CFD ANALYSIS OF 3D FLOW STRUCTURE & HEAT TRANSFER IN A LINEAR CASCADE OF TURBINE BLADE

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INTRODUCTION

Axial flow turbines were developed in the late 19th century. Today's turbines for power generation are capable of delivering 600MW power or more. Their design is critically dependent upon advanced fluid mechanics and the cascade mode is an essential tool in turbine blade analysis

. A small but consistent improvement in blade efficiency will have corresponding economic implications for the nation. Even efficiency improvements by a fraction of percent lead to considerable gains in the power output of turbines. Simultaneously, they lead to a reduction of costs of operation. Turbine manufacturers are constantly competing to produce more efficient, higher thrust and lighter engines. Correspondingly, the research and development of the turbo machinery components is directed for higher efficiency, higher power output and less weight mainly by the reasons given above, a great number of studies and experiments were performed in order to enhance the efficiency of turbo machines and to understand the loss creation phenomenon. To achieve these goals, the study of flows is essential.

Keywords:, Computational fluid dynamics (CFD), Temperature, pressure, kinetic energy

SCOPE OF PRESENT WORK

The method of Computational Fluid Dynamics (CFD) is utilized in this project for the study of flow effects. The details about CFD, the mathematical methods, the procedure and the solving equations are described Geometry, the methods of the mesh construction, the mesh quality and the boundary conditions

APPLICATIONS

CFD is used by engineers and scientists in a wide range of fields. Typical applications include: Process industry: Mixing vessels, chemical reactors Building services: Ventilation of buildings, such as atriums Health and safety: Investigating the effects of fire and smoke Motor industry: Combustion modeling, car aerodynamics Electronics: Heat transfer within and around circuit boards Environmental: Dispersion of pollutants in air or water

RESULTS

Analysis of turbine cascade with Static temperatures 3500K and 315 oK

Results obtained from analysis of turbine cascade with 3500K and 3150K are presented. Pressure, velocity, Mach number and turbulent kinetic energy contours are plotted to analyze the flow.

1 Mid-span Pressure Distribution:

Case 1: Static temperature 3500K

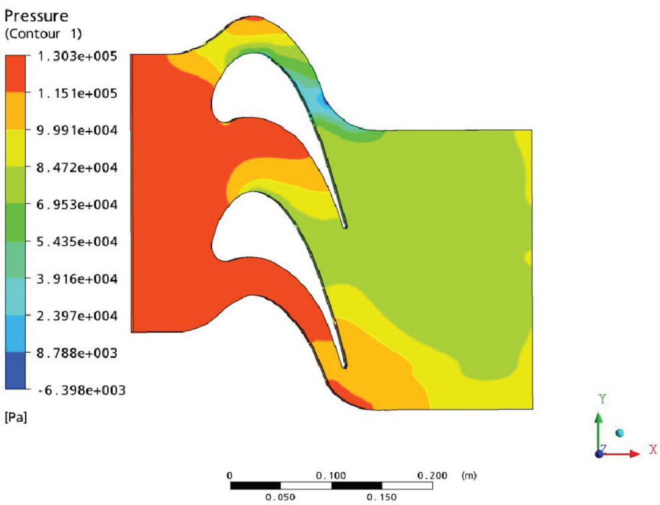

Fig. 3.1.1 Case1 Pressure contours at mid span for T=3500K

There is a gradual decrease in the pressure between the blades from leading edge to the trailing edge which shows that there is no shock formation. The inlet pressure used for

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the pressure output graph is 1, 30,000 Pa. The outlet static pressure being 90,000. It is observed that on pressure side of the blade is higher than suction side at any medicinal location. The decrease in pressure from inlet to outlet is observed due to the increase in velocity of the flow. The volume reduction due to the presence of the blades is the reason for increase in velocity. An increase in pressure is observed on suction side of the bladenear trailing edge. This may be due the decrease in blade thickness in these areas.

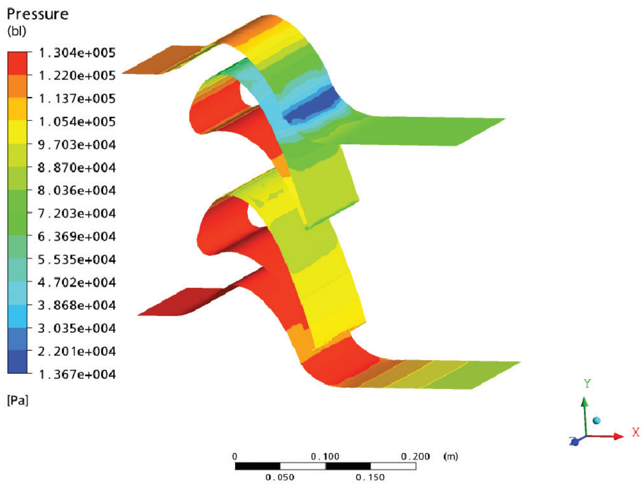
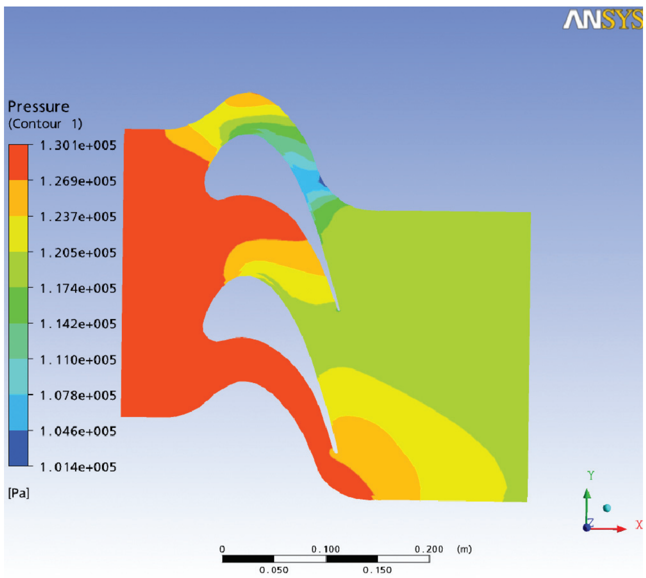


Fig.3.1.1 case1 Pressure contours at Blade side View at T=3500K

Case 2: Static temperature 3150K

Pressure contours at mid span of the turbine cascade is shown in fig. 5.3. The Pressure contour ranging for 3150K is almost same as 3500K. There is a gradual decrease in the pressure between the blades from leading edge to the trailing edge which shows that there is no shock formation. Here it is observed that there is a uniform Pressure on the trailing edge at the range of 1, 17400 Pa. The flow encounters decrease in pressure till the mid-section in the region just above the blade surface. This drop in static pressure is expected across the turbine stage.



3.1.1 case 2 Pressure contours at mid span for T=3150K

2 Mid-span Total Pressure Distribution:

Case 1: Static temperature 3500K

There is a gradual decrease in the pressure between the blades from leading edge to the trailing edge at the range of 70,000 Pa. The decrease in pressure from inlet to outlet is observed due to the increase in velocity of the flow. The volume reduction due to the presence of the blades is the reason for increase in velocity. An increase in pressure is observed in between suction side and pressure side.

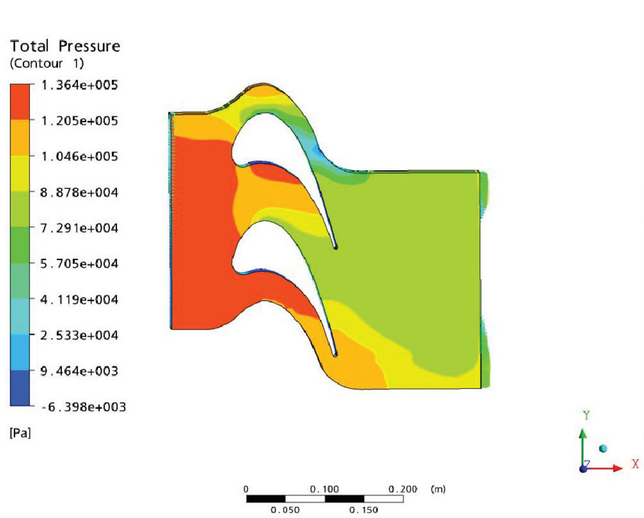


Fig. 4.1.2 case1 Total Pressure contours at mid span for T=3500K

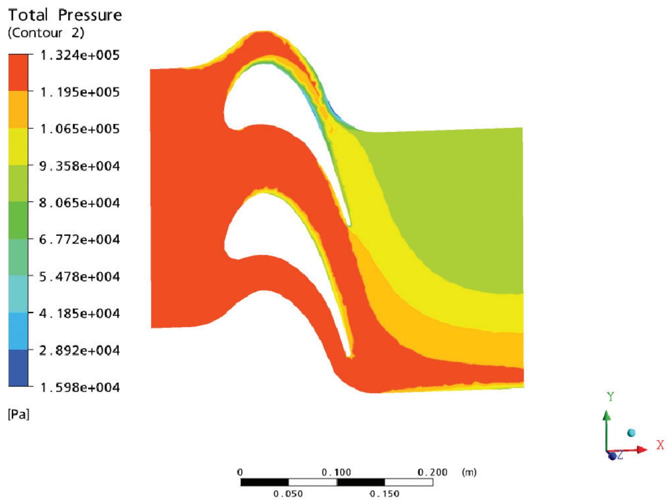


Fig. 4.1.2 case2 Total Pressure contours at mid span for T=3150K

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Case 2: Static temperature 315oK

There is a gradual decrease in the pressure between the blades from leading edge to the trailing edge at the range of 67,000 Pa. Here it is observed that there is a uniform Pressure in between suction side blade to Pressure side blade.

3: Mid-span Temperature contours

Case 1: Static temperature 350oK

Temperature contours at mid span of the turbine cascade is shown in fig. 5.6. Temperature variation is ranging from 350oK to 420oK. The variation can be observed since the inlet boundary conditions are applied on the end walls . It is obseved an increase in temperature between the Suction side blade and the Pressure side blade. The flow passage is gradually increases from Pressure side blade to suction side blade.

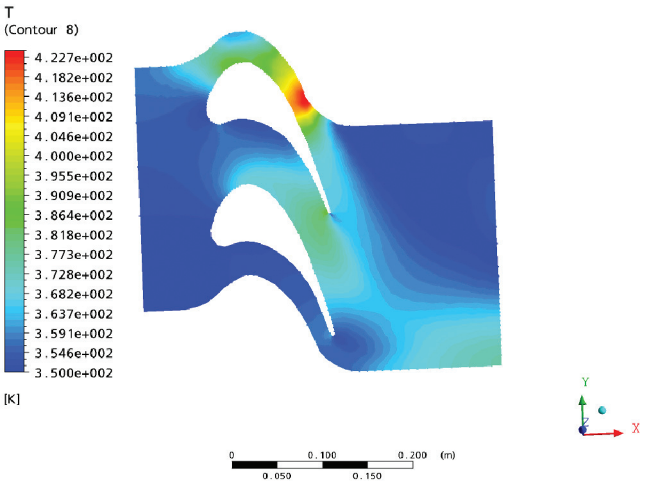

Fig 4.1.3 Case 1 Temperature contour at mid span for T=350oK

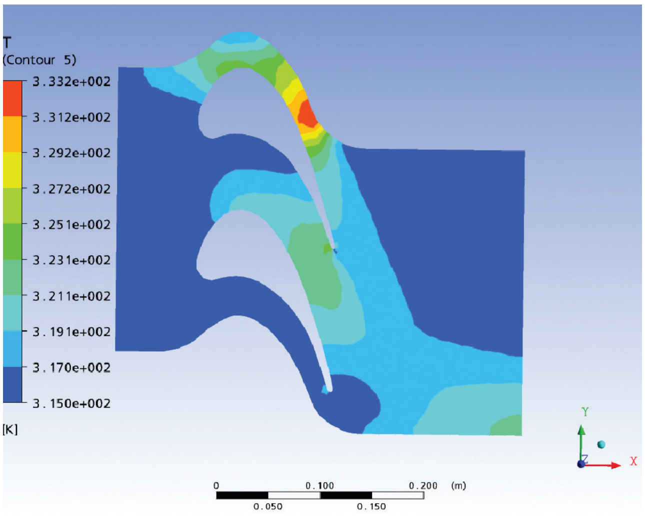

Fig 4.1.3 Case 2 Temperature contour at mid span for T=315oK

Case 2: Static temperature 315oK

Temperature local ranging from 315oK to 330 oK. The variation can be observed since the Inlet boundary conditions are applied on the end wall . It is obseved an increase in temperature between the Suction side blade and the Pressure side blade at the range of 321oK.

4: Mid-span Velocity contour

Case 1: Static temperature 350oK

Velocity contours at mid span of the turbine cascade is shown in fig. 5.8. There is a pressure difference in the suction and pressure side of the blade and hence we get a Lift force for the blade. There is a gradual increase in the velocity of the flow passage between the pressure side blades to suction side blade. As the velocity increases the normal forces on the blades also increases. Here it is observed that there is a flow separation on the suction side at the trailing edge which results in Kutta condition near the exit.

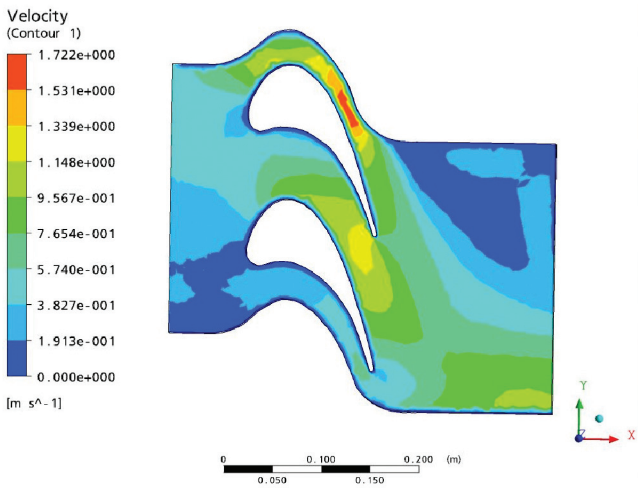

Fig 4.1.4 Case 1 Velocity contour at mid span for T=350oK

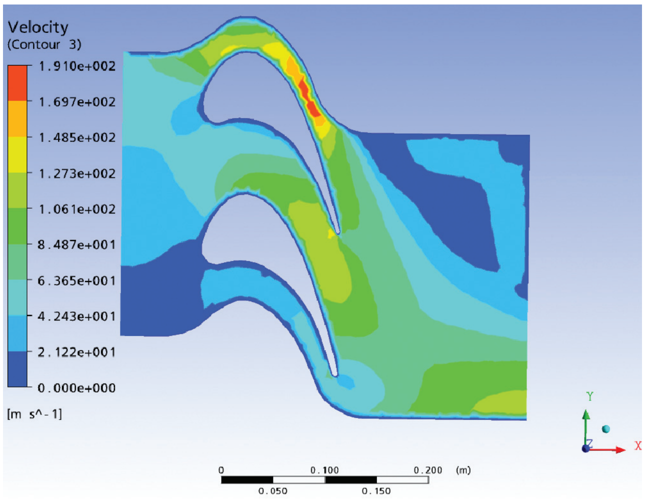

Fig 4.1.4 Case 2 Velocity contour at mid span for T=315oK

Case 2: Static temperature 315oK

Velocity contours at mid span of the turbine cascade is shown in fig. 5.9. When the Static temperature 315 oK is applied from leading edge to trailing edge, the Velocity is increased gradually. Here it is observed that there is a flow separation on the suction side at the trailing edge which results in Kutta condition near the exit. There is a pressure difference in the suction and pressure side of the blade and hence we get a Lift force for the blade. There is a gradual increase in the velocity of the flow passage between the pressure side blades to suction side blade. As the velocity increases the normal forces on the blades also increases.

5: Mid-span Mach number contours:

Case 1: Static temperature 350oK

Because of the pressure gradient from leading edge to trailing edge of the blade, it is observed an increase in Mach number. And also the fig 5.10 shows that, as the Mach number increases the normal force on the blades also increases. The Mach number increases in the flow passage from leading edge to trailing edge of the blade. It is observed that there is a gradual increase in Mach number in the flow passage between the pressure side blade and suction side blade

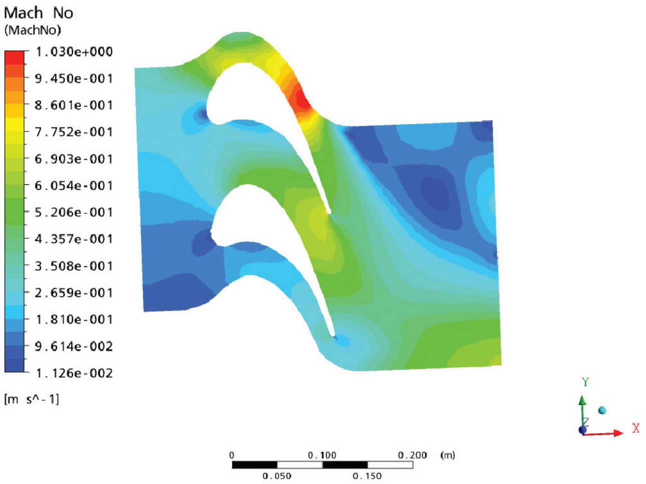

Fig 4.1.5 Case 1 Mach Number Distribution at mid span for T=350oK

Case 2: Static temperature 315oK

When the Static temperature 315 oK is applied from leading edge to trailing edge, the mach number is increased gradually. Because of the pressure gradient from leading edge to trailing edge on the suction side, it is observed the increase in Mach number. And also the Fig 5.11 shows that as the Mach number increases the normal force on the blades also increases. The Mach number increases in the flow passage between the suction side blades to pressure side blade. The figure shows that the flow is subsonic flow.

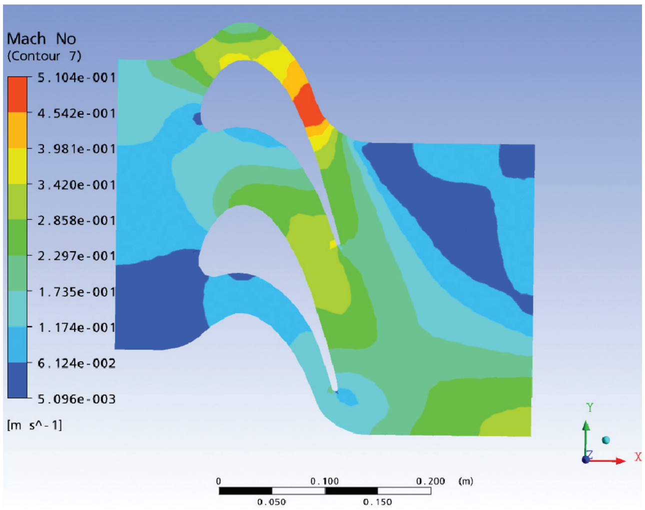

Fig 4.1.5 Case 2 Mach Number Distribution at mid span for T=315oK

6: Mid-span Turbulence kinetic energy:

Case 1: Static temperature 350oK

Turbulence kinetic energy is observed constant throughout the passage between the blades. However, an increase in turbulent kinetic energy is observed on suction side of the blade. Because of the pressure gradient from leading edge to trailing edge on the blade, near the wall as there is a constrictive passage between the wall and the blade side, the zone is subjected to lower turbulence kinetic energy as shown in the figure 5.12.

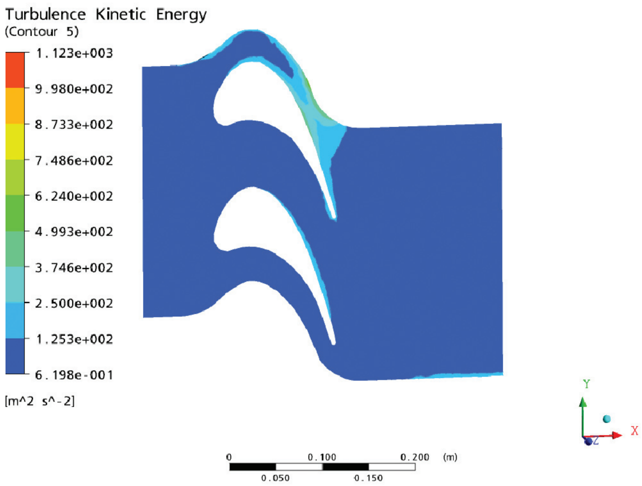

Fig 4.1.6 Case 1Turbulence Kinetic Energy at mid span for T=315oK

Case 2: Static temperature 3150K

Because of the pressure gradient from leading edge to trailing edge on the suction side near the wall as there is a constrictive passage between the wall and the blade side, the zone is subjected to low flow Turbulence kinetic energy as shown in the figure 5.13. Analysis of the computational data reported allows a conclusion that computations with grids produce wall pressure distribution, and the Turbulence kinetic energy is low. It is observed that the Turbulence kinetic energy is low for the flow passage between the suction side blade and pressure side blade.

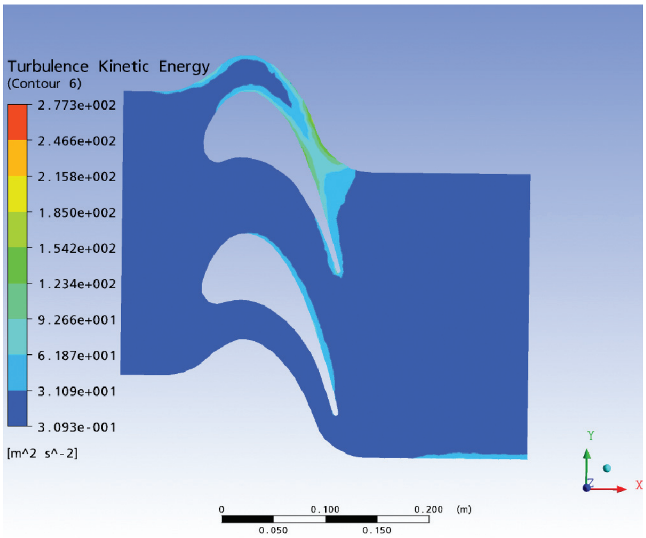

Fig 4.1.6 Case 2 Turbulence Kinetic Energy at mid span for T=3150K

CONCLUSIONS AND FUTURE SCOPE

The developed CFD model provided useful understanding of flow with in turbine cascade. The model can be used as a basis for further work on considering flow with in turbine cascade. The study enhances our knowledge on secondary flows for future turbine. Further progress on secondary flows is dependent on a deeper understanding of the physics of end wall boundary layers.

REFERENCES

[1] Giel, P.W., Thurman, D.R., Lopez, I., Boyle, R.J., Van Fossen, G.J., Jett, T.A.,Camperchioli, W.P., and La, H., "Three-dimensional flow field measurements in a transonic turbine cascade," ASME Paper 96-GT-113 (1996).

[2] Giel, P.W., Thurman, D.R., Van Fossen, G.J., Hippensteele, S.A, and Boyle, R.J.,"Endwall heat transfer measurements in a transonic turbine cascade," ASME Paper 96-GT-180 (1996)

[3] Giel, P.W., and Gaugler, R.E., "NASA Blade 1. Endwall heat transfer data.Version 1," NASA-Glenn Research Center, Turbine Branch, CD ROM (2001).

[4] Garg, V.K., and Ameri, A.A., "Two-equation turbulence models for prediction of heat transfer on a transonic turbine blade," Int. J. Heat and Fluid Flow, Vol. 22, 593-602 (2001).

[5] Kalitzin, G., and Iaccarino, G., "Computation of heat transfer in a linear turbine cascade", Center for Turbulence Research Annual Research Briefs, 277-288 (1999).

[6] Wilcox, D.C., "A two-equation turbulence model for wall-bounded and free-shear flows", AIAA Paper 93-2905 (1993).

[7] Menter, F.R., "Two equation eddy-viscosity turbulence models for engineering applications", AIAA Journal, Vol. 32, 1598-1605 (1994).

[8] Yahya,S.M.," Turbines, Compressors and fans ",Satya Prakashan,New Delhi,1972. CFX help manual.www.ansys.com.

[9] Ameri, A. A., Arnone, A. [1994]. "Prediction of turbine blade passage heat transfer using a zero and two-equation turbulence models". ASME paper. No. 94-GT-122, 8 p.