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Test Section Design for Investigations of SBLIs in Highly Loaded Compressor Stator

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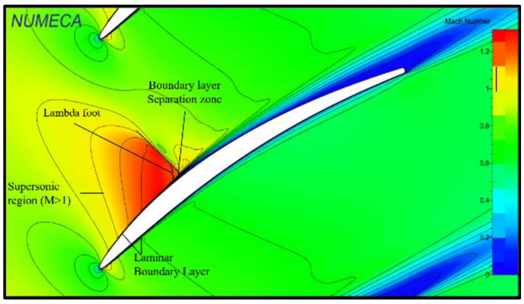
Modern turbofan engines are designed based on certain design requirements such as aerodynamic performance improvement. Many investigations have been carried out to create an optimal design which satisfies these requirements. These requirements could be achieved in engines by reducing the number of compressor stages and increasing the stage pressure, which will decrease the weight constrain but results in higher blade loading. Increase of compressor stage pressure can be achieved by increasing the blade turn angle which leads to high adverse pressure gradient resulting boundary layer separation and severe passage blockage [1]. The research on how to reduce the flow separation in transonic compressors and improve the flow efficiency of are still in progress. Boundary layer on compressor blade surfaces mostly would be laminar state upstream the shock wave, which are more liable to separate than turbulent boundary layer [2]. When shock wave interacts with laminar boundary layer it tends to separate resulting rotating stall in blade passage, which affects the performance. Thus, the low Reynolds number (Re) has significant influence on engine performance and aerodynamic stability [3]. Boundary layer separation is an inherently unsteady phenomenon and can cause large scale fluctuation in the flow, such as causing shock oscillations in compressor blades. Shock oscillation causes the pulsation of pressure thus changes the blade loading. The mitigation of unsteady effects of Shock Wave Boundary Layer Interaction (SBLI) in stator vane becomes more crucial for aerodynamic performance improvement.



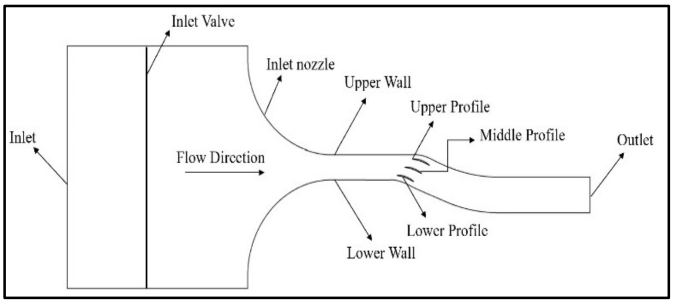


Figure 1: Normal shock on the suction side of stator profile. **Figure 2**: Sketch of a rectilinear Test Section

The main objective is to analyse the SWBLI on highly loaded compressor stator cascade which are operated under low Reynolds number of 200000 based on blade chord length and an inflow mach number of 0.9 at 45kft altitude. Based on these requirements, a steady state Reynolds Averaged Navier Stocks (RANS) simulation using Spalart Allmaras and Explicit Algebraic Reynolds Stress Model (EARSM) turbulence model in Fine/Turbo Numeca were carried out for cascade configuration (Figure 1). A test section has been designed to perform experimental investigation of SWBLI on stator cascades. The test section should be reproducing the same flow structure as in cascade with identical blade configuration. To retain the periodicity in test section we extract the streamlines from the cascade simulations to design the upper and lower wall of the test section (Figure 2). The rectilinear shape of the test section has been inspired from TFAST project [4]. The shock location and the secondary flows are influenced by the downstream boundary conditions and sidewalls of test section. To achieve this inflow condition, the design concept of the inlet nozzle has been used. The test section configuration will include a valve upstream the inlet nozzle to control the inlet total pressure to reduce the Reynolds number. With the numerical predictions of cascade simulations, a test section has been designed for experimental investigations. This test section will be manufactured and mounted at IMPPAN transonic windtunnel facility. A database for the flow structure in the considered SWBLI could be determined based on the validation of numerical simulations with experimental data.

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