DESIGN OF A HIGH-TEMPERATURE TEST FACILITY TO STUDY THE IMPACT OF TEMPERATURE RATIO ON COOLING PERFORMANCE

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ABSTRACT

This paper describes the design of a high temperature (600 K) test facility to be used for parametric studies of metal effectiveness and adiabatic cooling effectiveness for fully cooled systems (internal and film) under wide ranges of temperature ratio variation, in the range $0.5 < T_{0h}/T_{0c} < 2.35$. The purpose is to improve understanding of—and validation of—the scaling process from typical rig conditions to engine conditions. The working section is designed to accommodate cooled flat plates with realistic cooling systems at engine-matched conditions of Mach and Reynolds number. To achieve this over a wide range of temperature ratios necessitates a wide operating range of total pressure. The facility operates in semi-transient mode (run times of up to 100 s) and therefore the transient flow conditioning and transient thermal stresses were important issues addressed in the design. An unusual feature of the facility, required to perform the intended validation studies, is the ability to achieve full-surface real-time thermal measurements of both the external and internal faces of the cooling structure.

INTRODUCTION

There are numerous papers in the open literature that discuss the scaling of metal effectiveness and adiabatic cooling effectiveness results with blowing ratio and momentum flux ratio. Some of these results have been used as the basis for scaling between typical warm-rig and engine conditions, a matter that is of particular interest to designers. There is a *validation gap,* however, in that there are very few laboratory experiments which operate over the full range of temperature ratio between typical warm rig and engine. The purpose of the facility described in this paper is to bridge this gap, providing robust data over an extremely wide range of temperature ratios from $0.5 < T_{0h}/T_{0c} < 2.35$ to help understand, and directly validate these scaling arguments. In this paper the CFD-based aerodynamic design of the working section, the mechanical design (including transient thermal shock issues), the network thermal modelling to accurately predict operating points, the flat plate cooling system design and conjugate analysis, and the instrumentation design are discussed.