NUMERICAL INVESTIGATION ON EFFECTIVENESS OF AXIALLY UNIFORM AND NON-UNIFORM TIP CLEARANCE HEIGHT ON THE PERFORMANCE OF SINGLE STAGE TRANSONIC AXIAL FLOW COMPRESSOR

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Abstract:

A steady state numerical study of tip clearances has been carried out, to study the impact of tip clearance height on the performance of single stage transonic axial flow compressor of 1.35 pressure ratio, 24 Kg/s corrected mass flow rate at 12930 corrected rpm, using commercial software ANSYS Fluent. CFD analysis was carried out on both uniform and non-uniform tip clearance model to study their impact on the performance of single stage transonic axial flow compressor and to obtain the 'optimum' tip clearance for both the cases. The CFD results are validated with the earlier published experimental data on the same compressor at 70 % design speed.

The uniform rotor tip clearance is based on the concept of providing uniform clearance in the casing above the entire rotor chord of the axial flow compressor. The non-uniform tip clearance is based on the concept of a smaller tip-clearance in the front portion of the rotor blade chord and a large clearance in the rear portion. An 'optimum' value of rotor tip clearance was noticed for a single stage axial flow compressor, both for axially uniform and axially non-uniform tip clearance.

Shear stress transport (SST) K-ω turbulence model has been used to capture viscous effect. The steady flow computations have been carried out for two speeds namely 70 %, and 100 % of the compressor design speed and obtained the overall performance characteristics of the compressor stage. For validation, CFD data were compared with the experimental results. CFD data showed good agreement with the experimental results and hence, the analysis was extended to five uniform tip clearances of 0.25 mm, 0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm and three non-uniform tip clearances of 0.5-1.0 mm, 0.5-1.5 mm and 0.5-2.0 mm. The study showed that the uniform clearance of 0.5 mm showed better performance and 0.5-1.0 mm showed better performance for non-uniform tip clearances. Moreover non uniform tip clearances showed better performance than uniform tip clearances.

Computational flow domain and boundary conditions as applied are shown in Fig. 1.Fig. 2 and Fig. 3 shows effect of tip clearances on the overall performance of single stage compressor for different uniform tip clearances varying from 0.25 mm, 0.5 mm, 1.0 mm, 1.5 mm and 2.0 mm and non-uniform tip clearances of 0.5-1.0 mm, 0.5-1.5 mm and 0.5-2.0 mm. Fig. 4 shows the variation in peak stage total pressure ratio with increase in uniform and non-uniform tip clearance height. Fig. 5 shows the variation in stage efficiency with increase in uniform and non-uniform tip clearance height. Numerical results shows very close match with the experimental results at 70 % design speed.

There is a decrease in peak stage total pressure ratio as the tip clearances are increased from 0.25 to 2.0 mm. This can be noticed from the Fig. 2 and Fig. 4.

There is a decrease in peak efficiency as the tip clearances are increased from 0.25 to 2.0 mm, as can be noticed from the Fig. 3 and Fig. 5. With the increase in uniform tip clearances

from 0.25 mm to 1.5 mm, the stall margin increases but there is decrease in stall margin for higher uniform tip clearances of 2.0 mm.

The uniform and non-uniform tip clearance results are discussed in more details in the main report.

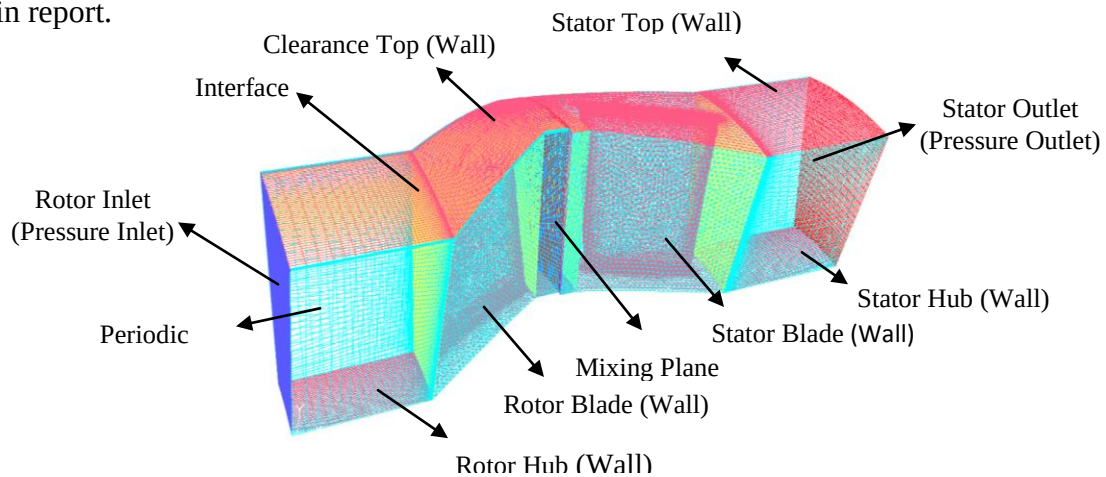

Fig. 1 Computational flow domain and with boundary conditions.

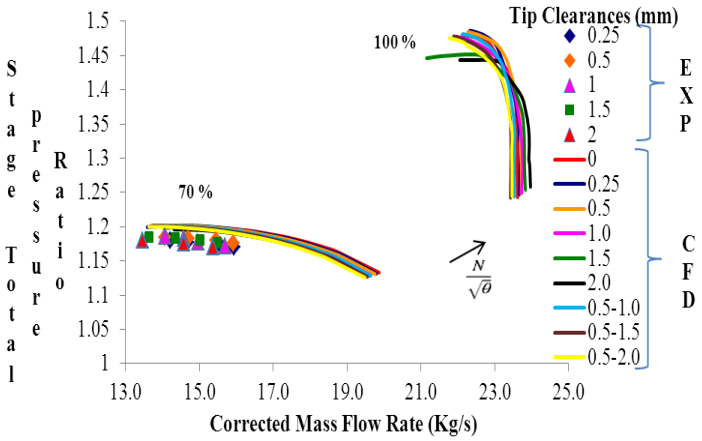

Fig. 2 Compressor performance map of stage total pressure ratio with corrected mass flow rate.

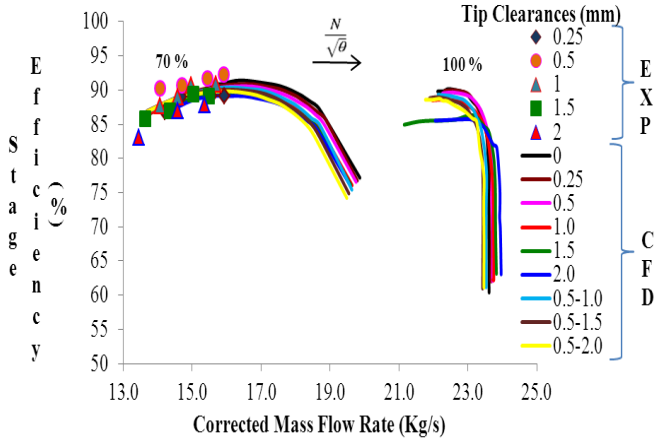

Fig. 3 Compressor performance map of stage efficiency with corrected mass flow rate.

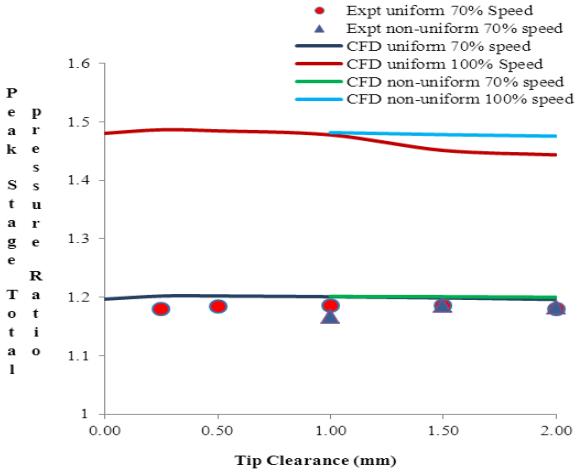

Fig. 4 Variation in peak stage total pressure ratio with increase in uniform and non-uniform tip clearance

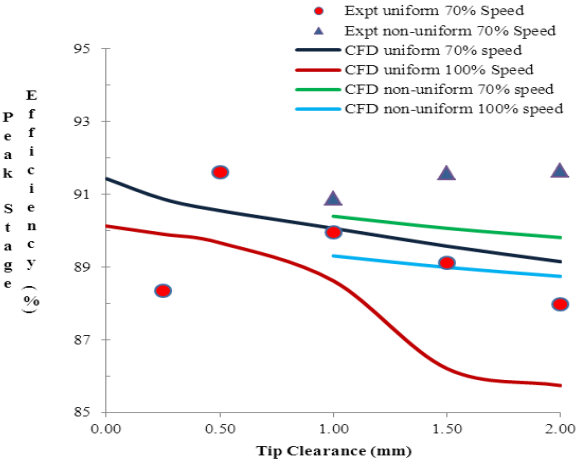

Fig. 5 Variation in peak stage efficiency with increase in uniform and non-uniform tip clearance height.