AERODYNAMIC VALIDATION OF A TRANSONIC COMPRESSOR TEST RIG

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ABSTRACT

This paper presents an experimental study of several casing treatments applied to a single-stage transonic compressor operating at a design tip Mach number of 1.1. Five casing treatment styles were implemented: full half-hearts, reduced half-hearts, grooves, and skewed axial slots with and without a plenum. These were compared against a baseline across a range of operating speeds and under clean and tip-low distortion inlet conditions. High-frequency pressure transducers were used to capture unsteady shock physics upstream of the rotor, while a virtual three-hole probe was used downstream of the stator to compare radial pressure distributions. The rig configuration enabled repeatable testing of the casing treatments under matched operating conditions, allowing their performance to be compared directly.

INTRODUCTION

Transonic axial compressors often operate close to their stability limit. Extending the stable operating range is therefore important for compressor longevity and its ability to withstand inlet distortion. Casing treatments can be implemented to improve stability margins in axial compressors. While subsonic performance and flow physics are well documented, the transonic physics typical of high-speed engines remain less well understood.

The present study investigates five casing treatment styles applied to a single-stage transonic compressor. These configurations were tested across a range of operating speeds under clean and tip-low distortion inlet conditions. Tip-low distortion induced rotating stall across a range of speeds, while the half-heart and groove configurations attenuated this behaviour and improved pressure ratios across the compressor map.

RESULTS AND DISCUSSION

Figure 1a shows the control system for the Green Rig, a transonic compressor facility based on a turboexpander architecture. The compressor operating condition is controlled using a bleed valve and a bypass valve. The bleed valve is used to vary the pressure ratio across the compressor, while the bypass valve controls the rig speed. In conjunction with the control system, the rig's suction is provided by the Whittle Laboratory high-speed loop and can be run at full Reynolds number up to transonic tip Mach numbers. Figure 1b presents the plain casing tests under clean inflow conditions. These measurements provide the baseline compressor characteristic and define the experimental stall boundary for the untreated configuration. This baseline is used as the reference case for the later comparison of casing treatment performance. The final paper will extend this analysis to include an aerodynamic assessment of multiple casing treatment designs under both radial and circumferential distortion a)

b)

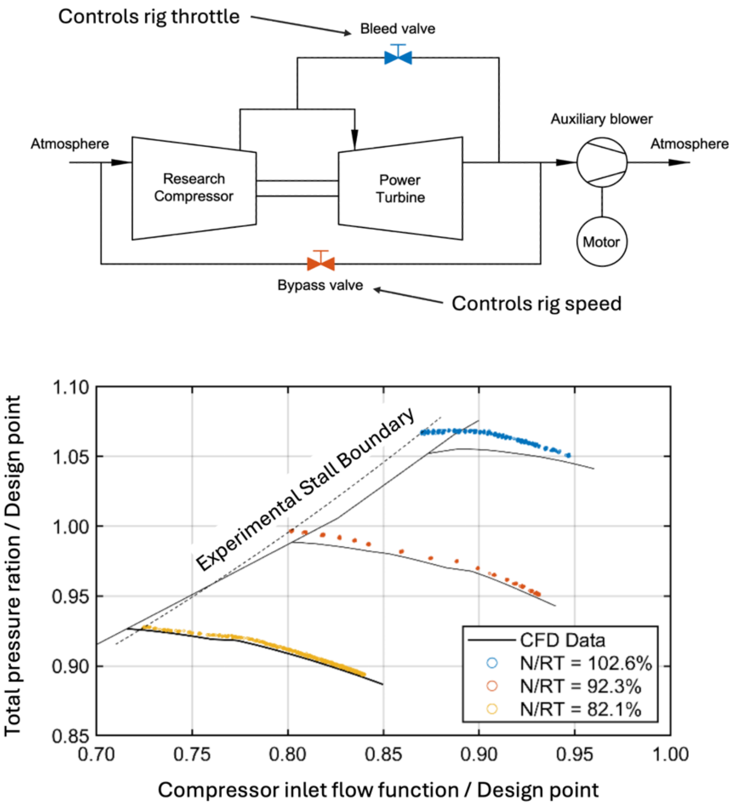

Figure 1. a) Compressor turboexpander architecture, b) High speed compressor map