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THERMAL ANALYSIS OF A GAS TURBINE BLADE

N.VINAY KUMAR[1], P.RAJU[2] AND P.SRINIVASULU[3]

[1]*M.tech (te) student Department of mechanical engineering, vaagdevi college of engineering Boolikunta, warangal,telangana, india*

[2]*Assistance professor Department of mechanical engineering, vaagdevi college of engineering Boolikunta, warangal,telangana, india*

[3]*professor Department of mechanical engineering, vaagdevi college of engineering Boolikunta, warangal,telangana, india*

Abstract- In this thesis a turbine blade is designed and modeled in Pro/Engineer software. The turbine blades are cooled using film cooling. The turbine blade with film cooling for no holes, 3 holes, 7 holes, 13 holes is modeled. CFD, Thermal analysis is done to determine the heat transfer rates, heat transfer coefficients of the blade. The present used material for blade is chromium steel. In this thesis, it is replaced with Nickel alloys. The better material for blade is analyzed.

Key words- Turbine blade, Heat transfer rate, Heat transfer coefficient, Chromium steel, Nickel alloy

I. INTRODUCTION

A **turbine** is a rotary engine that extracts energy from a fluid flow and converts it into useful work. The simplest turbines have one moving part, a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades, or the blades react to the flow, so that they move and impart rotational energy to the rotor. **Gas**, **steam**, and **water** turbines usually have a casing around the blades that contains and controls the working fluid. A working fluid contains potential energy (pressure head) and kinetic energy (velocity head). The fluid may be compressible or incompressible. Several physical principles are employed by turbines to collect this energy. A **gas turbine**, also called a combustion turbine, is a type of internal combustion engine. It has an upstream rotating compressor coupled to a downstream turbine, and a combustion chamber in-between. Gas turbines are sometimes referred to as turbine engines. Such engines usually feature an inlet, fan, compressor, combustor and nozzle (possibly other assemblies) in addition to one or more turbines. A simple gas turbine is comprised of three main sections: **a compressor**, **a combustor** and **a turbine**. The gas turbine operates on the principle of the **Brayton** cycle where compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is expanded through a turbine to perform work.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.

Since the design of turbo machinery is complex, and efficiency is directly related to material performance, material selection is of prime importance. Gas and steam turbines exhibits similar problem areas, but these problems areas are of different magnitudes. Turbines components must operate under a variety of stress, temperature, and corrosion conditions. Compressor blades operate relatively low temperatures but are highly stressed. The combustor operates at a relatively high temperature and low-stress conditions. The turbine blades operate under extreme conditions of stress, temperature, and corrosion. These conditions are more extreme in gas turbine than in steam turbine applications. As a

result, the material selection for individual components is based on varying criteria in both gas and steam turbines. A design is only as efficient as the performance of the selected component materials.
In the 1980s, IN 738 blades were widely used. IN-738, was the acknowledged corrosion standard for the industry. New alloys, such as GTD-111 possesses about a 35^{o}F (20^{o}C) improvement in rupture strength as compared to IN-738. GTD-111 is also superior to IN-738 in low-cycle fatigue strength. The design of this alloy was unique in that it utilized phase stability and other predictive techniques to balance the levels of critical elements (Cr, Mo, Co, Al, Wand Ta), thereby maintaining the hot corrosion resistance of IN-738 at higher strength levels without compromising phase stability. A super alloy, or high-performance alloy, is an alloy that exhibits excellent mechanical strength and creep (tendency for solids to slowly move or deform under stress) resistance at high temperatures, good surface stability, and corrosion and oxidation resistance.

II. LITERATURE REVIEW

THE DESIGN AND ANALYSIS OF GAS TURBINE BLADE by Pedaprolu Venkata Vinod

This project summarizes the design and analysis of Gas turbine blade, CATIA is used for design of solid model and ANSYS software for analysis for F.E. model generated, by applying boundary condition, this project also includes specific post processing and life assessment of blade. How the program makes effective use of the ANSYS preprocessor to mesh complex turbine blade geometries and apply boundary conditions. Here under we presented how Designing of a turbine blade is done in CATIA with the help of co-ordinate generated on CMM. And to demonstrate the pre-processing capabilities, static and dynamic stress analyses results, generation of Campbell and Interference diagrams and life assessment. The principal aim of this project is to get the natural frequencies and mode shape of the turbine blade.

Effect of Temperature Distribution In. 10c4/60c50 Gas Turbine Blade Model Using Finite Element Analysis by V.Veeraragavan

In this research paper is mainly apprehensive with aircraft gas turbine engine. Turbine blade is an important part of aircraft gas turbine engine. The research focus of 10 C4 / 60 C 50 turbine blade model, because of its common use in all types of aircraft engines. Investigate used, Pro-e model and ANSYS tools. Present research was focused on using Finite element methods (FEM) to predict the location of possible temperature areas on turbine blades. The conventional alloys such as titanium, zirconium, molybdenum, super alloys are chosen for analysis. Initially the model is created with the help of Pro-e and then it is imported to Ansys. The static analysis of solid model is carried out by applying temperature from external circumference tip of turbine blade to root of the blade and the temperature distribution is plotted. At that time measured the maximum temperature withstood capacity in gas turbine blade. Finally the entire four alloy materials are compared with respect to temperature distribution to found out of the best one. Then suggested to which material is better performing in gas turbine engine applications.

Heat Transfer Analysis of Gas Turbine Blade through Cooling Holes by K Hari Brahmaiah, M.Lava Kumar

In advanced gas turbines, the turbine blade operated temperature is for above the melting point of blade material. A sophisticated cooling scheme must be developed for continuous safe operation of gas turbines with high performance. Several methods have been suggested for the cooling of blades and one such technique is to have radial holes to pass high velocity cooling air along the blade span. In the present work to examine the heat transfer analysis of gas turbine with four different models consisting of blade with without holes and blades with varying number of holes (5, 9&13) were analyzed The analysis is carried out using commercial CFD software FLUENT (a turbulence realizable k-ϵ model with enhanced wall treatment) has been used. On evaluating the graphs drawn for total heat transfer rate and temperature distribution, the blade with 13 holes is considered as optimum. Steady state thermal and structural analysis is carried out using ANSYS software with different blade materials of Chromium steel and Inconel718. While comparing these materials Inconel718 is better thermal properties and induced stresses are lesser than the Chromium steel.

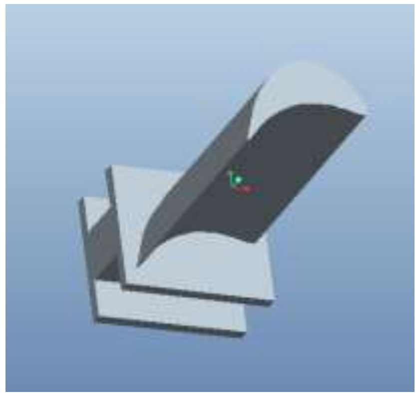
THERMAL ANALYSIS OF BLADE

MATERIALS - CHROMIUM STEEL, NICKEL ALLOY 617 AND NICKEL ALLOY 188

MATERIAL PROPERTIES

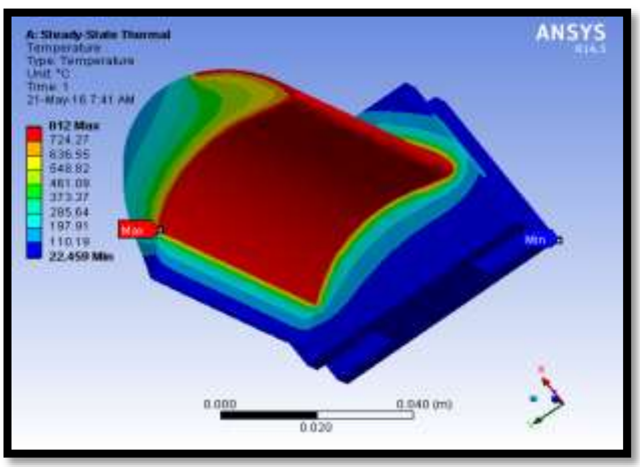
Chromium Steel Thermal conductivity = 24.38W/m-k
Nickel Alloy 617 Thermal conductivity = 13.6W/m-k
Nickel Alloy 188Thermal conductivity = 24.1W/m-k

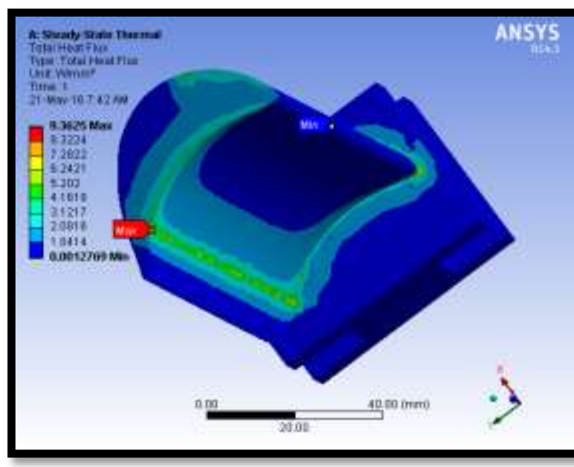
WITHOUT HOLES



MATERIAL - CHROMIUM STEEL

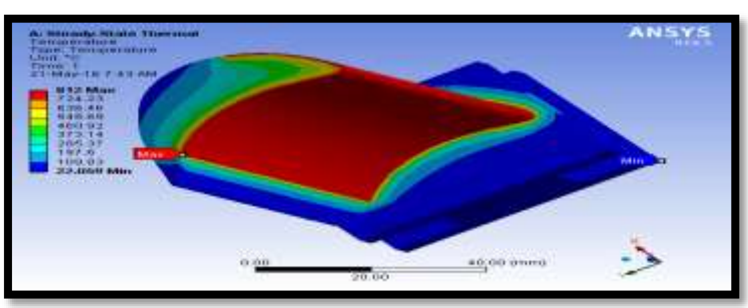
TEMPERATURE **HEAT FLUX**

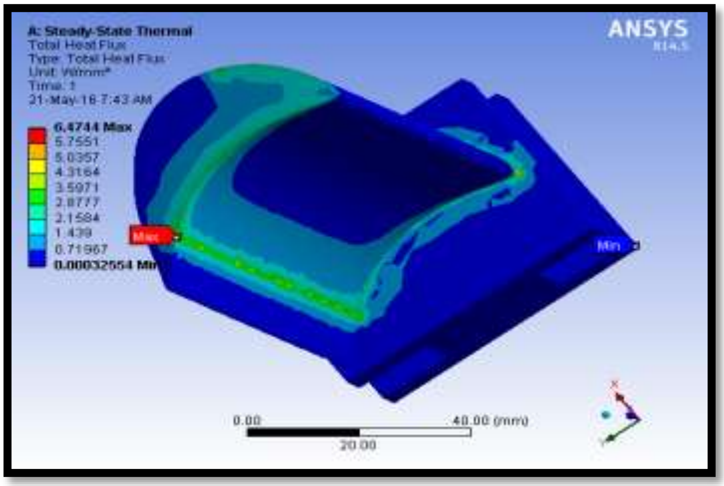




MATERIAL – NICKEL ALLOY617

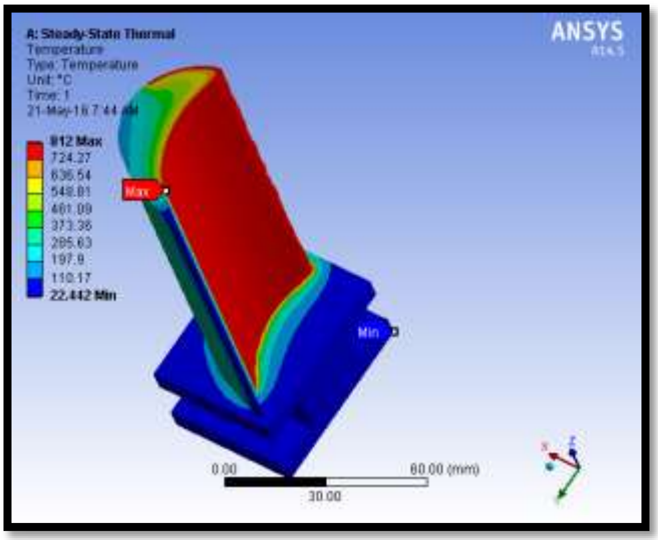
TEMPERATURE **HEAT FLUX**

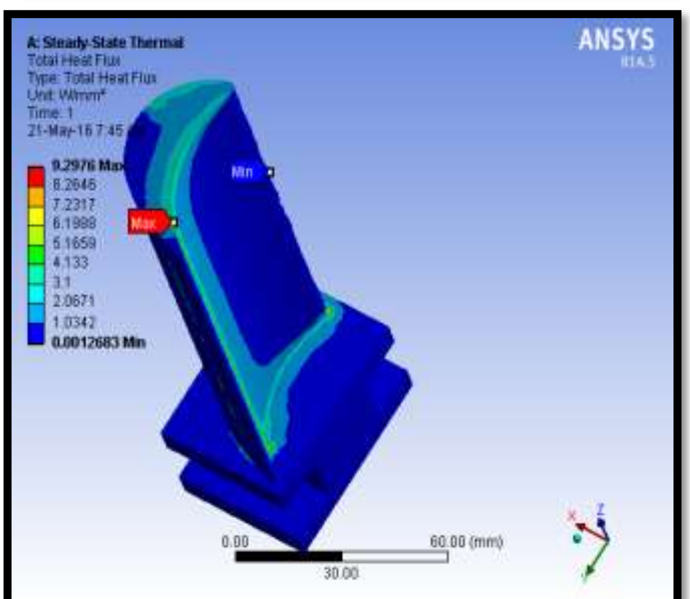




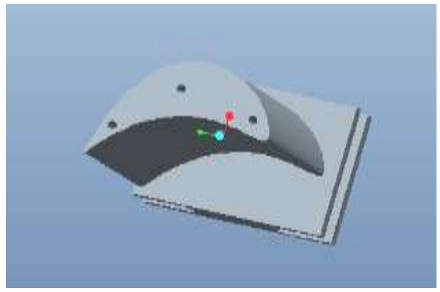
MATERIAL – NICKEL ALLOY188

TEMPERATURE **HEAT FLUX**



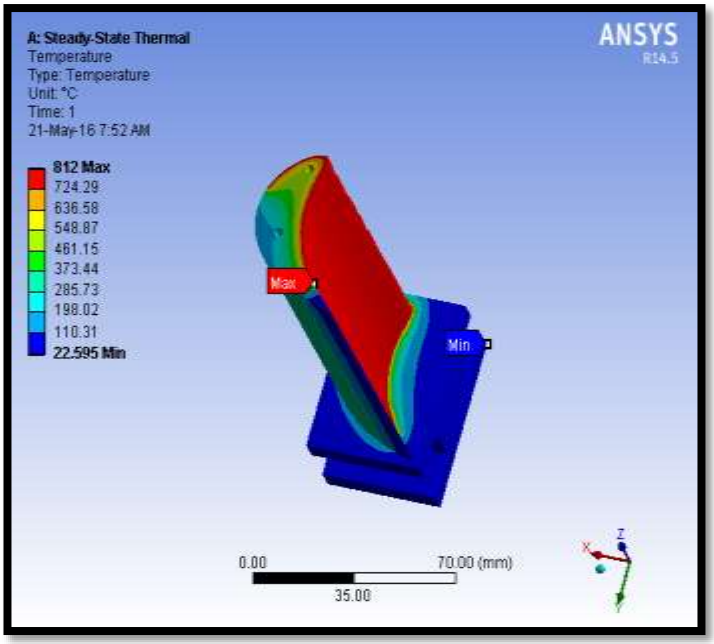


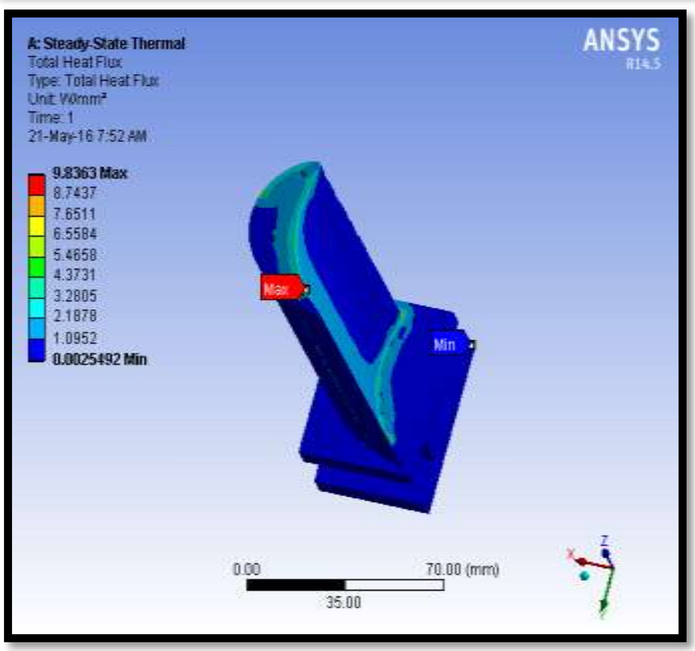
WITH 3 HOLES



MATERIAL- CHROMIUM STEEL

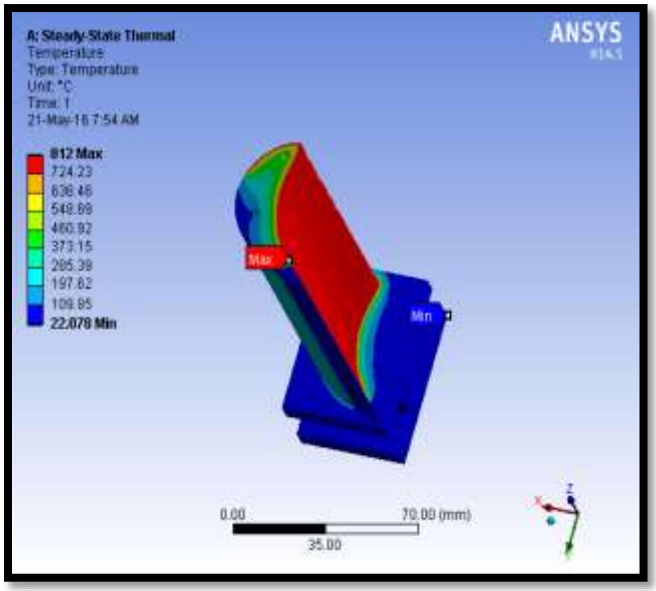
TEMPERATURE **HEAT FLUX**

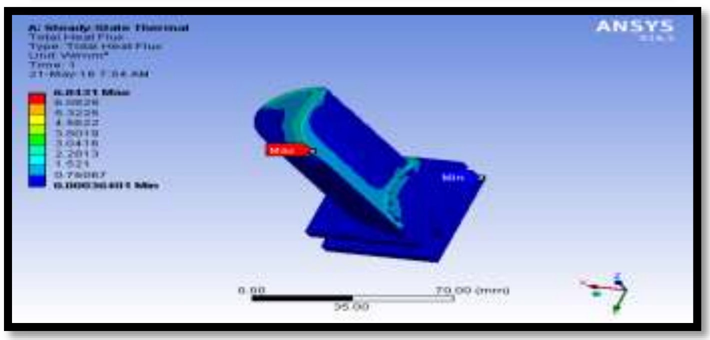




MATERIAL – NICKEL ALLOY617

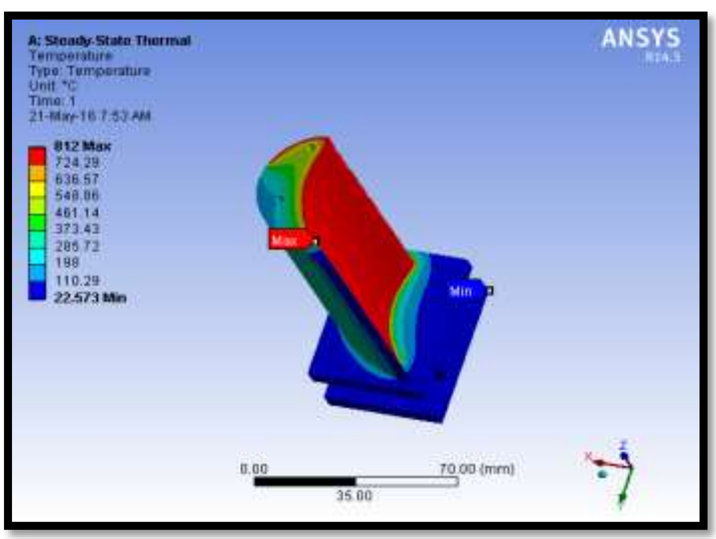
TEMPERATURE **HEAT FLUX**

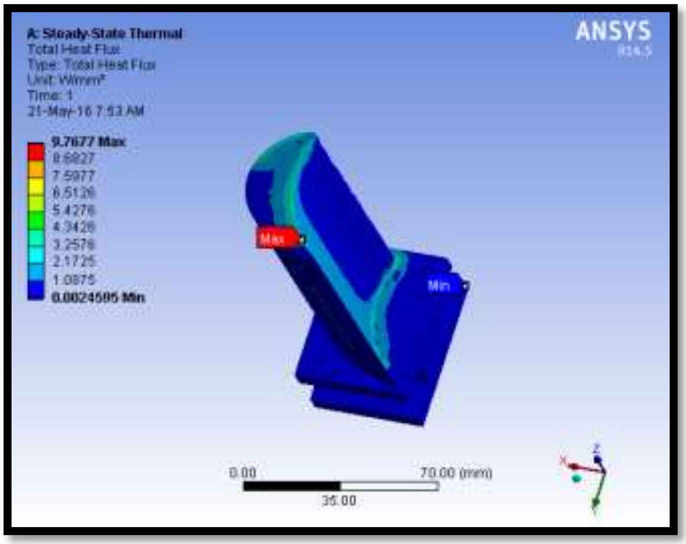




MATERIAL- NICKEL ALLOY 188

TEMPERATURE **HEAT FLUX**

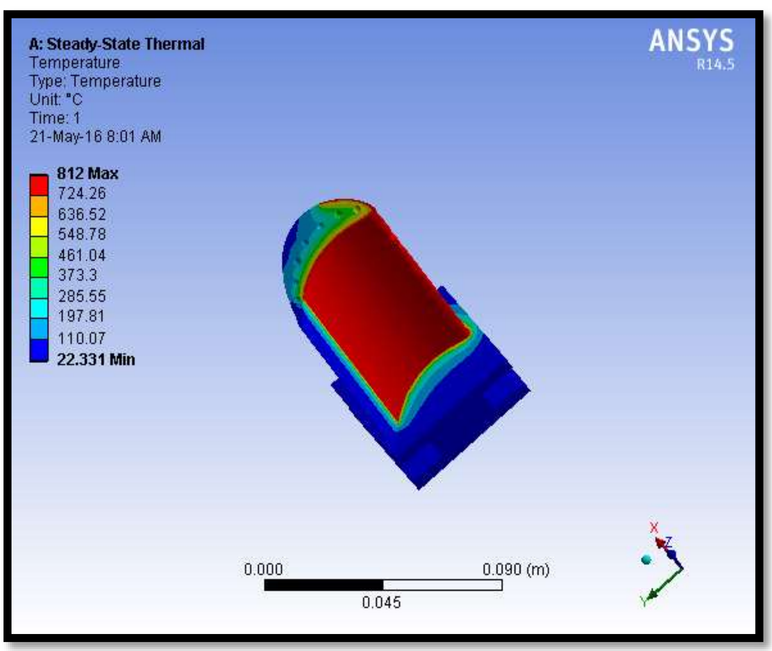


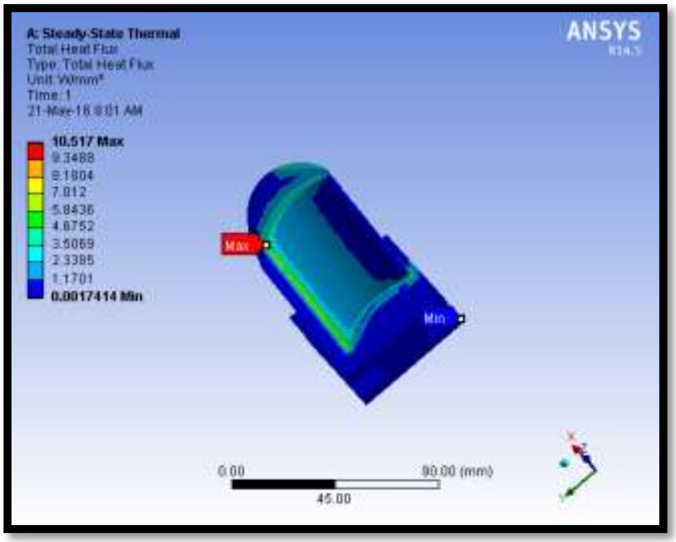


WITH 7 HOLES

MATERIAL – CHROMIUM STEEL

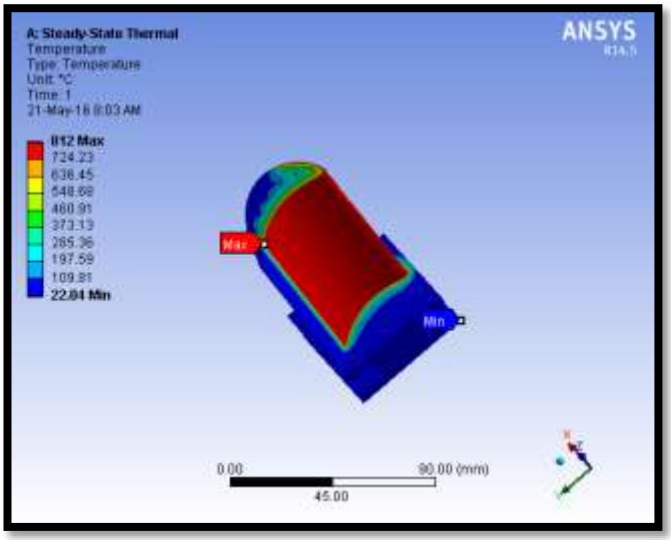
TEMPERATURE **HEAT FLUX**

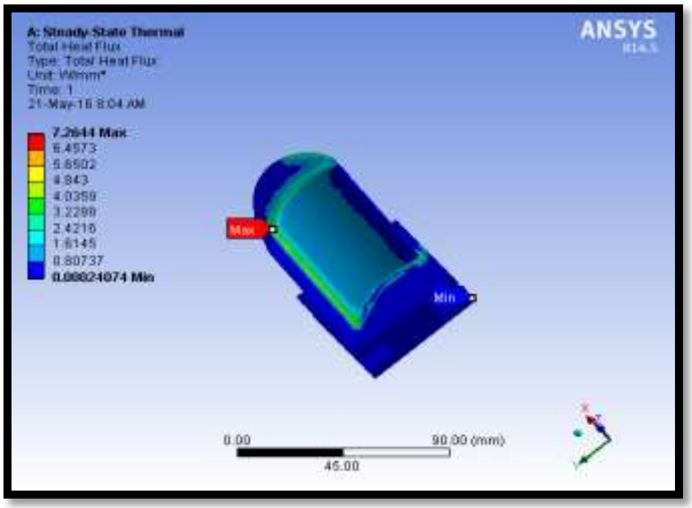




MATERIAL-NICKEL ALLOY617

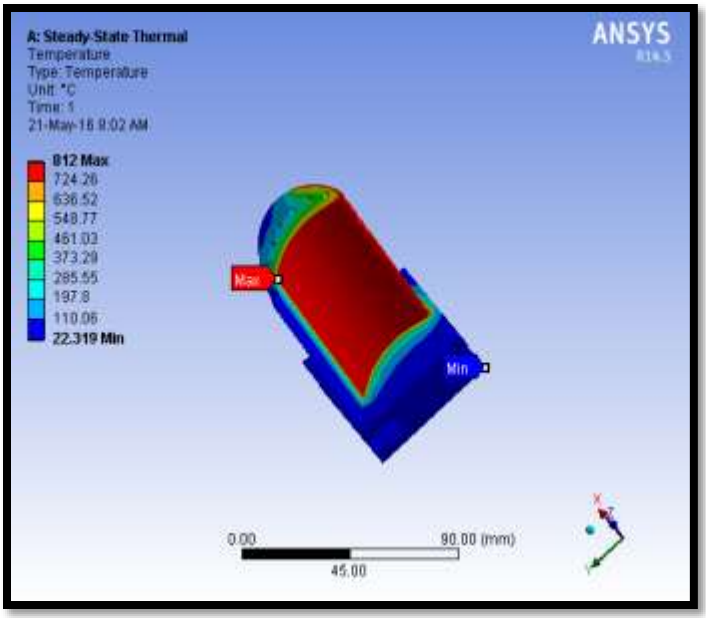
TEMPERATURE **HEAT FLUX**

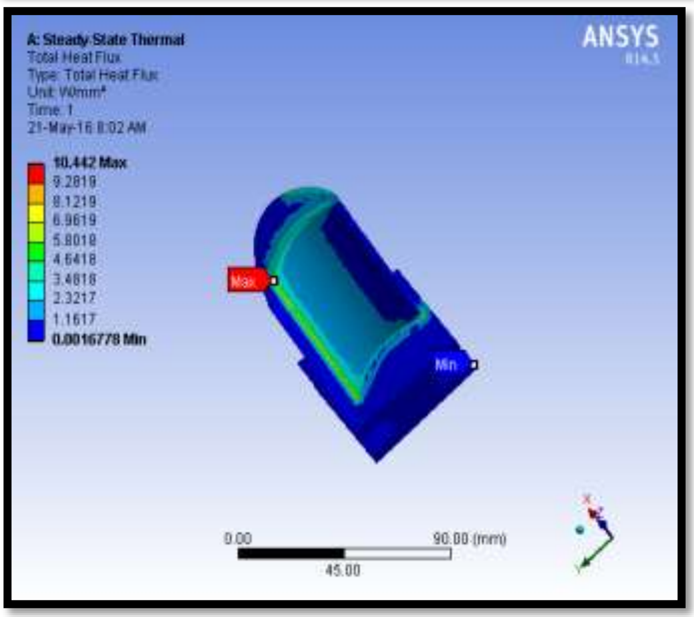




MATERIAL-NICKEL ALLOY188

TEMPERATURE **HEAT FLUX**

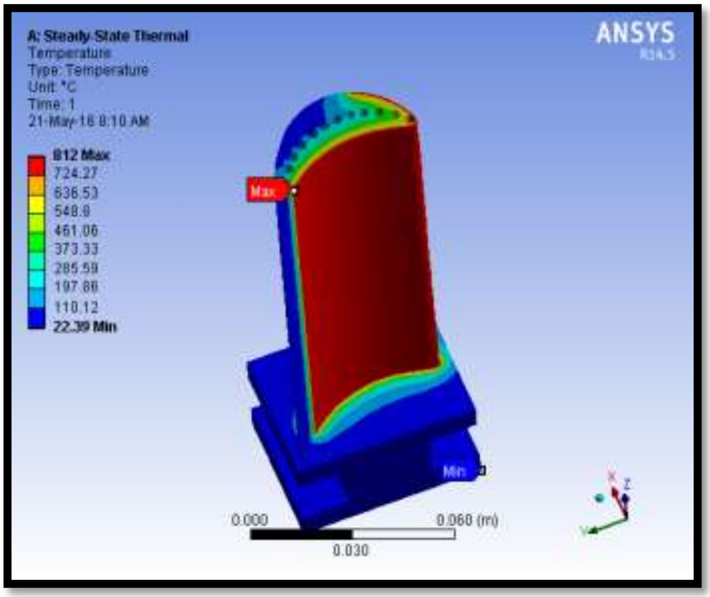


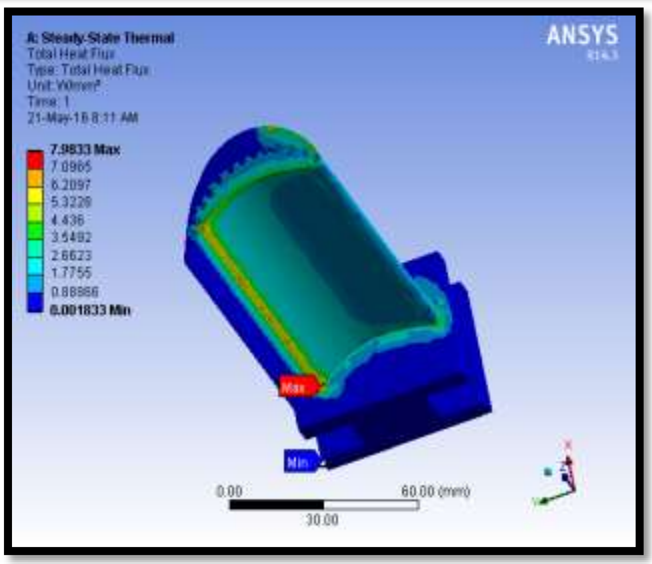


WITH 13 HOLES

MATERIAL – CHROMIUM STEEL

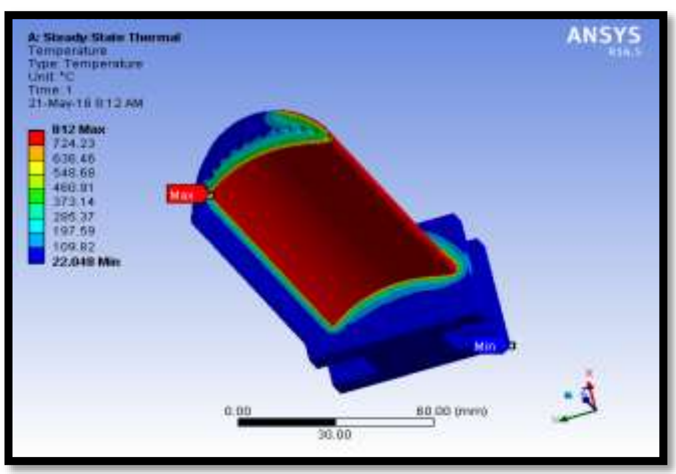
TEMPERATURE **HEAT FLUX**

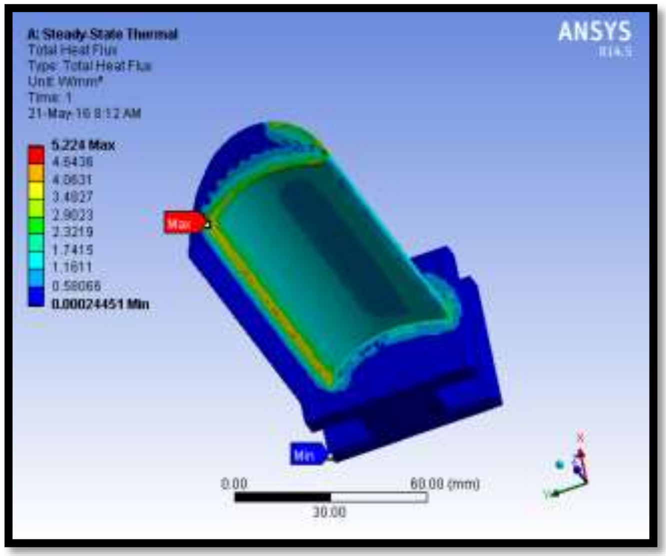




MATERIAL-NICKEL ALLOY617

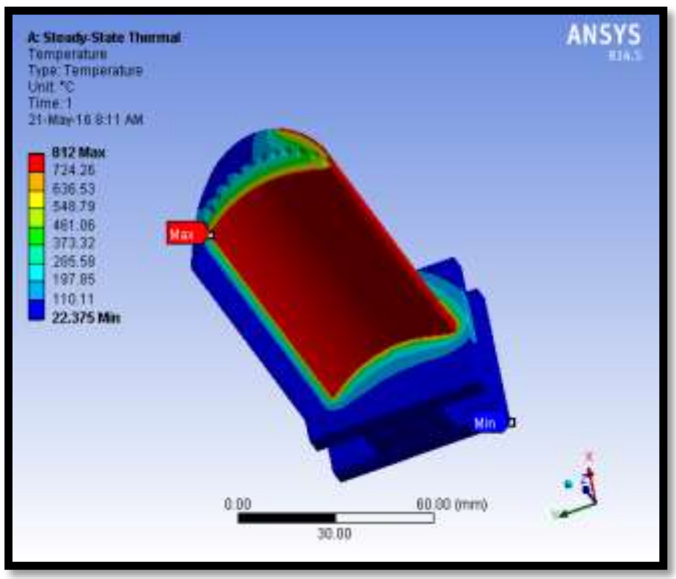
TEMPERATURE **HEAT FLUX**

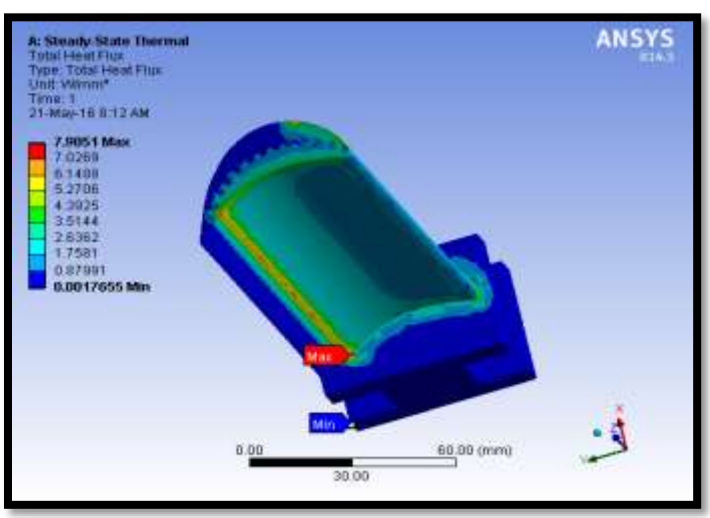




MATERIAL-NICKEL ALLOY188

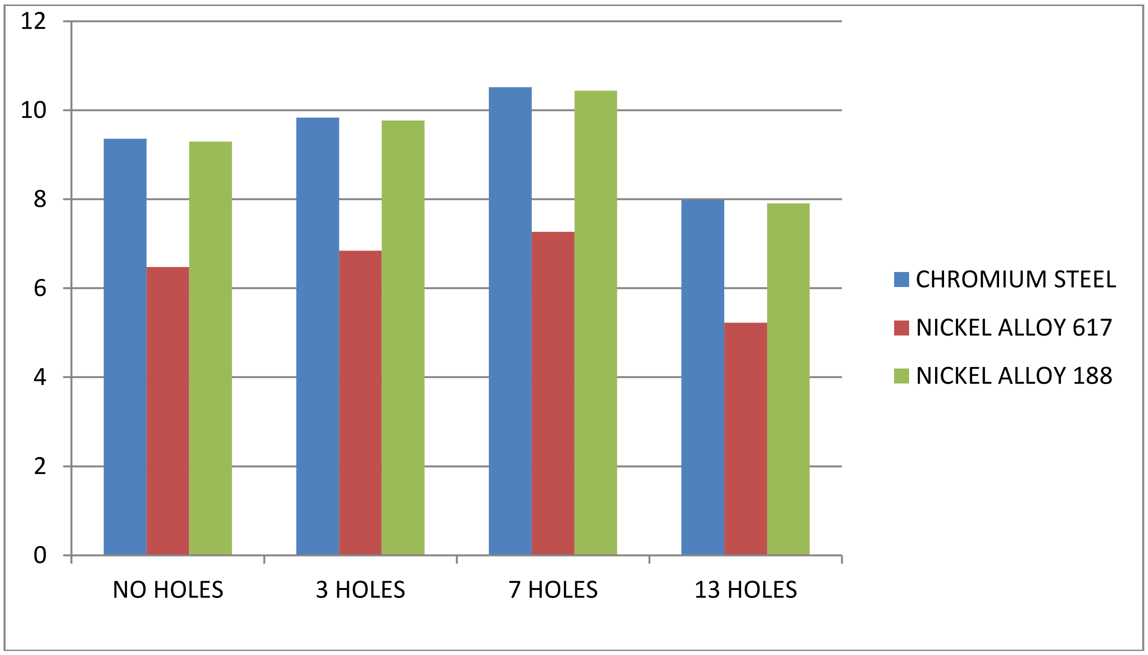
TEMPERATURE **HEAT FLUX**





RESULTS

Models	**Materials**	**results**		
		Temperature(°C)		**Heat flux(W/mm^2)**
		Max.	Min.	
No-holes	Chromium steel	812	22.459	9.3625
	Nickel alloy617	812	22.059	6.4744
	Nickel alloy188	812	22.442	9.2976
3-holes	Chromium steel	812	22.595	9.8363
	Nickel alloy617	812	22.078	6.8431
	Nickel allou188	812	22.573	9.7677
7-holes	Chromium steel	812	22.331	10.517
	Nickel alloy617	812	22.04	7.2644
	Nickel allou188	812	22.319	10.442
13-holes	Chromium steel	812	22.39	7.9833
	Nickel alloy617	812	22.048	5.224
	Nickel allou188	812	22.375	7.9051



III. CONCLUSION

By observing the thermal analysis results, the heat flux is almost similar for Nickel alloy 188 and Chromium Steel. So heat transfer rate is more when Nickel alloy 188 and Chromium Steel. But the strength of Nickel alloy is more than that of Chromium Steel so using Nickel alloy 188 is better. When compared results for models, using 7 holes has more heat transfer rate. So from the above two analysis it can be concluded that providing 3 holes for Nickel alloy 188 is better.

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