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Hy2C : EXPERIMENTAL AND NUMERICAL EVALUATION OF A HIGHLY-LOADED MULTISTAGE LOW-SPEED AXIAL COMPRESSOR FEATURING TANDEM STATOR VANES: ROBUSTNESS INVESTIGATION OF INLET PRESSURE PROFILE VARIATIONS

Introduction

Objectives

- ❑ Comparison of Experimental and Numerical results for the 3.5 stage Baseline configuration.
- ❑ Robustness Study of the compressor under the influence of inlet pressure profile variation.
- ❑ Blockage development in the multistage compressor system.

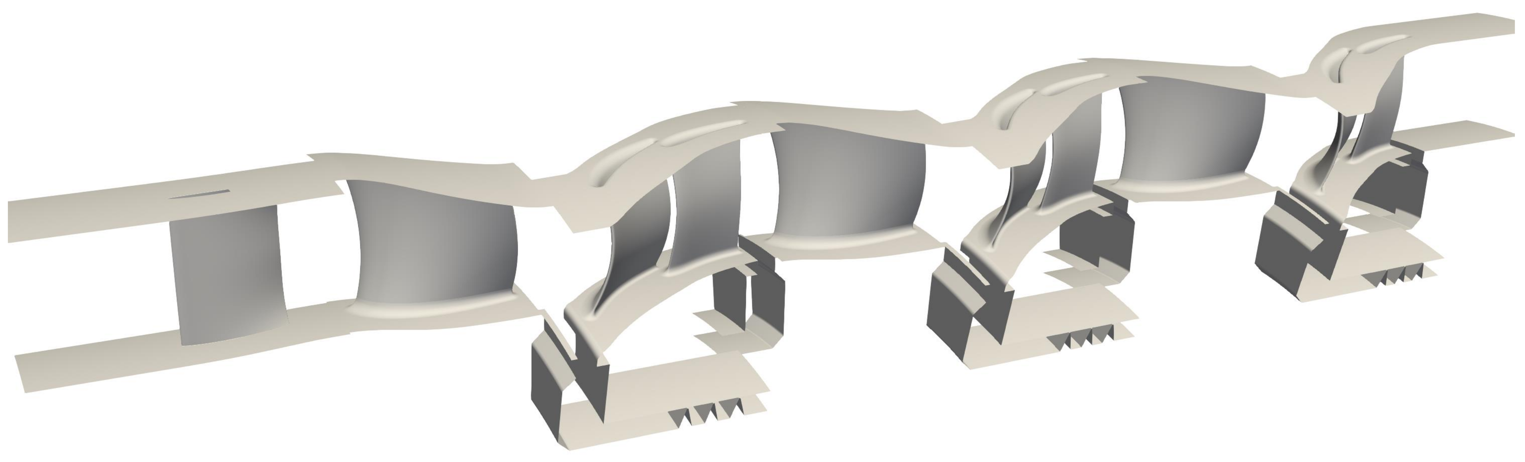

Fig. 1: 3.5 Stage Axial Compressor

3.5 Stage Axial Compressor

The FRANCC (Fundamental Research and New Concepts Compressor) 1.0 is a 3.5 stage highly loaded axial compressor with tandem stator vanes.

Blade Count	40 (IGV, R,S)
Design Speed	1485.24 rpm
Inlet Corrected Mass flow rate	17.953 kg/s
Design flow coefficient	0.57
Design work coefficient	0.59
Hub to tip ratio	0.8

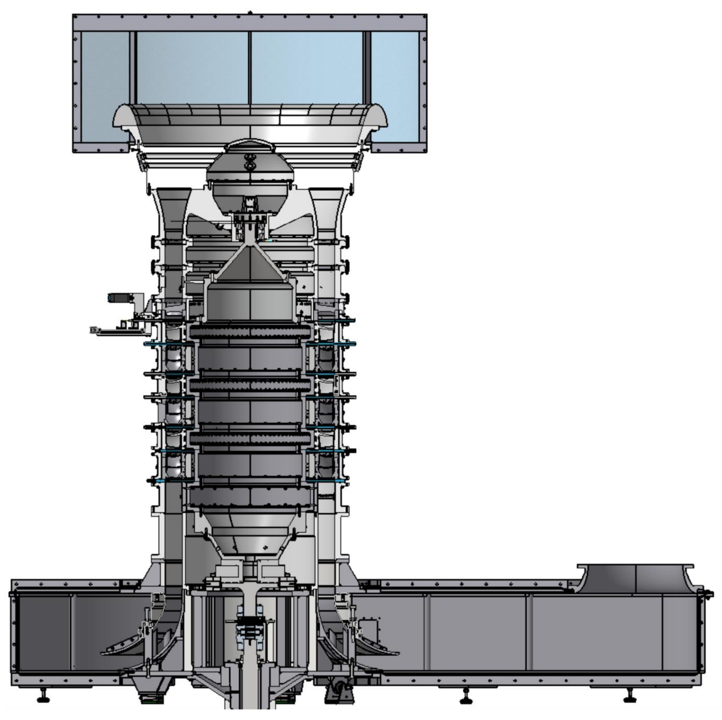

Fig. 2: FRANCC 1.0 Experimental Setup

For CFD, a structured mesh is used with y+ <1.5. All geometric features like penny gaps, fillets and cavities are considered and meshed. K- ω SST turbulence model is used without any wall function. A constant mass flow rate boundary condition is used at the outlet.

Base Configuration Study

Results

- CFD is not able to predict the better performance observed in the experiment.
- The operating range is predicted well by the CFD.
- In CFD, each stage is equally less efficient than the experiment.
- Exit behavior of the Stator from experiment agrees more with CFD than Rotor.
- Rotor is performing higher flow turning in experiment than CFD by 4 degrees.

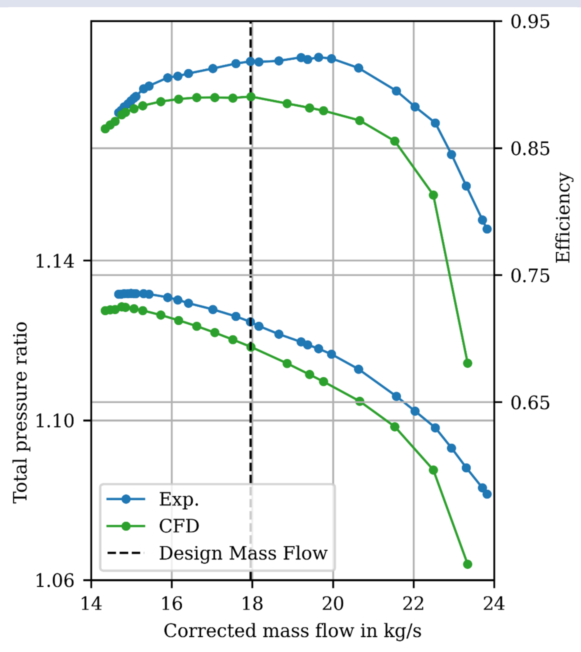

Fig. 3: Speedline Characteristics

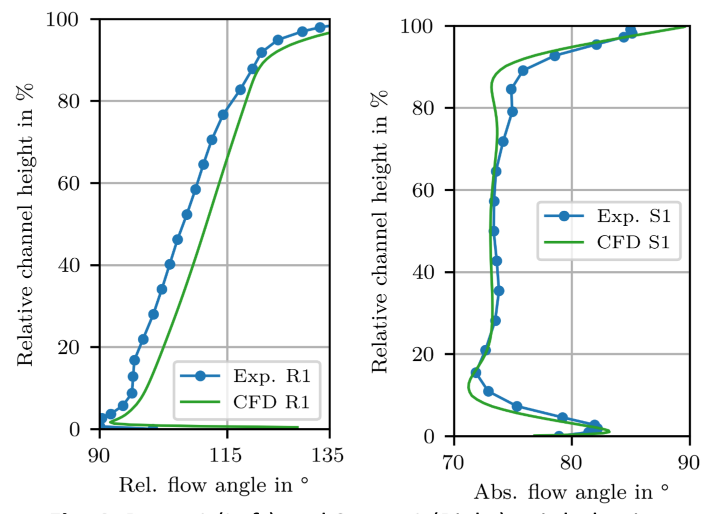

Fig. 4: Rotor 1 (Left) and Stator 1 (Right) exit behavior

- The behavior at the inlet to the Rotor matches well between the experiment and CFD.
- The major difference comes after the rotor.

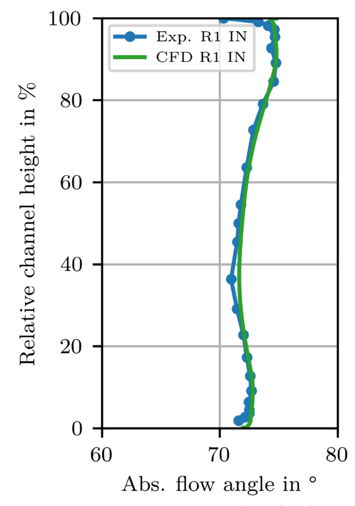

Fig. 5: Rotor 1 inlet behavior

Blockage Behavior Study

Results

- CFD is able to closely predict the blockage behavior in the experiment.
- A repeating pattern of DT behavior can be seen in each stage after Rotor 1.
- The DT decrease in the IGV as it is an accelerating row. The increase in DT at the TE of IGV is due to the leakage flow from the penny gap at the hub and shroud.
- DT decreases at the rotor entry due to acceleration of the flow. Influence of tip leakage flow becomes dominant near the casing.
- DT increases in the stator due to deceleration, but at the hub the increase is more due to the cavity leakage flow.
- Drop in DT at hub at Sx45 and Sx85 is due to suction effect from the opening of the stator cavity.
- Difference between the DT for P1 and P2 vanishes after IGV.

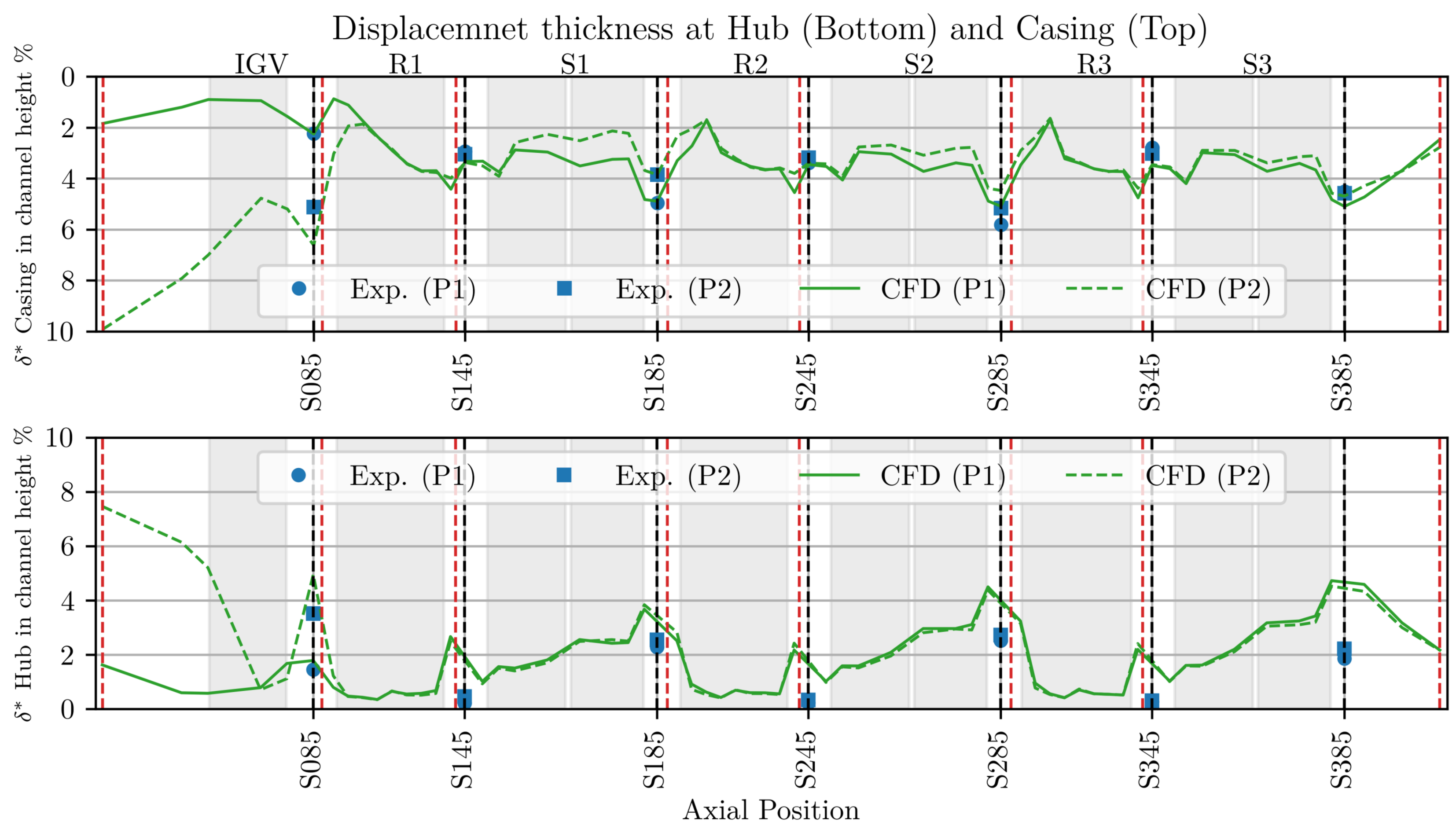

Fig. 12: DT at hub and casing behavior through the stage

Inlet Pressure Profile Variation

Inlet Conditions

- Two different inlet Pressure profiles (P1 and P2) is given with different endwall boundary layer thicknesses.
- The aim is to investigate the influence of inlet endwall boundary wall thickness.

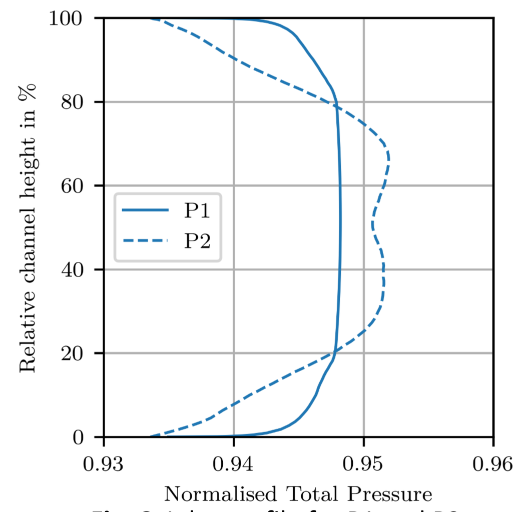

Fig. 6: Inlet profile for P1 and P2

Results

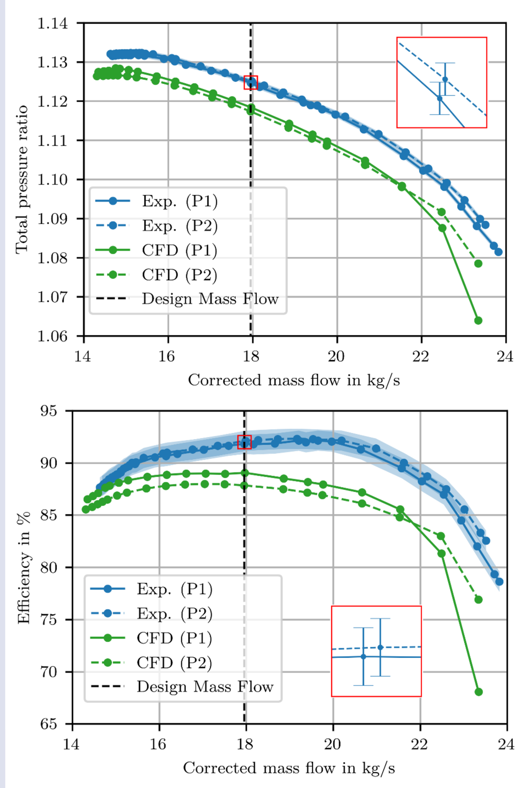

Fig. 7: Speedline Characteristics of P1 and P2

- CFD is under-predicting the performance.
- Compressor is robust to inlet condition variation in experiment.
- In CFD, P2 has lower performance than P1.
- Offset in flow turning at rotor exit is present.

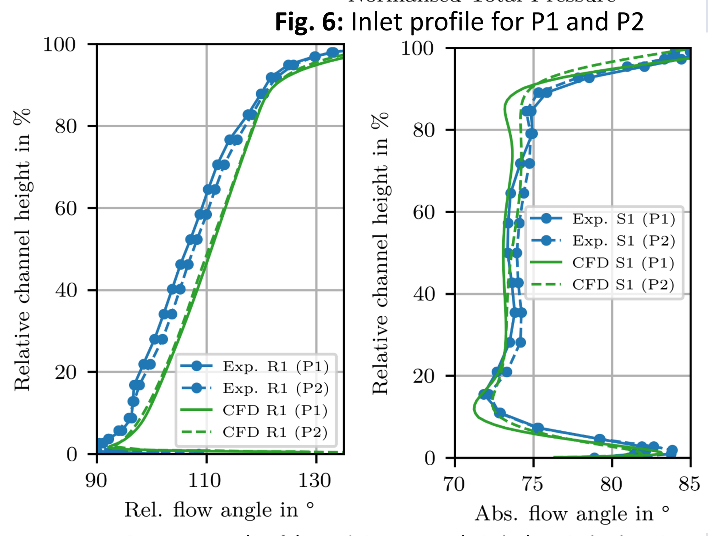

Fig. 8: Rotor 1 (Left) and Stator 1 (Right) exit behavior

- The wakes from the two tandem stator vanes are visible.
- P2 is producing lower losses at the endwalls compared to P1 in the experiment.
- This is due to the high turbulence near the endwalls for P2 which made the flow robust to flow separation.

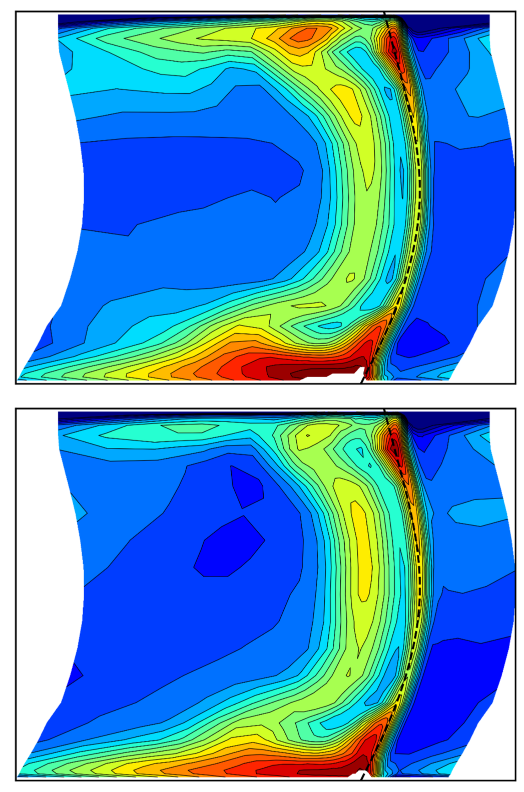

Fig. 9: Stator 1 loss for P1 (Top) and P2 (Bottom)

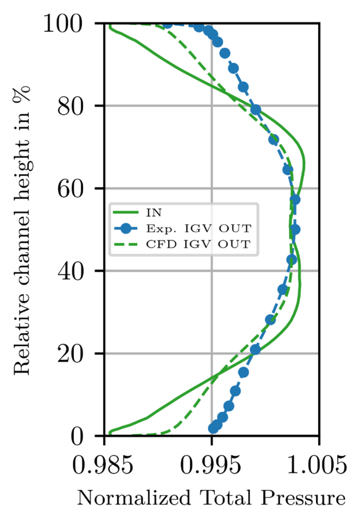

Fig. 10: Pressure profile at inlet and exit of IGV for P2

- IGV experiences a flow redistribution and high turbulence decay for P2.
- High pressure flow from the midspan goes towards the endwalls.
- IGV have more losses for P2 compared to P1.

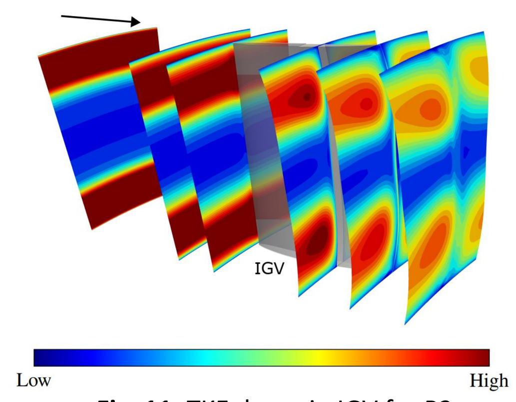

Fig. 11: TKE decay in IGV for P2

Future Studies

- ❑ Further investigation is needed to understand the offset between the experimental and numerical data.
- ❑ Investigations regarding the effect of instrumentation geometry also have to be quantified.

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