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Investigation of Effect of Tip Clearance in Centrifugal Compressor

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ABSTRACT

In this thesis investigations are done to determine the tip clearance effect in centrifugal compressor diffuser used in an industrial gas turbine. Two different configurations of original & one pinched diffuser at 10% by varying the tip clearance 0.028, 0.054, 0.083, 0.107. Design calculations are done by varying the tip clearance values in the range 0.028,0.054, 0.083 & 0.107, thickness 3mm and diffuser width 1mm to determine diffuser height, diffuser width and diffuser radius. 8 models are modeled with 4 each in original & pinched respectively in Creo 2.0. CFD analysis is performed on the models to determine pressure, velocity and turbulent kinetic energy.

I.INTRODUCTION

Centrifugal compressors, typically called radial compressors, are dynamic ax symmetric work absorbing turbo machinery sub class. Pressure rise is achieved by them by adding kinetic energy or velocity to a fluid continual flow through the impeller or rotor.

Fig 1:-Centrifugal compressor impeller

Working

Air is pulled into the middle of an impeller which is rotating consisting of radial blades and is pushed toward the middle by force. The air's radial movement leads to a pressure rise & therefore the generation of mechanical energy. Before the air led into the middle of the impeller, kinetic energy is additionally reborn into pressure by passing through a diffuser & volute.

Tip Clearance

Tip clearance is the gap between the tip of a rotating airfoil & a stationary component.

- Propeller (aircraft or ship): Propeller & structure
- Gas turbine: Rotor blade & casing
- Wind turbine: blade & tower
- Ground tip clearance

Effect of tip clearance

The velocity distributions with the biggest and therefore the second smallest clearance. In the least 3 tested lows, the result of the increasing tip clearance is most clearly seen at the diffuser water close to the shroud. There it will be ascertained that increasing the tip clearance will increase the secondary flow region leading to larger losses. The result is a lot of pronounced at the high flow, explaining the larger potency decrease at the high flow. At the diffuser outlet, the distinction within the rate distribution is smaller, indicating that the blending of slow flow region is stronger once the tip clearance is larger. The stronger commixture causes higher losses, part explaining the loss of potency with the increasing tip clearance. At the upper mass flow, wherever the result of tip clearance is larger than at the low or style flows, the result

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of tip clearance is smaller once the diffuser dimension is reduced, or the pinch is accumulated. This means that to the effect of tip clearance pinched diffusers are less sensitive. Antecedently Backmanet al.(2007) over that vaneless pinched diffusers compressors are less sensitive to changes in tip clearance Because pinched diffuser is a smaller amount sensitive to tip clearance, it's doubtless that the pinch encounters some losses created by tip clearance. The losses some part are depicted as a rise within the secondary flow region, that the pinch suppresses, resulting in associate improved mechanical device potency.

II.LITERATURE REVIEW

Indraneel Phirke, Qasim Siddiqui, Shubham Sonawane, Pratik Sondkar[1], Review is completed for gathering the economical technique for planning and analyzing the centrifugal compressor. So as to fulfill these demands the applying of variable geometry techniques is commonly thought of and applied. **P M Came, Chris Robinson[2],** reviewed centrifugal compressor style strategies that are normally utilized in business and reviews the underlying engineering supporting the planning practices. The planning method, beginning with the preliminary style and its reliance on empirical rules through to progressive mechanics style utilizing CFD, is given. The necessities of vane mechanical style also are embody the paper.

III.DESIGN CALCULATIONS

Design calculations are done by varying the tip clearance values t_2/b_2 in the range 0.028,0.054, 0.083 & 0.107, thickness t_2 = 1 and diffuser width $\frac{b}{b2+t2}$ = 1 to determine diffuser height, diffuser width and diffuser radius for two different configurations of original & one pinched diffuser at 10%.

The value is taken from the journal paper, **"The tip clearance effects on the centrifugal compressor vaneless diffuser flow fields at off-design conditions" by A. Jaatinen-V¨arri - T. Turunen-Saaresti - A. Gr¨onman - P. R¨oytt¨a - J. Backman**

Case1 (unpinched)			Case2 (10%pinch)		
t2/b2	*b/(b2 + t2)*	*r3/r2*	*t2/b2*	*b/(b2 + t2)*	*r3/r2*
0.028	0.9727	1.68	0.028	0.97273	1.68
0.054	0.9487	1.68	0.054	0.94867	1.68
0.083	0.9241	1.68	0.083	0.92316	1.68
0.107	0.9042	1.68	0.107	0.90301	1.68

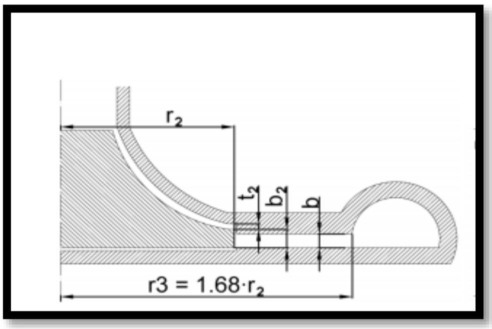

Fig 2: – A schematic view of the flow path and pinch.

Where

t_2 = thickness of diffuser = 3mm, b_2 = diffuser height, b = diffuser width, r_2 = outlet radius, r_3 = diffuser radius

3D MODELS OF CENTRIFUGAL COMPRESSOR WITH TIP CLEARANCE

3d models of the centrifugal compressor's diffuser with tip clearance are done in Creo 2.0 for all 8 cases from the design calculations. Drafting is also done for all the cases

Original Configuration

Case 1 – t_2/b_2 = 0.028

Model 1

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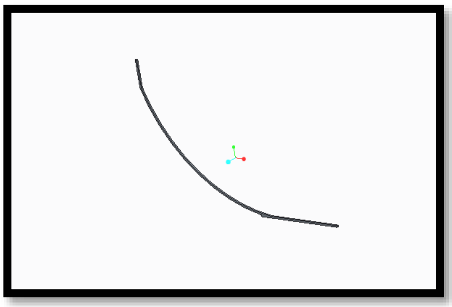

Fig 3:-Model 1 with t_2/b_2 = 0.028 for original configuration

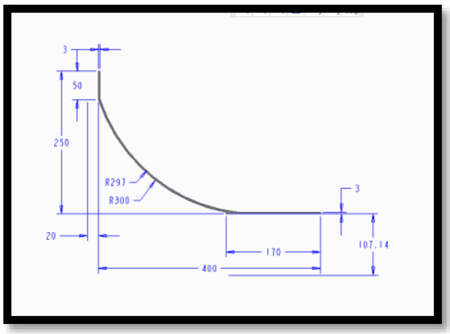

Fig 4:-Drafting of model 1 with t_2/b_2 = 0.028 for original configuration

10% PINCHED CONFIGURATION

Case 5 – t_2/b_2 = 0.028

Model 5

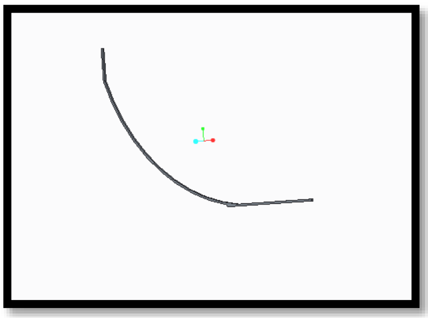

Fig 5:-Model 5 with t_2/b_2 = 0.028 for 10% pinched configuration

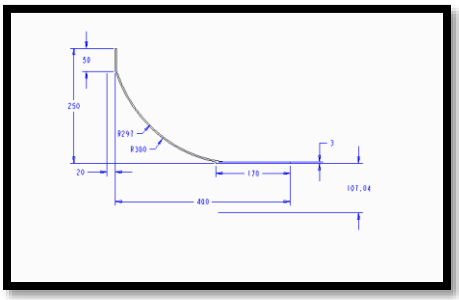

Fig 6:-Drafting of model 5 with t_2/b_2 = 0.028 for 10% pinched configuration

IV.CFD ANALYSIS

CFD analysis is performed on all the 8 models to compare the fluid characteristics using two fluids Air and Gas. The inlet velocity of 20m/s is taken from the journal paper, **"The tip clearance effects on the centrifugal compressor vaneless diffuser flow fields at off-design conditions"** by **A. Jaatinen-V¨arri - T. Turunen-Saaresti - A. Gr¨onman - P. R¨oytt¨a - J. Backman**

Model 1 with t_2/b_2 = 0.028 for original configuration

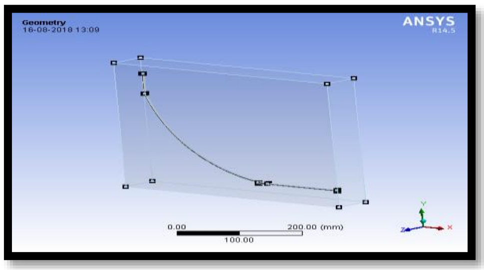

Fig 7:-Imported geometry of model 1 from creo 2.0 with fluid enclosure

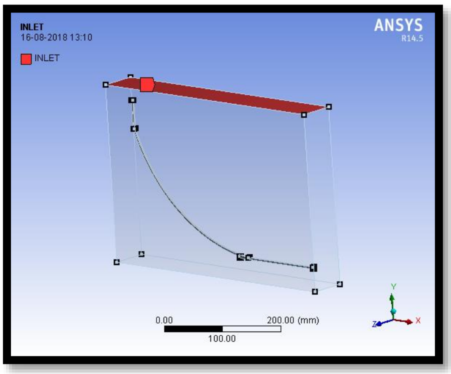

Fig 8:- Fluid inlet

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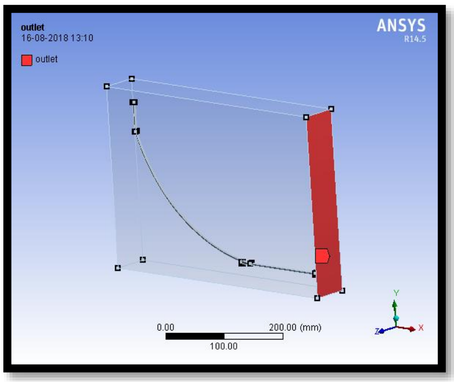

Fig 9:- Fluid outlet

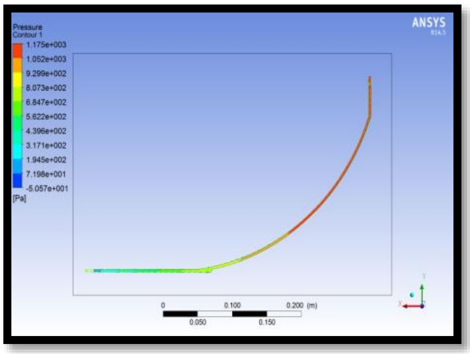

Fig 10: -Pressure in Model 1 using air

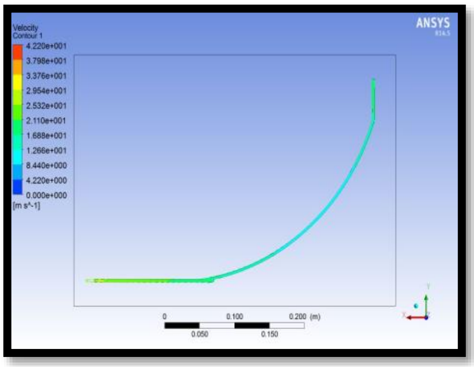

Fig 11:- Velocity magnitude in Model 1 using air

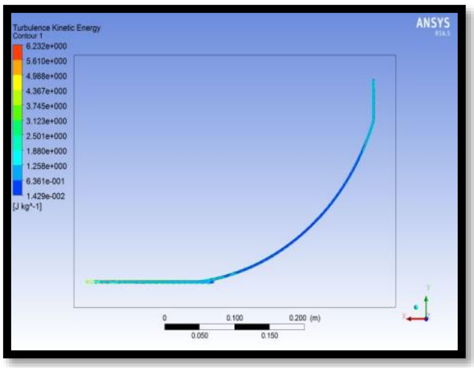

Fig 12:-Turbulence kinetic energy in Model 1 using air

V.RESULTS & DISCUSSIONS

RESULTS TABLES

The following tables shows the pressure variations, velocity variations and turbulent kinetic energy variations for two configurations using Air and Gas from the results of CFD analysis.

Original Configuration

Air

	Pressure(Pa)	Velocity (m/s)	Turbulence kinetic energy $(J\,Kg^{-1}$	Wall heat Transfer coefficient $(W\,m^{-2}$
Model 1	1.181e+003	4.220e+001	6.565	1.110e+002
Model 2	1.175e+003	4.203e+001	6.232	1.109e+002
Model 3	1.160e+003	4.203e+001	4.513	1.106e+002
Model 4	1.127e+003	4.162e+001	4.409	1.092e+002

From the above table, the following observations can be made:

The pressure is decreasing by increasing the tip clearance value. When compared with Model 1 of original configuration t_2/b_2 = 0.028, the pressure value is decreasing by

0.5% for model 2 t_2/b_2 = 0.054, by 1.17% for model 3 t_2/b_2 = 0.083, by 4.45% for model 4 t_2/b_2 = 0.107. The velocity is decreasing by increasing the tip clearance value. When compared with Model 1 of original configuration t_2/b_2 = 0.028, the velocity value is decreasing by 0.4% for model 2 t_2/b_2 = 0.054, by 0.4% for model 3 t_2/b_2 = 0.083, by 1.3% for model 4 t_2/b_2 = 0.107. The turbulent kinetic energy is decreasing by increasing the tip clearance value. When compared with Model 1 of original configuration t_2/b_2 = 0.028, the turbulent kinetic energy is decreasing by 5% for model 2 t_2/b_2 = 0.054, by 31% for model 3 t_2/b_2 = 0.083, by 33% for model 4 t_2/b_2 = 0.107.

Gas

	Pressure(Pa)	**Velocity (m/s)**	**Turbulence kinetic energy $(J\,Kg^{-1})$**	**Wall heat Transfer coefficient $(W\,m^{-2}\,k$**
Model 1	7.989e+005	4.213e+001	3.583	7.55e+003
Model 2	7.966e+005	4.206e+001	2.709	7.584e+003
Model 3	7.936e+005	4.202e+001	2.680	7.718e+003
Model 4	7.851e+005	4.159e+001	2.656	7.553e+003

The pressure is decreasing by increasing the tip clearance value. When compared with Model 1 of original configuration t_2/b_2 = 0.028, the pressure value is decreasing by 0.28% for model 2 t_2/b_2 = 0.054, by 0.6% for model 3 t_2/b_2 = 0.083, by 1.7% for model 4 t_2/b_2 = 0.107. The velocity is decreasing by increasing the tip clearance value. When compared with Model 1 of original configuration t_2/b_2 = 0.028, the velocity value is decreasing by 0.16% for model 2 t_2/b_2 = 0.054, by 0.26% for model 3 t_2/b_2 = 0.083, by 1.2% for model 4 t_2/b_2 = 0.107. The turbulent kinetic energy is increasing by decreasing the tip clearance value. When compared with Model 1 of original configuration t_2/b_2 = 0.028, the turbulent kinetic energy is decreasing by 24% for model 2 t_2/b_2 = 0.054, by 25% for model 3 t_2/b_2 = 0.083, by 26% for model 4 t_2/b_2 = 0.107.

10% Pinched Configuration

Air

	Pressure(Pa)	**Velocity(m/s)**	**Turbulence kinetic energy $(J\,Kg^{-1})$**	**Wall heat Transfer coefficient $(W\,m^{-2}\,k$**
Model 5	1.303e+003	4.215e+001	6.202	1.092e+002
Model 6	1.301e+003	4.045e+001	5.47	1.103e+002
Model 7	1.161e+003	4.045e+001	4.425	1.058e+002
Model 8	1.133e+003	3.761e+001	4.164	1.001e+002

The pressure is decreasing by increasing the tip clearance value. When compared with Model 1 of 10% pinched configuration t_2/b_2 = 0.028, the pressure value is decreasing by 0.15% for model 2 t_2/b_2 = 0.054, by 11% for model 3 t_2/b_2 = 0.083, by 13% for model 4 t_2/b_2 = 0.107. The velocity is decreasing by increasing the tip clearance value. When compared with Model 1 of 10% pinched configuration t_2/b_2 = 0.028, the velocity value is decreasing by 4% for model 2 t_2/b_2 = 0.054, by 4% for model 3 t_2/b_2 = 0.083, by 10.7% for model 4 t_2/b_2 = 0.107. The turbulent kinetic energy is increasing by decreasing the tip clearance value. When compared with Model 1 of 10% pinched configuration t_2/b_2 = 0.028, the turbulent kinetic energy is decreasing by 11.8% for model 2 t_2/b_2 = 0.054, by 28% for model 3 t_2/b_2 = 0.083, by 32.8% for model 4 t_2/b_2 = 0.107.

Gas

	Pressure(Pa)	**Velocity(m/s)**	**Turbulence kinetic energy ($J\,Kg^{-1}$)**	**Wall heat Transfer coefficient ($W\,m^{-2}\,k$**
Model 5	1.81e+003	4.220e+001	6.565	1.109e+002
Model 6	1.175e+003	4.211e+001	6.232	1.092e+002
Model 7	1.160e+003	4.203e+001	4.513	1.106e+002
Model 8	1.127e+003	4.162e+001	4.409	1.110e+002

The pressure is decreasing by increasing the tip clearance value. When compared with Model 1 of 10% pinched configuration t_2/b_2 = 0.028, the pressure value is decreasing by 35% for model 2 t_2/b_2 = 0.054, by 36% for model 3 t_2/b_2 = 0.083, by 37.7% for model 4 t_2/b_2 = 0.107. The velocity is decreasing by increasing the tip clearance value. When compared with Model 1 of 10% pinched configuration t_2/b_2 = 0.028, the velocity value is decreasing by 0.2% for model 2 t_2/b_2 = 0.054, by 0.4% for model 3 t_2/b_2 = 0.083, by 1.37% for model 4 t_2/b_2 = 0.107. The turbulent kinetic energy is increasing by decreasing the tip clearance value. When compared with Model 1 of 10% pinched configuration t_2/b_2 = 0.028, the turbulent kinetic energy is decreasing by 5% for model 2 t_2/b_2 = 0.054, by 31% for model 3 t_2/b_2 = 0.083, by 32.8% for model 4 t_2/b_2 = 0.107.

VI.CONCLUSION

By observing CFD analysis results, the pressure, velocity magnitude and turbulent kinetic energy are decreasing by increasing the tip clearance. When comparing the results for original and pinched configurations, the pressure & velocity are decreasing and turbulent kinetic energy is increasing for pinched configuration.

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