Numerical simulation of gas turbine blade cooling

Parthas arathy Garre* and Chikateri Susmitha[1]

*Assoc. Professor, Dept. of Aeronautical Engineering, MLR Institute of Technology, Hyderabad-500043. India, 9396965153, gps.mlrit@gmail.com

[1] M.Tech Scholor, Aerospace Engineering, Dept. of Aeronautical Engineering, MLR Institute of Technology, Hyderabad-500043. India

Abstrac t. One of the most important co mponents in gas turbine power-plant are turbine blades, which flow of h igh pressure gases takes place and produce work. A Blade can be defined as the med iu m of transfer of energy fro m the gases to the turbine rotor. There exist a great drive in turbine industry to increase the turbine blade and vane cooling. In typical gas turbine engines nozzle guide vane (NGV) endure the highest operating temperature. Due to high operating temperatures and speeds, failure of the turbine blades is inevitable. Hence there is a pressing need for cooling of turbine blades. External and Internal cooling methods are the common techniques to reduce overall surface temperature distribution over the NGV. The design, analysis and modification of the gas turbine blade design have to be made, on wh ich CATIA V5 and Turbo grid is used for design of solid model of the turbine. ANS YS 15 Software is used to analysis of model generated by meshing of the blade by applying boundary conditions. A heat transfer analysis has to be carried out to investigate the surface temperature of the blade by using some internal cooling techniques .

Keywords: NGV, CATIA, ANSYS, Blade, CFX

1. Introduction

The turbine blades are the limiting component of gas turbines. The Power developed in gas turbine by the internal combustion, which is used to drive the turbine. Losses occur in compressor and turbine stages due to the power absorbed by the compressor, caused to decrease the power output of the turbine. A certain fuel is added to the fluid will be required before one component can drive the other. This fuel produces addition energy to overcome the losses and will result in a useful power output. The fuel-air ratio used is governed by the working temperature of turbine blades. Fuel to air ratio will affect the material of turbine blade and increase the life. The two main factors which affect the performance of gas turbines are efficiencies of various components and turbine working temperature.

Material having low efficiencies and poor working temperature which caused the failure. In a gas turbine engine turbine blades are one of the most important components. This turbine blade component will converts the high pressure gases into work. Turbine blade acts as a medium to transfer energy from the gases to the turbine rotor. The blade as an entity is subjected to a large number of forces, some are inevitable and some are caused by the rotation of blade. Generally turbine blade is possessed forces in all directions in radial direction by rotor driving force, in axial direction by the gas flow and force normal to the turbine shaft (by centrifugal). Compression, combustion and expansions of air takes place in different stages in gas turbine. These stages of gas turbines are designed, developed, tested and manufactured individually. In compression and expansions stages of turbine engine are rotating machines and the combustion stage is heat addition. Auxiliary devices such as heat

IOP Conf. Series: Materials Science and Engineering **455** (2018) 012012 doi:10.1088/1757-899X/455/1/012012

exchanger, intercooler and re-heater are the additional complex systems in engine. Heat transfer analysis of gas turbine blades of different models, with and without holes on it and blades with varying number of holes. This heat transfer analysis takes place between two different blade materials (Chromium steel and Inconel-718). Finally by comparing the results, chromium steel having better properties [1]. This paper explains design of turbine blades in detail and various angles of air flow along the turbine blade [2]. This paper provides the various failure methods of turbine blades like fatigue, erosion wear, creep; environmental effects [3].For an N155 first stage rotor blade of turbine engine, thermal and structural analysis is done by ANSYS 9.0 [4]. Fatigue failure of turbine blades in turbine engine are investigated in this paper. This fatigue failure is investigated by finite element modeling method [5].

.

2. Methodology

To investigate the total temperature difference of turbine blade, we have to simulate the method by the use of few computer aided software. In this method we follow a list of steps to complete the analysis. In our project, there is a need to compare the temperature difference between the blade with cooling and blade without cooling. It implies to generate the two models of a turbine blade, one with internal channels and other without channels. Blade without internal channels is created by using the CatiaV5 and ANSYS Turbogrid 15. Here blade curve is designed in Catia and Flow path for domain is created in ANSYS Turbo grid. But in case of blade with cooling channels, we use Catia only. Further the model generated is exported to ANSYS ICEM 15.0 software, where geometry cleanup and meshing has to be done. Then we use ANSYS CFX to solve the design. From the geometry survey made, we obtained the geometry specifications of the required model of blade with and without cooling channels as shown in the figure 1 shows the front, top and isometric views of our blade model without cooling channels. First of all we create the model of NGV blade without cooling channels in the ANSYS as shown in figure 2. In parallel we developed in catia NGV blade with cooling channels as shown in figure 3.

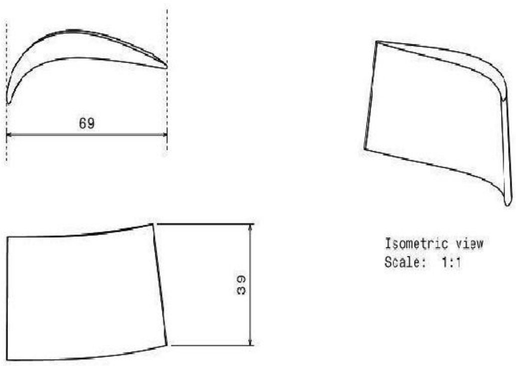

Figure 1: Blade Geometry

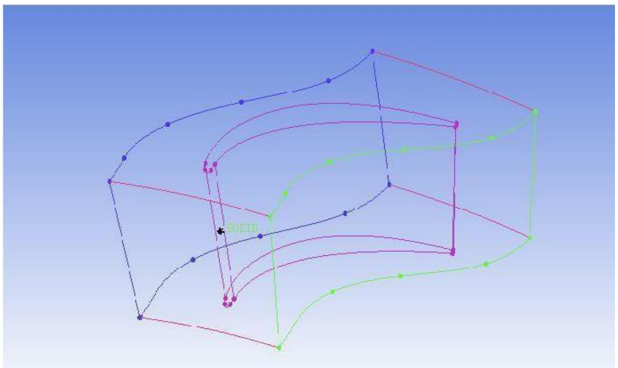

Figure 2: Blade along with flow path

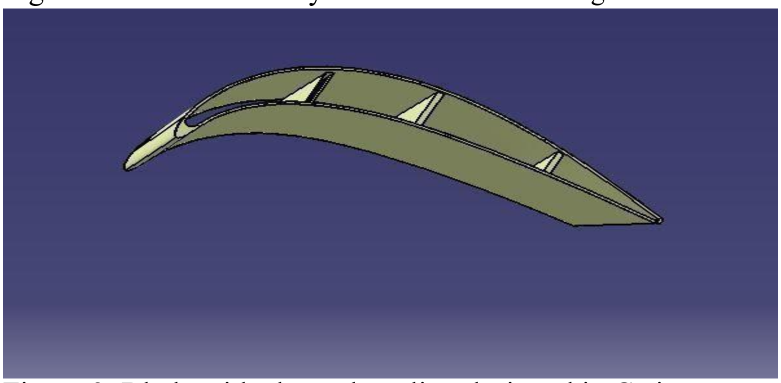

Figure.3. Blade with channel cooling designed in Catia

IOP Conf. Series: Materials Science and Engineering **455** (2018) 012012 doi:10.1088/1757-899X/455/1/012012

3. Results

ANSYS CFX is chosen for next process, to create the domains, interfaces and boundary conditions the following information is given to the software, there are two domains, namely, air and solid. Air represents the fluid domain section that is flow path where hot air flows and solid represents the blade section. The specifications given to air domain are molar mass, density, specific heat capacity and thermal conductivity. In basic settings includes location of solid, domain of solid, material as inconel, heat transfer. In blade with cooling channels, there are three domains. They are hot air, solid and cold air. Hot air and solid domains are same as the air and solid domains in above model respectively. Cold air is that we have provided channels in the blade to pass the cold air into it. So that we have to assign the specifications for cold air parameters as follows. Last step in CFX-pre is to run the program to solve the governing equations. For that, go to define run save the file in new folder created earlier. Automatically open solver manager. Now start run. It runs the program using those predefined inputs with specified iterations. While running the solver program the colored graphs have observed which denotes solving the program up to convergence limit as follows. Finally .res file is created which is nothing but result file. The following results were included for blades with cooling and without cooling channels as shown in figures 4 to 7.

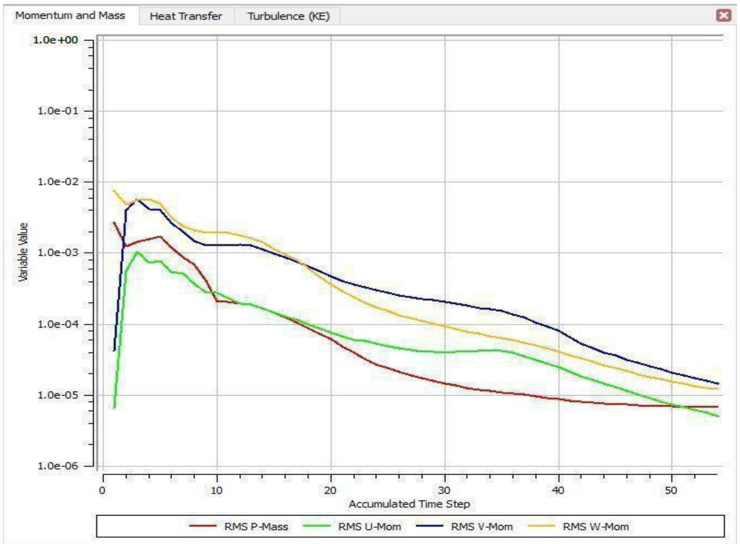

Figure 4: Continuity and Momentum Equation (Blade without channels)

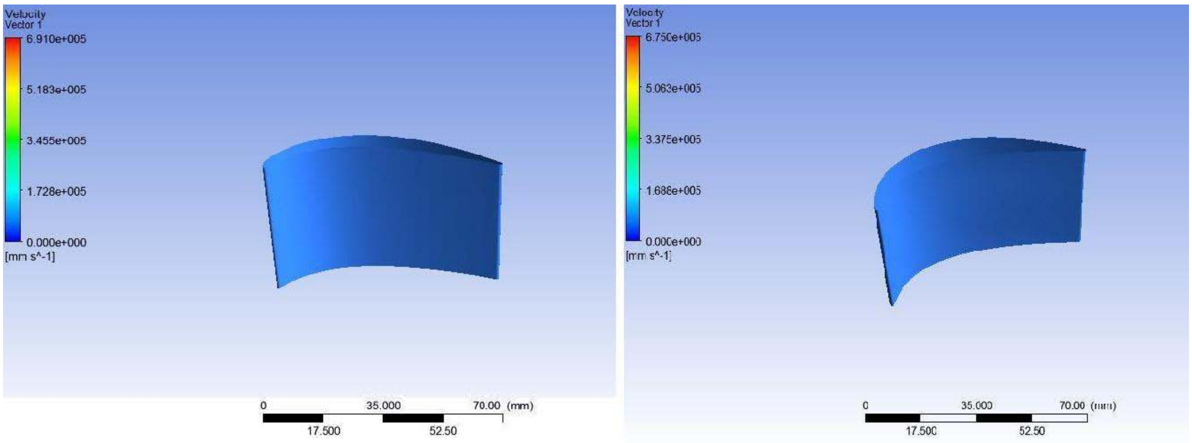

Figure 5: Velocity vector plot on blade surface without and with channels

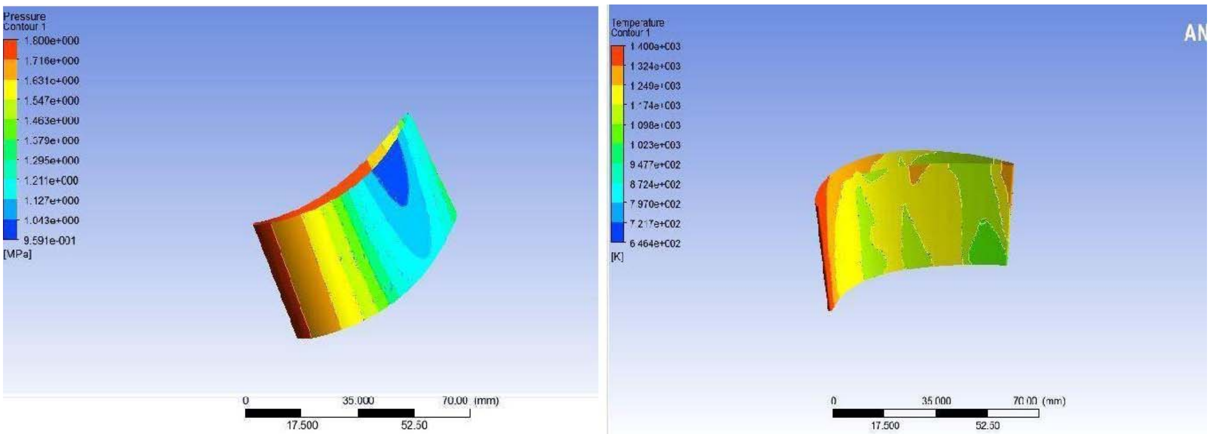

Figure 6: Pressure Contour on blade surface without and with cooling channels

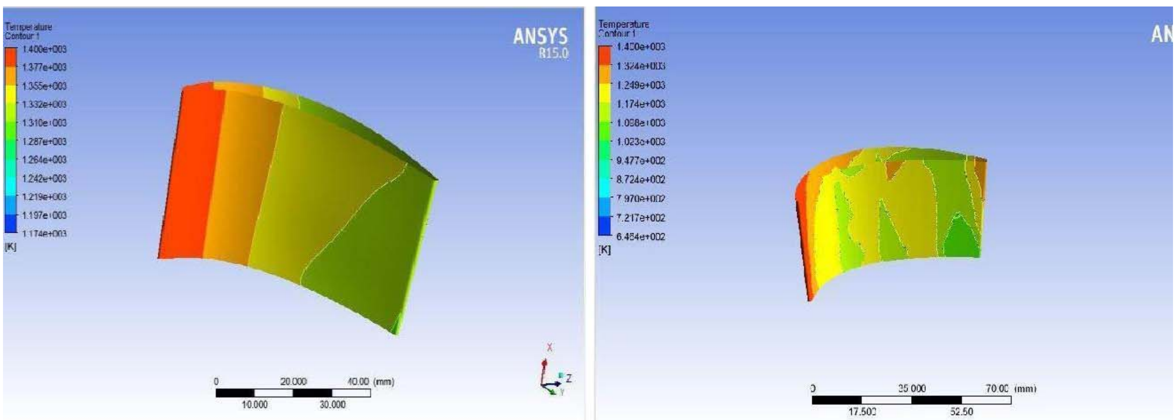

Figure 7: Temperature Contour on blade surface without and with cooling channels

4. Conclusion

Heat transfer analysis has been carried out on gas turbine stator blade that is Nozzle Guide Vanes (NGV) using ANSYS15 has a same effect in the overall turbine blades. One turbine blade without cooling channels showed that overall surface temperature as 1361.89k. Other blade with three cooling channels showed that overall surface temperature as 1213.04k. Hence by redesigning the blade with three cooling channels we have reduced the temperature over the surface of the blade up to 148.85K.

IOP Conf. Series: Materials Science and Engineering **455** (2018) 012012 doi:10.1088/1757-899X/455/1/012012

References

[1] K HariBrahmaiah, M. Lava Kumar, 2014, International journal of computational engineering research, 4.
[2] Yoshio Samaizu Perez Zuniga, 2011, Thermodynamic analysis and testing of K03 turbocharger.
[3] Cyrus B.Meher-Homji, George Gabriles, “Gas Turbine Failures- Cause, Avoidance And Troubleshooting”.
[4] G Narendranath, S. Suresh, 2012, International journal of engineering research and applications, 2.
[5] Jianfuhou, Bryon J. Wicks, Ross A. Antoniou, 2002, An Investigation On Fatigue Failures Of Turbine Blades In A Gas Turbine Engine By Mechanical Analysis, Engineering Failure Analysis.