = x_f \cos\theta$, using an empirically validated correlation for this wind tunnel:

$$Tu = 0.75 \left(\frac{x_f}{b}\right)^{-\frac{5}{7}}$$

The rods were designed to generate a turbulence intensity of 5% at the blade leading edge and an integral length scale of 5% of axial chord length (B_{ax}). Low turbulence tests were performed without the rods, yielding an average Tu, measured using Hotwire Anemometry, of 0.6%. The pressure distribution model has 22 mid-span static pressure taps and 12 off mid-span static pressure taps, with 6 above and 6 below mid-span. A steel shim was adhered to the surface of the heat flux model and produced a constant heat flux when a DC power supply was connected to the shim. IR Cameras viewed the model in the wind tunnel through NaCl window ports.

Figure 2. Pressure model and heat flux model

References

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