Institute of Turbomachinery and Flight Propulsion
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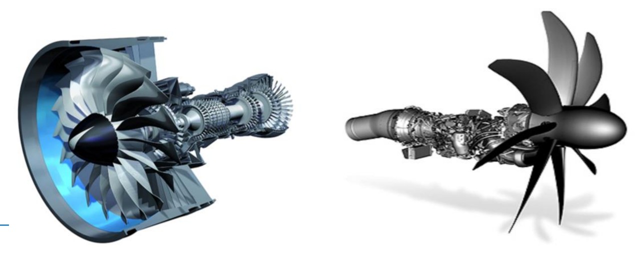

Future Research at LTF: New Ideas and Early Approaches

LIFT: Loaded Investigation For Turbomachinery*

Introduction

Motivation

As the aviation industry pushes toward CO_2 neutrality, modern aero-engine designs demand compressors that are more efficient, compact, and powerful. By increasing stage loadings while maintaining aerodynamic performance, designers can reduce the number of compressor stages, leading to lighter engines with lower specific fuel consumption (SFC).

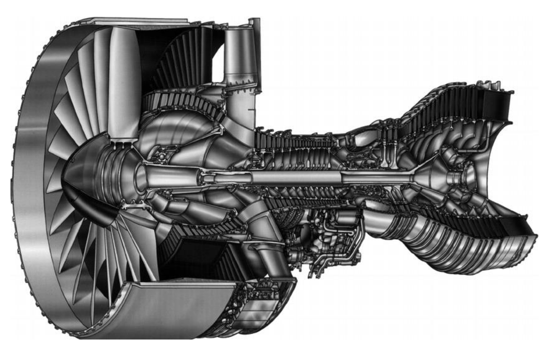

Fig. 1 A modern jet engine PW4084.

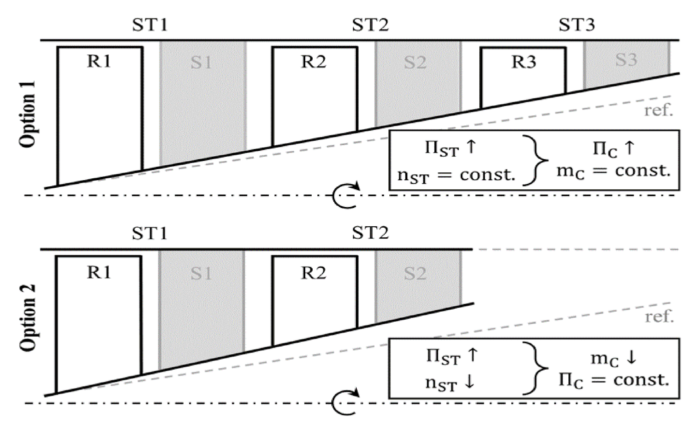

Fig. 2 Comparison of Two Axial Compressor Design Strategies.

State of the Art

Advanced design approaches, such as tandem/hybrid aerofoils, enable more highly loaded compressor designs while preserving efficiency, making them a key innovation in optimizing stage performance over single-blade configurations [1]. A tandem aerofoil design consists of two aerofoils on each compressor row, a front blade and a rear blade as depicted in Fig.2. In this context, two current projects are investigating the contribution of tandem blades to compact compressor designs and reduction of SFC.

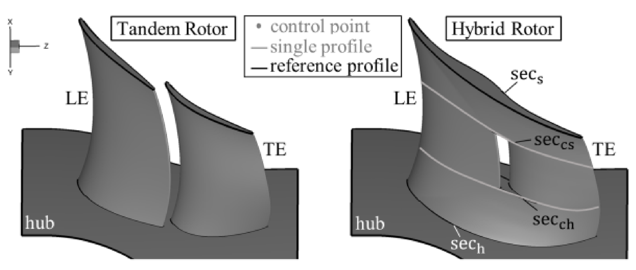

Fig. 3 Schematic of a tandem/hybrid blade.

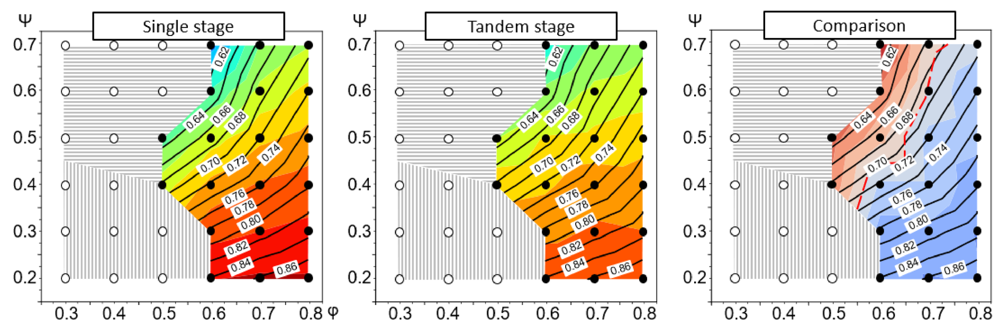

Fig. 4 Smith Chart of single and tandem aerfoil stage configuration

Projects Presentation

Project 1

Starting from an industrial 8 stages reference compressor, new highly loaded designs with reduced number of rows will be generated. Starting from a throughflow design in the S2 plan combined with a blade to blade analysis in the S1 plan will allow for a first quasi-3D (Q3D) analysis of those reduced highly loaded compressor designs as shown in Fig.7.

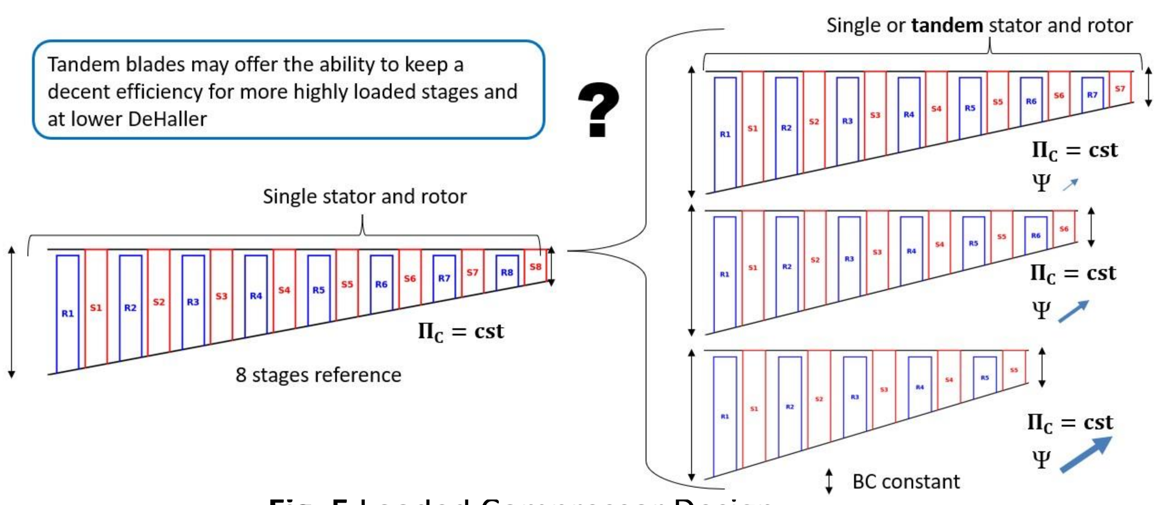

Fig. 5 Loaded Compressor Design.

Project 2

This project is based on the geometric and aerodynamic characteristics of the 3.5-repeating stage, low-speed axial research compressor (FRANCC) at LTF as presented by Hopfinger and Gümmer [2]. The first 1.5 stages of this compressor will be redesigned, considering an inlet guide vane (IGV), tandem-rotor, and tandem-stator setup.

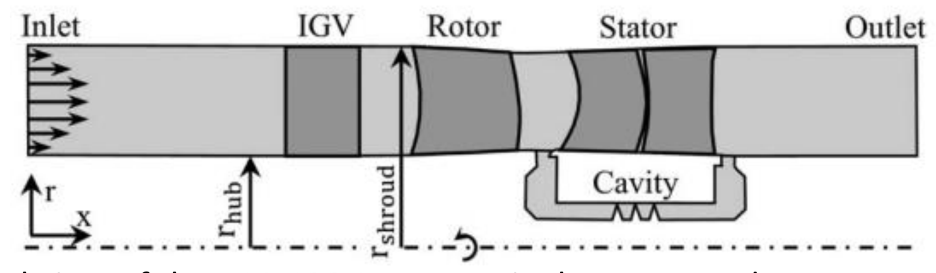

Fig. 6 Meridional view of the FRANCC 1.5 stage single-rotor, tandem-stator setup presented by Hopfinger and Gümmer [2].

The stage design is based on a quasi-3D approach, which in this context refers to the integrated design of 2D throughflow methods combined with multisectional 2D B2B analysis as shown in Fig.7.

Pre-Design

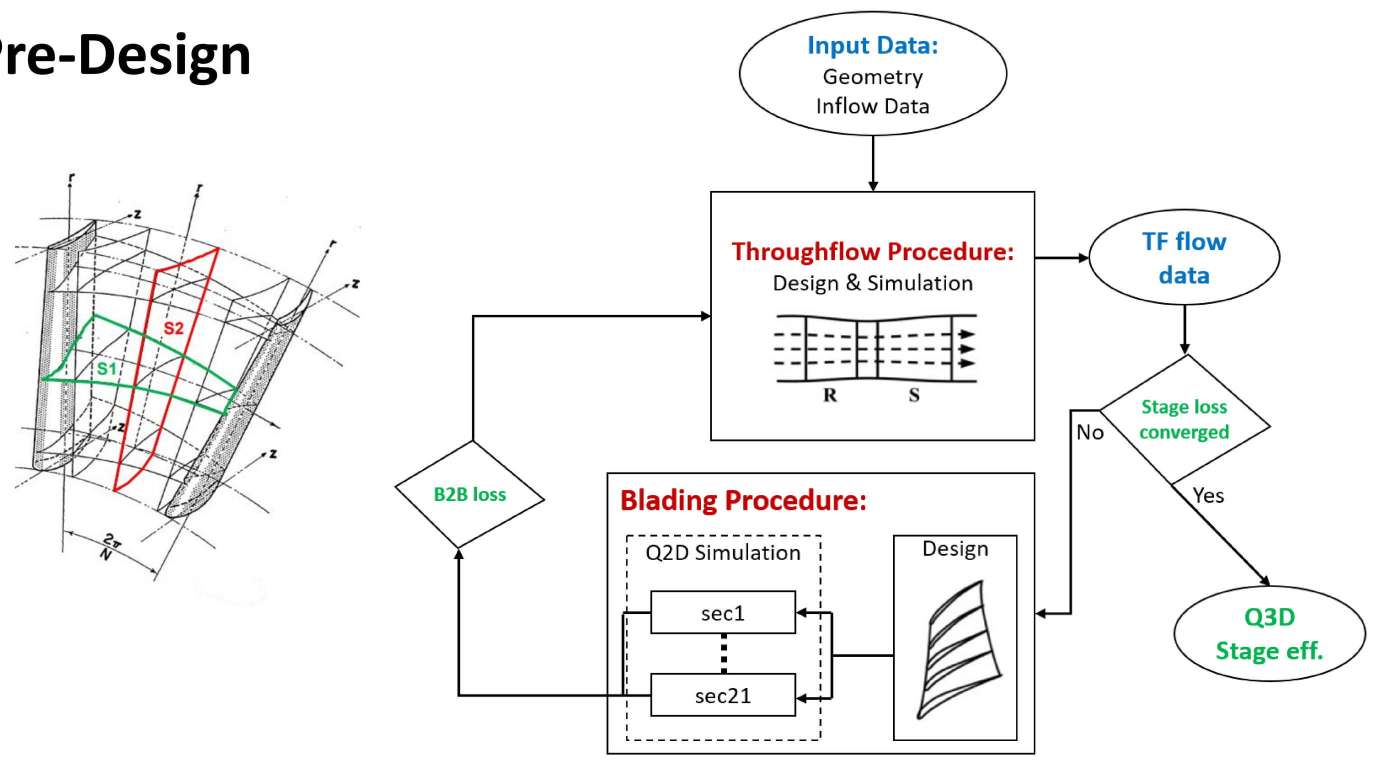

Fig. 7 Flowchart of the TF and B2B coupled Q3D design procedure

Design and Validation

A CFD and FEM analysis of the critical front and rear stage will be performed on the reduced compressor designs that passed the Pre-Design procedure. The CFD and FEM Validation will stand for the final approval of the investigated concept.

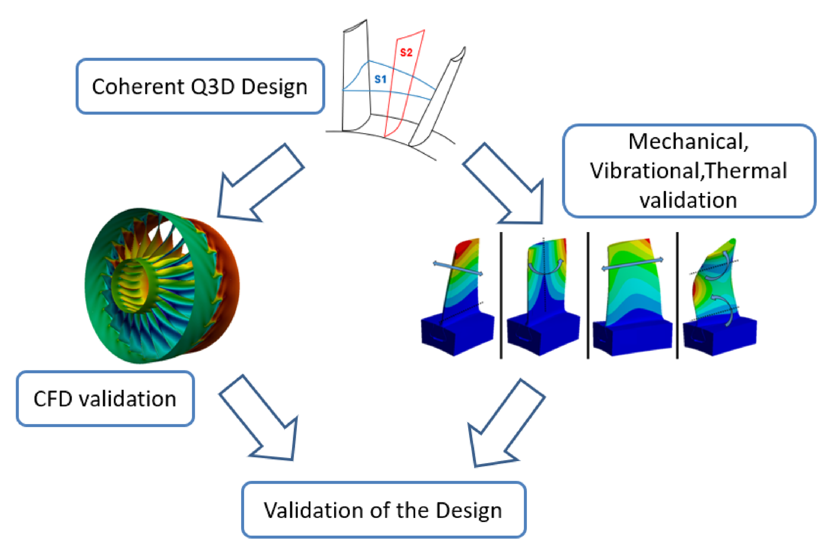

Fig. 8 Validation Procedure

References:

[1]: Philipp von Jeinsen, Jannik Eckel, Samuele Giannini, Volker Gümmer, A Numerical Design Space Investigation of Low-Speed Axial Compressor Stages Using Single-Row and Tandem Bladings, Journal of Turbomachinery 146(6):1-26, January 29, 2024

[2]: Hopfinger, M., and Guemmer, V., 2019, "Preliminary Design of a Three-Stage Low-Speed Research Compressor Using Tandem Vanes," AIAA Propulsion And Energy, Paper No. AIAA 2019-3909.

Time-Resolved Flow Field Measurements in Highly Loaded Compressor Stages**

Motivation

To capture unsteady flow structures and improve loss analysis in highly loaded compressor stages, the application of **time-resolved** measurement techniques is essential.

Traditional hot-wire anemometry provides time-resolved velocity and flow angle information, but **lacks robustness** and is **highly sensitive to contaminations**. This necessitates the investigation of alternative time-resolving measurement technologies suitable for compressor environments.

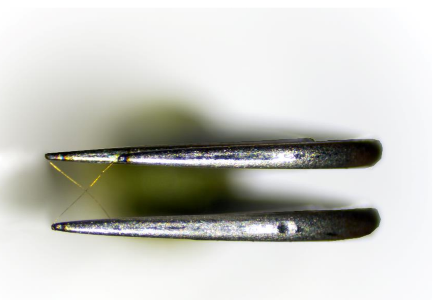

Fig. 1 X-Wire top view

Alternative Measurement Technologies

Split-fiber Probe

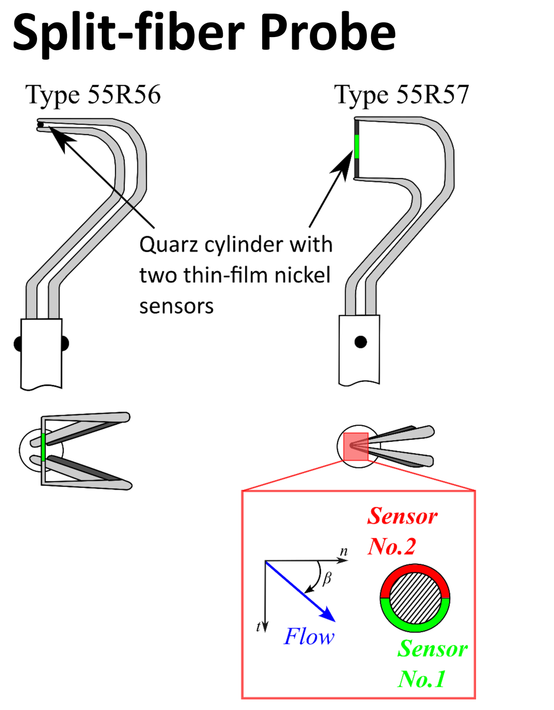

Fig. 2 Split-fiber Probe sketches

Fast-Response Pressure Probe

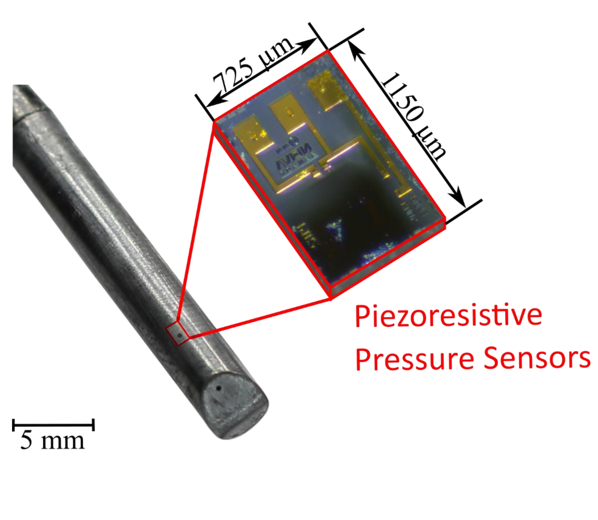

Fig. 3 First prototype with two sensor configuration

Objectives

- Developing a more robust time-resolved measurement technology compared to conventional measurement methods
- Evaluation of two alternative measurement techniques: **Fast-Response Pressure Probe** and **Split-fiber Probe**
- Investigation of time-resolved pressure (static and total) as well as velocity data

Current Progress:

- Initial prototype with miniaturized sensors manufactured with ongoing preliminary testing
- Next steps: comprehensive calibration and testing of probe characteristics

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