RESEARCH STATEMENT

Modern aircraft designs demand more sustainable and eco-friendly propulsion solutions. One of the solutions is the Fan Boundary Layer Ingestion (BLI) to achieve enhanced improvements in propulsive efficiency. This technique is being evaluated in many modern aircrafts such as hybrid and blended wing bodies, aircraft with distributed propulsion, NASA's STARC-ABL single aisle 150-passenger class commercial transport electric aircraft, Cambridge-MIT Silent blended wing Aircraft, and the D8 “double-bubble” with a wide fuselage.

Understanding the complex flow behavior of the fan stage with a low-velocity boundary layer being ingested is critical. The non-uniform loading of the fan blades along the span affects the aerodynamic performance if the design doesn't cater to the distorted entry flow. Also, the fan performance at various operating conditions/speeds needs to be studied to estimate the safe operating margin. The proposed research work aims to address the challenges pertaining to the complex flow behavior of the fan with BLI, and the safe operating margin is estimated. A suitable fan distortion tolerant flow control technique will be implemented to mitigate the associated aerodynamic penalty.

Background and Current Work

Axial compressor flow behavior and control

Over the years, my research work has focused on understanding the complex flow physics of the axial compressor stage available at the Propulsion Division, CSIR-NAL. This primarily involves having detailed steady and unsteady measurements along and across the compressor stage assisted by steady and unsteady RANS CFD computations. The stability margin, or the safe operating margin, is a very critical input for the pilot. A correct estimate will lead to harnessing higher performance from the aero-engine. Due to inlet flow distortions and adverse pilot maneuvers, the stall margin will be reduced. Hence, the eminent objective is to enhance the stall margin to cater for these events. This is achieved by incorporating active and passive flow control devices.

My interest in flow control led to the development of a novel Self-Recirculating type Casing Treatment (Self-RCT) during my doctoral studies. I designed and developed a new Self-recirculating type casing treatment (RCT). Using numerical and experimental techniques, the dual benefits of enhanced stall margin without drop in performance and improved aeroelastic benefits were demonstrated for the transonic compressor stage with Self-RCT. The outcome of this research led to many international publications [1-7], notably in the ASME Journal of Turbomachinery. The knowledge gained from the flow control research will be very useful for the present proposed work on Fan with BLI.

Fan stage performance evaluation

I was a co-PI for the steady and unsteady aerodynamic performance evaluation of the high-speed fan stage of the 4kN thrust category Small Turbofan Engine (STFE) developed by M/s. DRDO-GTRE for Subsonic Cruise Nirbhay Missile. A new fan stage test rig was completely designed and commissioned with necessary instrumentation schemes for fan stage performance evaluation.

Similarly, I was responsible for the test rig preparation, test rig health (vibration) monitoring (data acquisition and analysis), and conducting experiments for the technology demonstration program on the design and development of the aerodynamically advanced lightweight composite (non-metallic) blades for the transonic axial flow fans/compressors.

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Research Proposal

Futuristic advanced airframe-propulsion concepts are going for fan boundary layer ingestion concepts. In conventional wing-mounted engine configurations, a part of the total energy dissipation occurs in the wake of the airframe elements, such as the fuselage and in the jets of the engines. In the BLI technique, boundary layer fluid from the airframe is energized by the propulsor that reduces the wake and jet dissipation, hence increasing the overall propulsive efficiency. As a result, less propulsive power is required to sustain the flight.

Many renowned scientists, professors, and industries across the globe are working on the proposed futuristic and advanced aircraft design concept with Fan boundary layer ingestion that has shown improvements in propulsive efficiency by energizing the boundary layer.

Higher velocities are induced on the boundary layer fluid due to fan suction pressure hence altering the boundary layer profile. The aft-mounted fan stage receives non-uniform inlet total pressure and velocity distribution that leads to a performance penalty for the fan. Moreover, the periodic unsteady blade loadings can have a detrimental impact on the aeroelastic aspects as well.

The objective of the proposal is to understand the complex flow physics involved in the fan stage due to distorted inlet flow, estimate the safe aerodynamic margin available, and develop a suitable flow control technique. The stall limit/ operating margin will be established at various operating speeds for the fan stage with BLI. A flow control technique will be developed to overcome the drop in fan stage performance due to inlet distortion due to fan BLI. The knowledge gained from this study would be helpful in developing new fan stage configurations with BLI without sacrificing the stall margin.

I have 15 years of experience in carrying out experimental and numerical studies on transonic axial compressor stage and fan performance evaluations. At present, CSIR-NAL does not have the capability of using fan propulsors with boundary layer ingestion. This fellowship would provide experience in designing and understanding the fan BLI concept, which would be highly valuable to CSIR-NAL and other aircraft manufacturers in the country.

With my research experience at Propulsion Division, I am well equipped with the skill set required to accomplish the aforementioned research work. My fundamental research works on stall margin improvement studies on axial compressors will immensely aid in addressing the proposed research. I look forward to working closely with a number of fellow researchers toward understanding complex flows and developing solutions for challenging practical problems involved with fan BLI. I am sure that this opportunity could provide me with the right kind of research atmosphere to enrich my technical skills in the area.