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Analysis of the Gas Turbine Blade- Titanium-Aluminum alloy and Nickel-Chromium alloy with axial holes using CFD

AMRUTHAPU SHEKHAR¹ P VINOD KUMAR ²G.SUDHAKAR ³

PG Scholar, Dept. of Mechanical Engineering, St. Mary’s Group of Institutions Guntur, AP, India¹

Assistant Professor, Dept. of Mechanical Engineering, St. Mary’s Group of Institutions Guntur, AP, India²

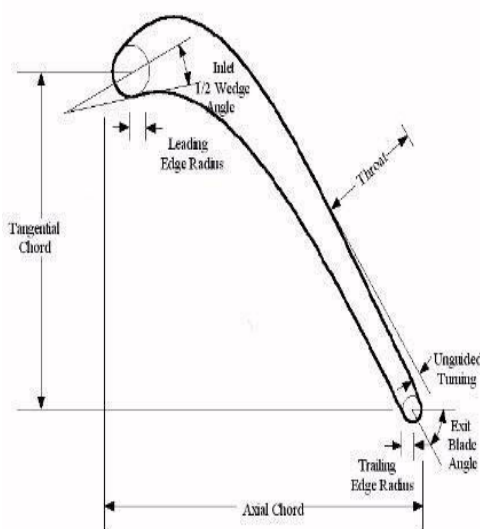
Assistant Professor, Dept. of Mechanical Engineering, St. Mary’s Group of Institutions Guntur, AP, India³

ABSTRACT: A turbine blade is the individual component which makes up the turbine section of a gas turbine. The objective of this thesis is to study the heat transfer problem in a gas turbine blade to give the optimum cooling. Various techniques have been proposed for the cooling of blades and one such technique is to have axial holes along the blade span. Cooling of blades has been a major concern since they are in higher temperature environment. In high temperature gas turbine, turbine blade cooling designs require key technologies. Gas turbine blade model is created using Gambit, mesh is created using CFD (Fluent) software, to perform the flow analysis. k-ε turbulence model is used for this analysis. Three models (6, 8 & 12) with Titanium-Aluminum alloy and Nickel-Chromium alloy were analyzed to find out the optimum number of holes for better cooling rates, better material with temperature distribution and determining cooling rate of gas turbine blade with different holes and different materials. Cooling rate of gas turbine blade with temperature distribution for different materials, Graphs are plotted for velocity, pressure and temperature distribution for existing design. When the number of holes increased in the blade, the temperature distribution falls down.

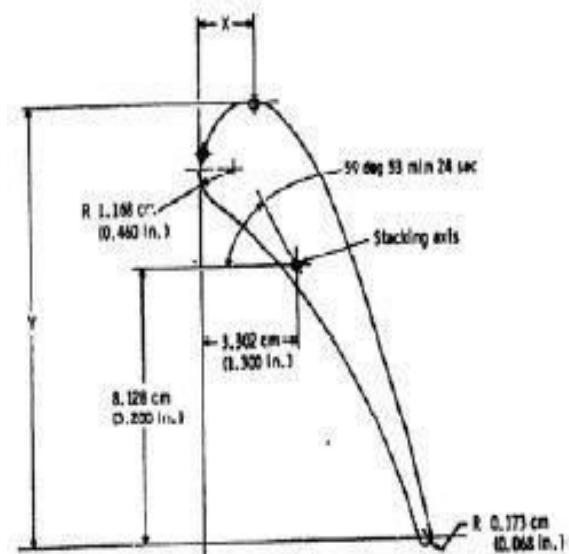
I. INTRODUCTION

Gas Turbine Blade

A turbine blade is the individual component which makes up the turbine section of a gas turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. The turbine blades are often the limiting component of gas turbines. To survive in this difficult environment, turbine blades often use exotic materials like super alloys and many different methods of cooling, such as internal air channels, boundary layer cooling, and thermal barrier coatings.



Gas Turbine Blade



Gas Turbine Blade Geometry

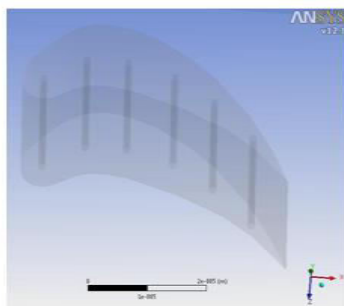
As the mass of the high velocity gas flows across the turbine blades, the gaseous energy is converted to mechanical energy. Velocity, temperature, and pressure of the gas are sacrificed in order to rotate the turbine to generate shaft power.

II.OBJECTIVES

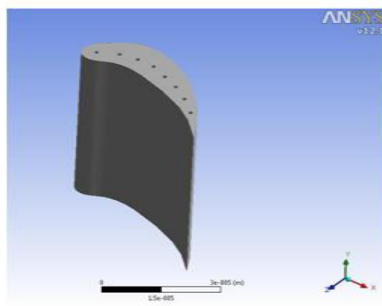
- Comparing a better material and cooling rate of the gas turbine blade.
- In analyzing the fluid flow around a gas turbine blade with numerical method(CFD).
- The geometry then optimized to get better cooling rate.
- The ultimate goal of this work is to modify the material to achieve its better cooling rate of gas turbine blade.

III.MODELING OF GAS TURBINE BLADE

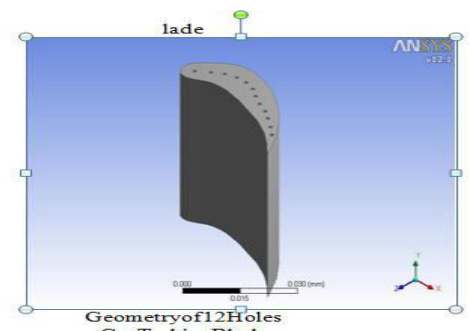
Using GAMBIT software, modeling is created with given dimensions as shown in above figure. Launch Gambit once Gambit is open make certain solver is set for the appropriate output. i.e., FLUENT 14.5, by selecting **start->FLUENT14.5**. The coordinated document must now be imported in to Gambit. This is done by selecting **File->import->ICEMInputs->**this will open the ICEM Import window/Make certain the edge command is selected and that the face command is deselected. Once the desired coordinate file to be imported is listed in the File Name text box, accept the settings. Since the text file told Gambit to read in two sets of one hundred coordinates, each set of one hundred coordinates will be defined by one edge resulting in Gambit window now displaying the gas turbine blade profile. Next the upper and lower surfaces of the gas turbine blade must be unite with each others, create the gas turbine blade edges as a face and then geometry operation -> **face command -> sweepface** select the gas turbine blade face up to same distance in negative Z- co ordinate system. **Geometry operation -> Volume Command -> volume** size of 15x15x15cm size volume as a boundary of gas turbine blade. In order to save processing time the gas turbine blade face doesn't need to be meshed. Therefore, the gas turbine blade can be subtracted from volume by selecting **geometry operation->face command->subtract** face box select the gas turbine blade face and then select apply.



GeometryOf6Holes GasTurbine Blade



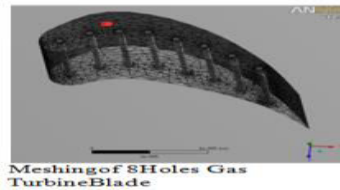
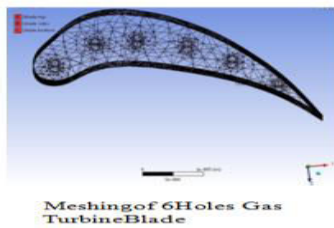
GeometryOf8HolesGasTurbineB



Geometryof12Holes GasTurbineBlade

Meshing of gas turbine blade with different models:

- The mesh is refined around the gas turbine blade to properly capture the boundary layer.
- Meshing is the process of discretization of space in which flow takes place.
- Meshing is the basic step in building a computer model for a flow problem. Depending on the discretization technique used, meshing procedure varies



Number Of Nodes And Number Of Elements:

Sl.No	Model Of Gas Turbine Blade	Number Of Nodes	Number Of Elements
1	6 holes	87950	131455
2	8 holes	296340	416570
3	12 holes	448982	632850

Boundary Conditions:

Inlet pressure	160kPa
Inlet temperature	800°C
Inlet velocity	5m/s
Exit static pressure	110kPa
Inlet turbulence intensity	9%
Coolant temperature	300°C

IV. RESULTS AND DISCUSSIONS

The cooling rate behind the gas turbine blade with Nickel-chromium alloy is better compared to Titanium-aluminum alloy depends on the blade material properties for the 6 holes blade, 8 holes blade and 12 holes blade. It is also evident from the Figures the number of holes affects the flow field significantly

Contours of Nickel Chromium alloy with 6 holes:

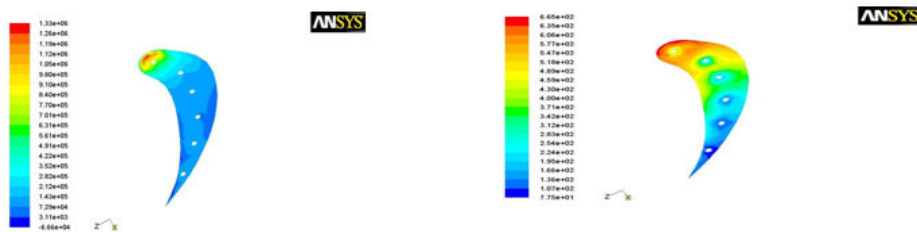
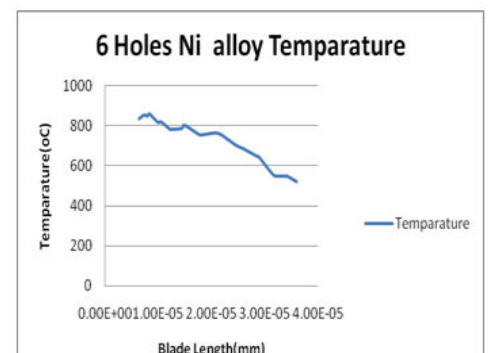
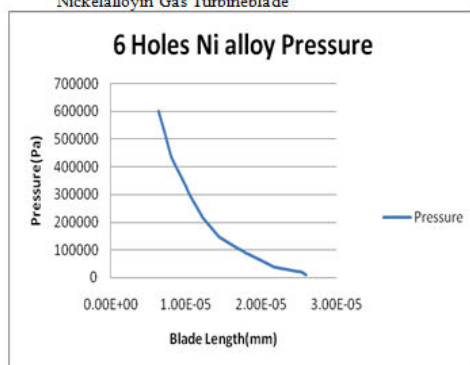


Fig. Variation of static pressure of 6 holes Nickel alloy in Gas Turbine blade

Fig. Variation of static temperature of 6 Holes Nickel alloy in Gas Turbine blade



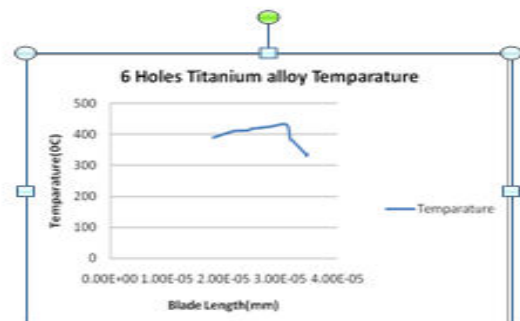
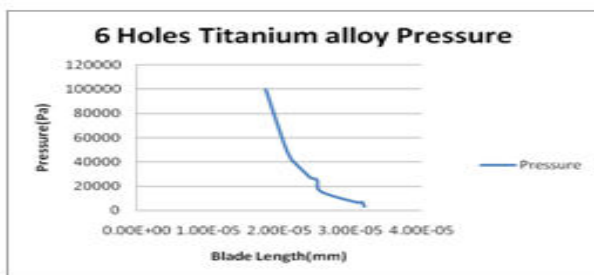
Contours of Titanium-Aluminum alloy with 6 holes



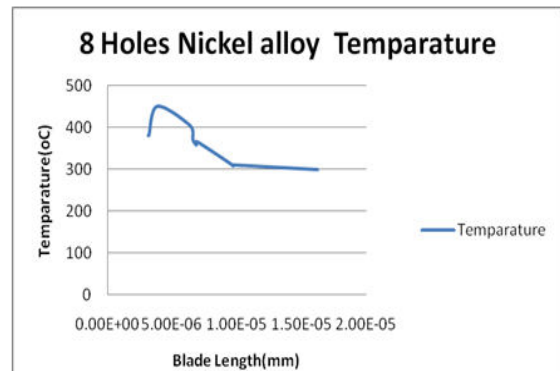
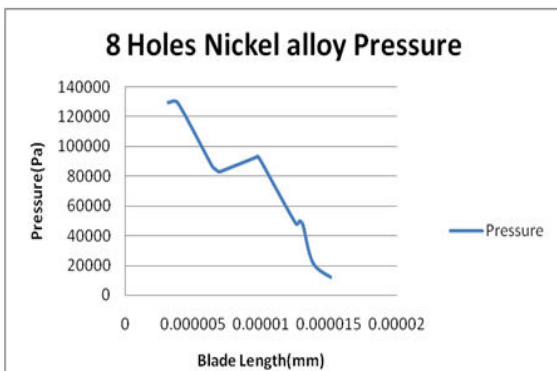
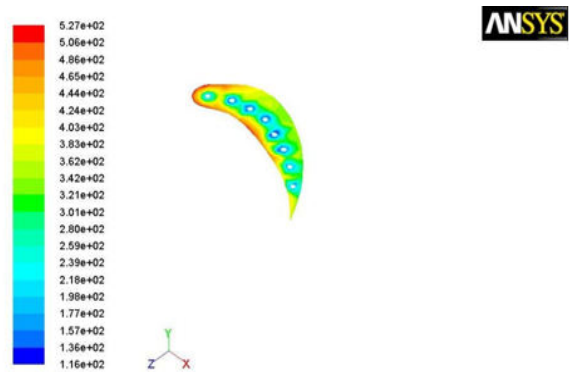
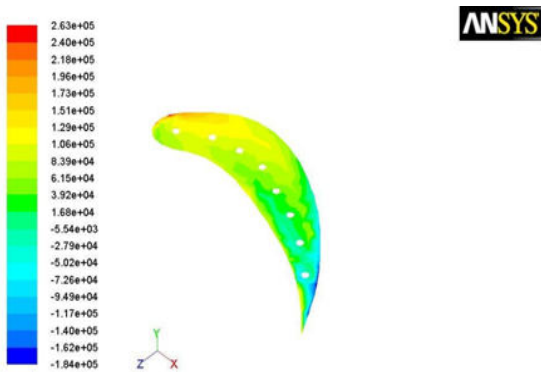
Fig4.5 Variation of static pressure of 6 holes Titanium alloy in Gas Turbine Blade



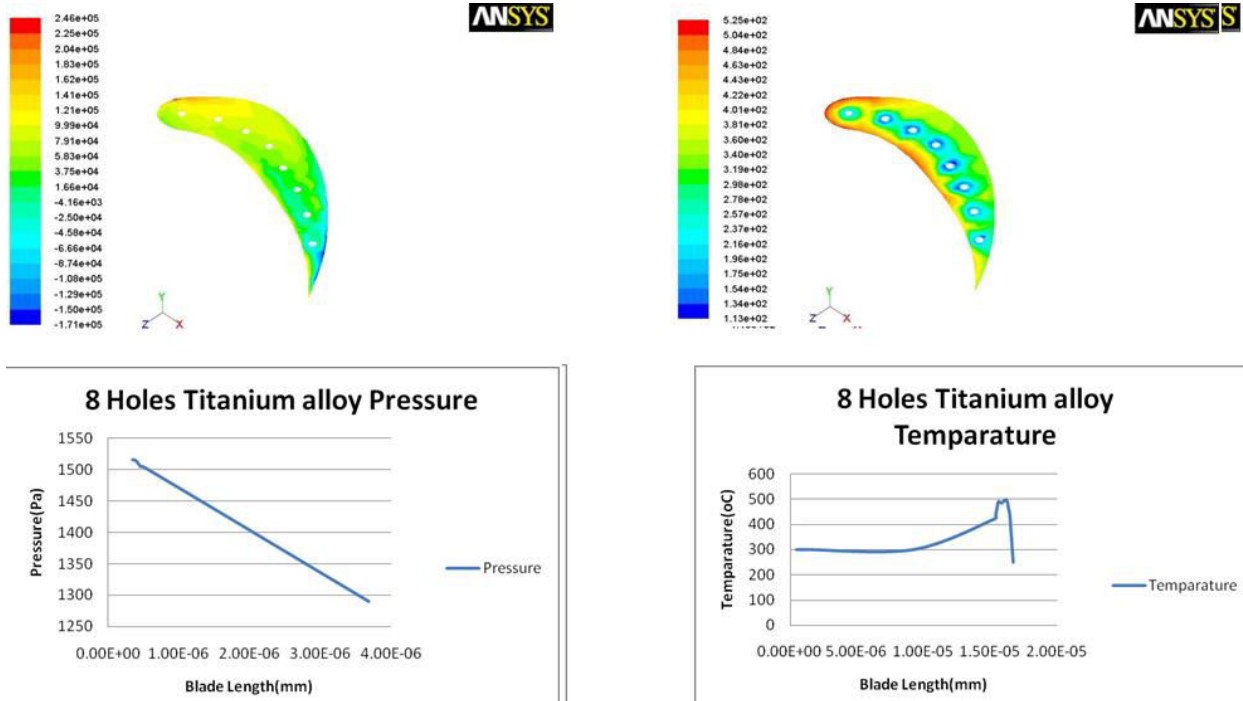
Fig4.7 Variation of static Temperature of 6 Holes Titanium alloy in Gas Turbine Blade



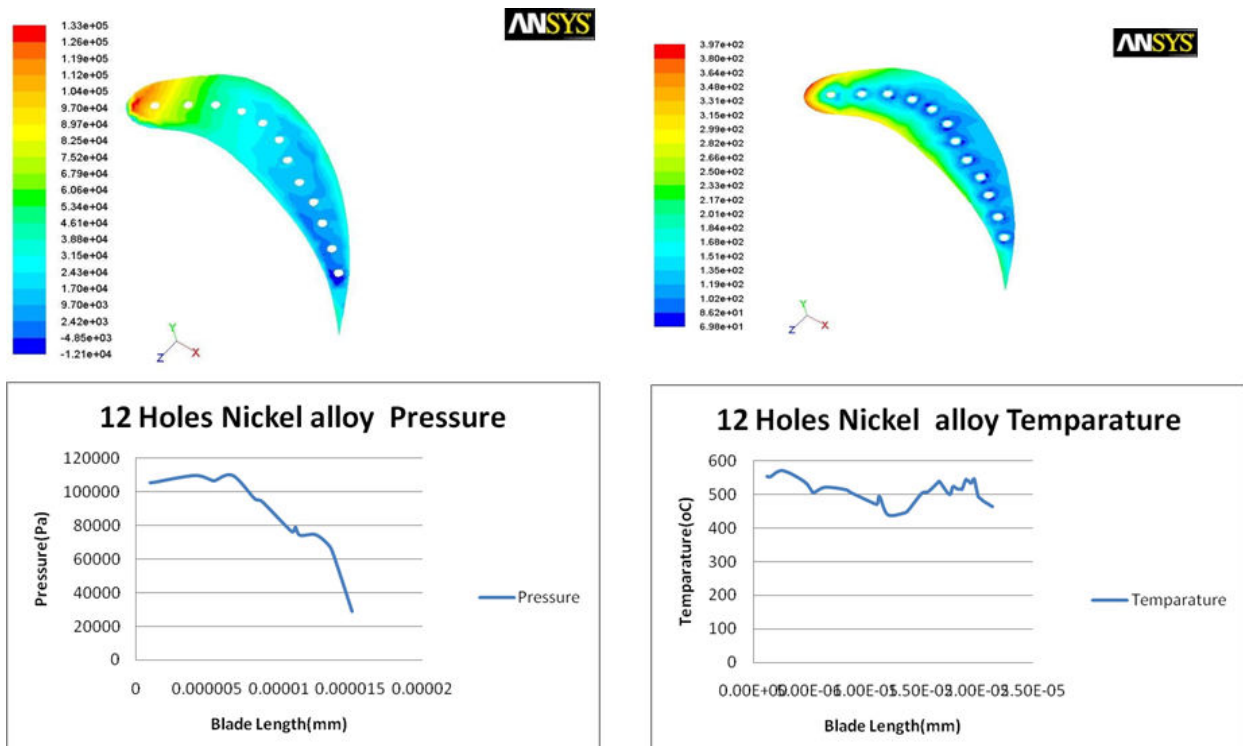
Contours of Nickel-Chromium alloy with 8 holes



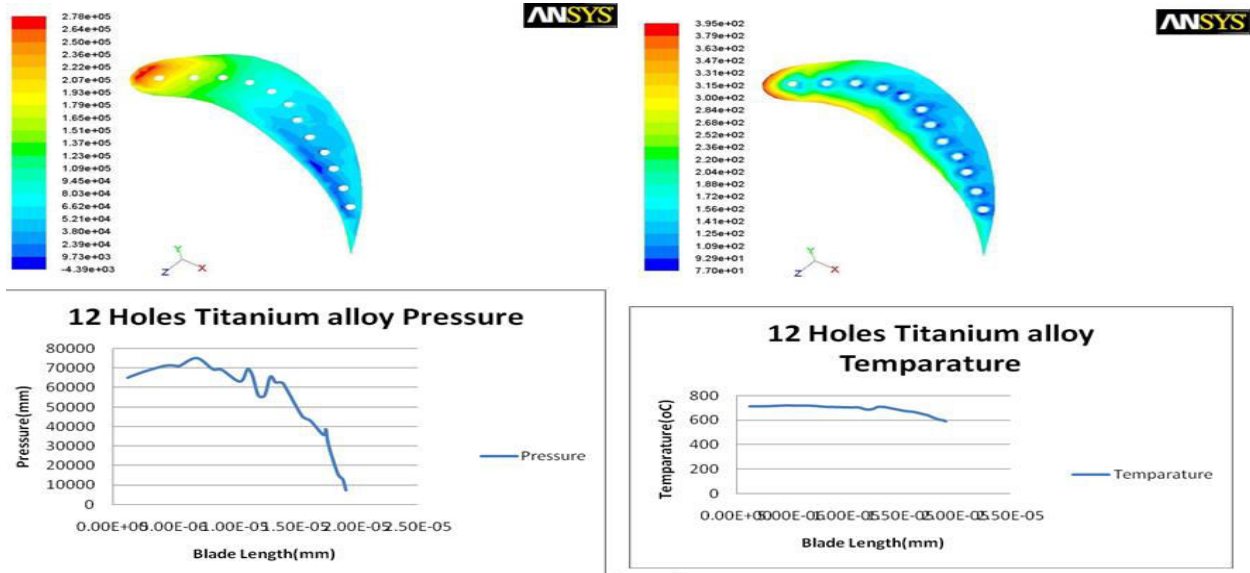
Contours of Titanium-Aluminum alloy with 8 holes



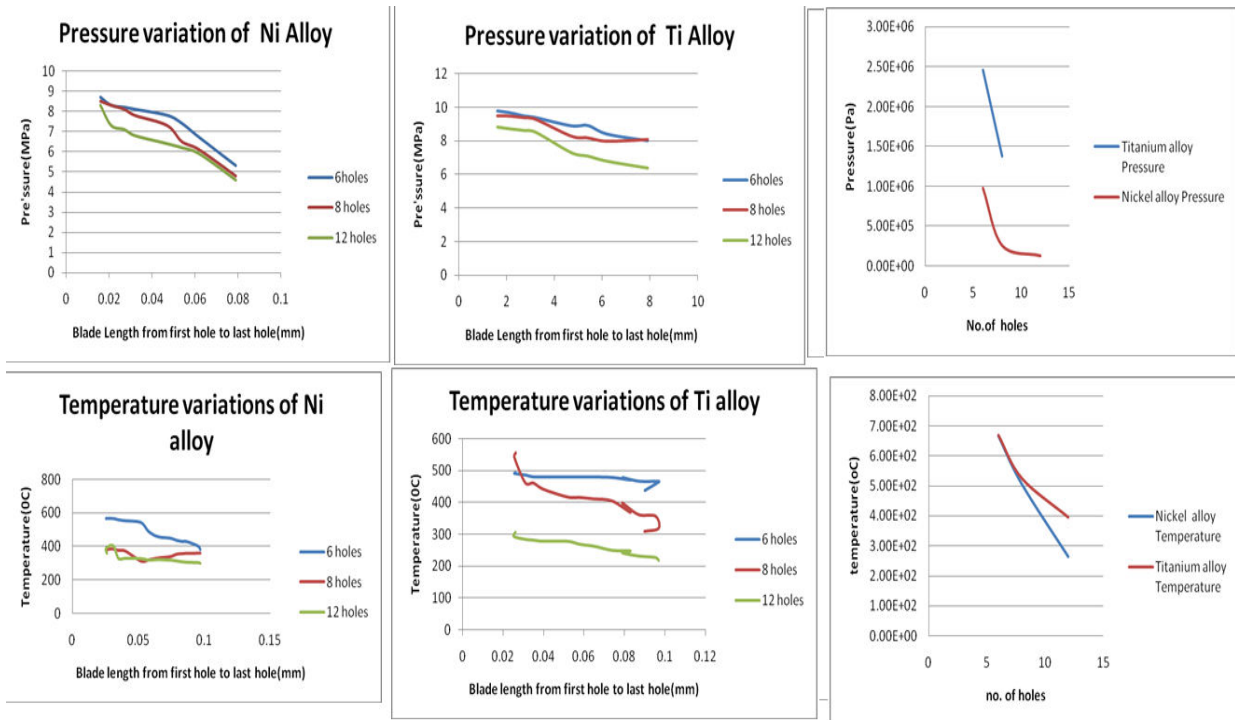
Contours of Nickel-Chromium alloy with 12 holes



Contours of Titanium aluminum alloy with 12 holes



Comparisons





No.of Holes	Pressure(Pa)		Temperature(°C)	
	Titanium alloy	Nickelalloy	Titanium alloy	Nickelalloy
6	2.76e6	9.80e5	6.68e2	6.65e2
8	2.46e6	2.63e5	5.25e2	5.06e2
12	1.38e6	1.33e5	3.95e2	2.64e2

V.CONCLUSION & FUTURE SCOPE OF WORK

- Temperature distribution for Titaniumalloy: 6-8holesis143°C,6-12 holesis273°C.
- TemperaturedistributionforNickelalloy:6-8holesis159°C,6-12holesis401°C.
- The placement of cooling holes in the blades results in increased turbine efficiency because gas turbine efficiency depends on temperature distribution.
- The gas turbine blade with different number of holes 6, 8 and 12 were used for analysis. It is found that the blade with 8 holes has the moderate cooling rate for both materials of the blade when the coolant temperaturewas 300°C.
- Theoverall coolingrateis 20%from theboth materials with 6,8and 12 holes models.

FUTURE SCOPE OF WORK

- One can study the effect of cooling rate of the gas turbine blade in better way with different methods and analysis by changing blade material and increasing the number of holes.
- We can change the shape of the Hole.
- By calculating the Thermal Stresses using factor of Safety we can decide whether that material with stand or not.
- The flow is considered in the present study to be in steady state however the simulation studies need to be considered under unsteady state with appropriate boundary conditions.
- This detailed pressure and temperature measurements also provides a reference for further experimental or computational study.

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