DESIGN OF A CLOSED-LOOp HIGH-SPEED FACILITY TO TEST DISTORTION SCREENS

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Abstract

Aircraft engine architectures are currently in the phase of a change to meet future market demands. Certain such novel architectures force engines to operate under distorted inflow conditions. Additionally, the present-day aircraft engines also incur inflow distortions which are undesirable during flight. It is important to test and characterise the effect of such inflow distortions to understand the impact on the performance of engine components. This paper discusses the design and development of a novel test-facility that has the capability to test distortion screens under desired flow conditions. To achieve this, the return loop of the high-speed closed-loop compressor rig R4 at the von Karman Institute for Fluid Dynamics (VKI) has been re-designed to incorporate a test section where distortion screens can be tested and characterised. Thus a compressor test-bench is now modified to act as a wind tunnel for testing distortion screens. The dynamic operational controls of the facility also allow to test the screens at engine-like conditions.

**INTRODUCTION**

Future aircraft engine architectures for low carbon footprint will be characterized by highly distorted inlet flows. In this framework, the EU funded ASTORIA project has the objective to develop a new methodology to design distortion screens replicating combined swirl and total pressure distortion patterns. With these devices, the effect of realistic inlet distortions on the performance and stability of components can be investigated. The high speed closed-loop compressor rig of the von Karman Institute for Fluid Dynamics, the R4 tunnel, has been equipped with a novel test section for distortion screen testing and characterization. The present paper describes the steps of the design process and provides details on the models and tools employed.  An initial bibliographic survey has been carried out to select the most suitable solutions for each element of the wind tunnel, such as the contraction zone upstream and the diffuser downstream of the test section. Successively, 3D RANS numerical simulations and a 0D lumped parameter model of the facility have been employed to properly quantify the total pressure losses over the whole return loop as well as to confirm the validity of the undertaken design choices. As a last step, a boundary layer control system has been designed to control the boundary layer thickness in the test section and guarantee a flow pattern as uniform as possible.

**THE NOVEL TEST-FACILITY**

The objective of this work is to design the return channel of the VKI R4 high-speed compressor test-rig to install a test section that is capable of testing distortion screens. To ensure the desired flow conditions are met at the test section, the following modifications are carried out on the existing facility:

1. The facility is equipped with a bypass duct, the mass flow through which can be individually controlled. This allows an additional control on the mass flow rate passing through the test section and thus on the Mach and Reynolds numbers.

2. Prior to the location of the test section, a flow settling unit consisting of a series of honeycombs and flow straighteners is proposed that ensures a uniform flow at the exit of this unit.

3. Since the test section has to also operate at different Mach numbers, a convergent section is designed which takes the flow at the exit of the settling unit to the desired Mach number in the test section. The convergent sections delivers a flow that is homogenous at a prescribed location in the test section.

4. To further address the non-uniformity in the boundary layer in the test section, a boundary layer control system using the idea of tangential air injection is designed.

5. The test section is designed as a constant-area cylindrical duct where distortion screens can be placed for testing.

6. Following the test-section, a cropped diffuser along with a diffusing bend is designed which ensures minimum pressure losses and also connects the test section to the rest of the portion of the return duct of the test facility.

Careful consideration is given during the design phase to ensure that the pressure losses across all the components of the novel facility are minimal and falls within the pressure budget available to run the compressor of the closed loop facility. Schematics of the old and novel facilities are shown in Figure 1. In summary, this methodology can be used as not limited to testing distortion screens, but as a general guideline to design closed-loop wind tunnels.

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| R4_facility.png **a. Old test facility: (1) Plenum (2) Compressor (test section) (3) Collector (4) Return duct (5) Throttle valve****b. Novel test facility: (1) Plenum (2) Compressor (driving section) (3) Collector (4) Flow settling unit (5) Convergent (6) Boundary layer control system (7) Test section (8) Cropped diffuser (9) Diffusing bend (10) Throttle valve** |
| **Figure 1. Schematics of the old and novel test facilities** |