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MODELING AND ANALYSIS OF STEAM TURBINE BLADE

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Abstract-- *A* steam turbine *is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft. The steam turbine gives the better thermodynamic efficiency by using multiple stages in the expansion of steam. The stages are characterized by the way of energy extraction from them is considered as impulse or reaction turbines. In this work the parameters of steam turbine blade varied and analysis is done for strength, life and heat transfer rates. The varied parameters are the ratio of X-axis distance of blade profile by chord length and ratio of maximum height of blade profile in Y-direction to the chord length. The 3D modeling is done by using catia software. The ANSYS software is used for static, thermal analysis, finally concluded the suitable design and material (Haste alloy, Chrome steel, Inconel 600) for steam turbine blade, after steam turbine blade imported the stl file 1:2 ratio in to 3d printing we done rapid prototyping method.*

Key Words: *Steam Turbine, Thermal Energy, Impulse Turbine, Reaction Turbine, Static Analysis, Thermal Analysis.*

I. INTRODUCTION

A turbine (from the Latin turbo, a vortex, related to the Greek, meaning "turbulence") is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. The work produced by a turbine can be used for generating electrical power when combined with a generator or producing thrust, as in the case of jet engines. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Early turbine examples are windmills and waterwheels.

II. BLADE DESIGN CHALLENGES

A major challenge facing turbine design was reducing the creep experienced by the blades. Because of the high temperatures and high stresses of operation, steam turbine materials become damaged through these mechanisms. As temperatures are increased in an effort to improve turbine efficiency, creep becomes significant. To limit creep, thermal coatings and super alloys with solid-solution strengthening and grain boundary strengthening are used in blade designs. Protective coatings are used to reduce the thermal damage and to limit oxidation. These coatings are often stabilized zirconium dioxide-based ceramics. Using a thermal protective coating limits the temperature exposure of the nickel super alloy. This reduces the creep mechanisms experienced in the blade. Oxidation coatings limit efficiency losses caused by a buildup on the outside of the blades, which is especially important in the high-temperature environment.

The nickel-based blades are alloyed with aluminum and titanium to improve strength and creep resistance. The microstructure of these alloys is composed of different regions of composition. A uniform dispersion of the gamma-prime phase – a combination of nickel, aluminum, and titanium – promotes the strength and creep resistance of the blade due to the microstructure.

Refractory elements such as rhenium and ruthenium can be added to the alloy to improve creep strength. The addition of these elements reduces the diffusion of the gamma prime phase, thus preserving the fatigue resistance, strength, and creep resistance.

III. LITERATURE REVIEW

Many investigators have suggested various methods to explain the effect of stress and loading on turbine blade, rotor and analysis the various parameters. A paper on design and analysis of Gas turbine blade [1] uses to get the natural frequencies and mode shape of the turbine blade. In this paper we have analyzed previous designs and generals of turbine blade to do further optimization, Finite element results for free standing blades give a complete picture of structural characteristics, which can utilized for the improvement in the design and optimization of the operating conditions.
Design of high pressure steam turbine blade addresses the issue of steam turbine efficiency [3] had a specific focus on airfoil profile for high-pressure turbine blade, and it evaluates the effectiveness of certain Chromium and Nickel in

resisting creep and fracture in turbine blades. The efficiency of the steam turbine is a key factor in both the environmental and economic impact of any coal-fired power station. Based on the research presented modifications to high-pressure steam turbine blades can made to increase turbine efficiency of the turbine. The results and conclusions are presented for a concerning the durability problems experienced with steam turbine blades. The maximum operational Von Mises Stresses are within the yield strength of the material but the deformation is comparatively better for material CA-6 NM (Chromium Nickel). Modified solutions for Steam turbine blade values to machines to maximize their reduce life cycle costs, efficiency, and improve reliability Sanjay Kumar was investigated on creep life of turbine blade. Inertia load is the constant load that will cause creep failure. Creep is a rate dependent material nonlinearity in which material continues to deform in nonlinear fashion even under constant load. The main objective is to predict the creep life of the simple impulse steam turbine blade, and to give the FEM approach for creep analysis. The analysis of turbine blade for different loads, which shows that the maximum stresses, induced in each case. These stresses are within yield limit of the material and will not undergo plastic deformation during operation result is found that, creep life decreases as the stress value increases. Hence, by decreasing the stress value in the component we can increase its creep life. This was be achieved by modifying the blade design.

IV. PROBLEM DEFINITION

All modern steam power plants use impulse-reaction turbines as their blading efficiency is higher than that of impulse turbines. Last stage of steam turbine impluse-reaction blades are very much directly affect efficiency of plant. With the information that an understanding of the forces and stresses acting on the turbine blades is vital importance, in this work we will compute such a force acting on a last stage Low Pressure (LP) blade of a large steam turbine rotating at 3000 rpm in order to estimate the material stresses at the blade root. One such LP steam turbine blade is show in Figure 1. We studied structural and thermal analysis of blade using FEA for this work and by use of the operational data have performed by using FEA (ANSYS) and This study work involved the analyze blade and check FEA data of std. blade with various material.

V. OBJECTIVE

The objective of this work is to make a Steam turbine blade with 3D model, To study the static - thermal behavior of the steam turbine blade with different materials by performing the finite element analysis.3D modeling software (catia v5) was used for designing and analysis software (ANSYS) was used for analysis.

VI. METHODOLOGY

The methodology followed in the work is as follows:

A. Create a 3D model of the different Steam turbine blades using parametric software catia v5.
B. Convert the surface model into IGS and import the model into ANSYS to do analysis.
C. Perform static and thermal analysis on the steam turbine blade.
D. Finally it was concluded which material is the suitable for steam turbine blade on these three materials.

The scopes of this proposed project are

1. To generate 3-dimensional geometry model in catia workbench of the steam turbine blade.
2. To perform structural analysis on the model to determine the stress, shear stress, deformation, of the component under the static- thermal load conditions.
3. To compare analysis between three different materials of steam turbine blade.

VII. LOAD CALCULATION

M	=	Mass of stream flowing through turbine
Vm	=	velocity of steam in m/s [1310 m/s]
M	=	1000 kg / hr
F	=	362.87N
Blade area	=	23319.1mm^2
Pressure	=	F/A
P	=	0.01556N/mm^2

VIII. MATERIAL PROPERTIES

Material	Hastealloy
Density	8.89g/cc
Young's modulus	205Gpa
Poisson's ratio	0.33
Tensile strength ultimate	601.2Mpa
Tensile strength yield	275
Melting point	1400^0c
Thermal conductivity	15.0W/m/K
Specific heat capacity	0.427J/g-^{0}C

Table 1. HASTEALLOY PROPERTIES

Material	Inconel600
Density	8.36 g/cc
Young's modulus	210Gpa
Poisson's ratio	0.35
Tensile strength ultimate	570Mpa
Tensile strength yield	340MPa
Melting point	1370^0c
Thermal conductivity	13.6W/m/K
Specific heat capacity	0.419J/g-^{0}C

Table 2. INCONEL600 PROPERTIES

Material	Chrome Steel
Density	7.31 g/cc
Young's modulus	200Gpa
Poisson's ratio	0.3
Tensile strength ultimate	485Mpa
Tensile strength yield	275Mpa
Melting point	1365^0c
Thermal conductivity	14.0W/m/K
Specific heat capacity	0.418J/g-^{0}C

Table 3. CHROME STEEL PROPERTIES

IX. DIMENSIONS AND DESIGN PROCEDURE IN CATIA

Go to the sketcher fig1.workbench create profile blade shape by using spline and arcs as below dimensions after go to the

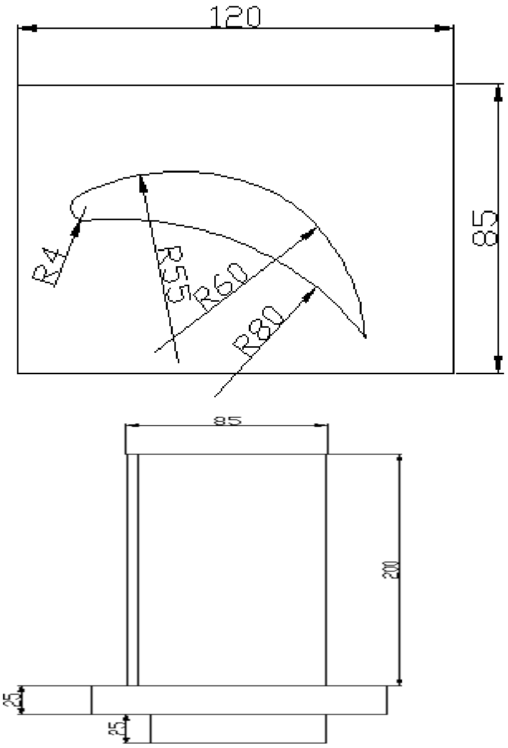


Fig 1. Sketch

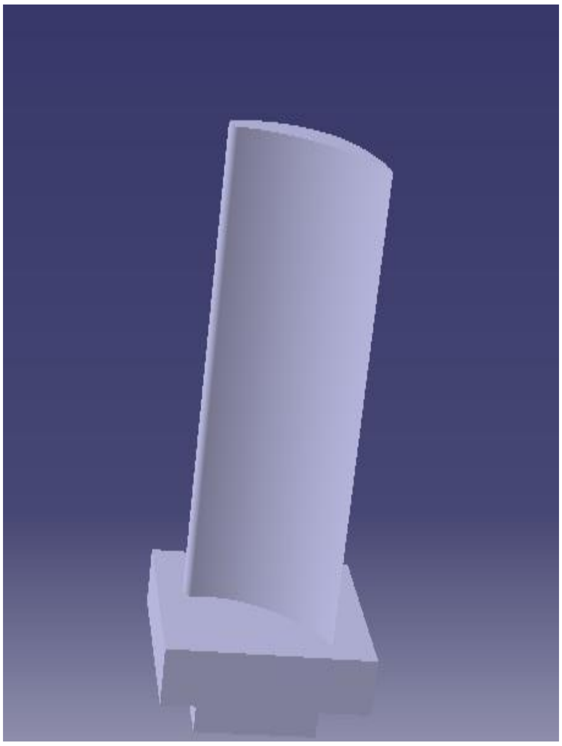


Fig 2. Steam Turbine Blade in Catia Work Bench

X. ANALYSIS PROCEDURE IN ANSYS

Designed component in CATIA workbench after imported into ANSYS workbench now select the steady state thermal analysis.

- Material Properties
- Create or import geometry.
- Model (apply meshing).
- Setup (boundary conditions)
- Solution
- Results

10.1. Static Structural Analysis

The static structural analysis calculates the stresses, displacements, strains, and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure's response are assumed to change slowly with respect to time. A static structural load can be performed using the ANSYS WORKBENCH solver. The types of loading that can be applied in a static analysis include

10.2. Steady State Thermal Analysis

A steady state thermal analysis calculates the effect of steady thermal load on a system or component, analyst were also doing the steady state analysis before performing the transient analysis.A steady state analysis can be the last step of transient thermal analysis. We can use steady state thermal analysis to determine temperature, thermal gradient, heat flow rates and heat flux in an object that do not vary with time Nodes 1580, elements 752

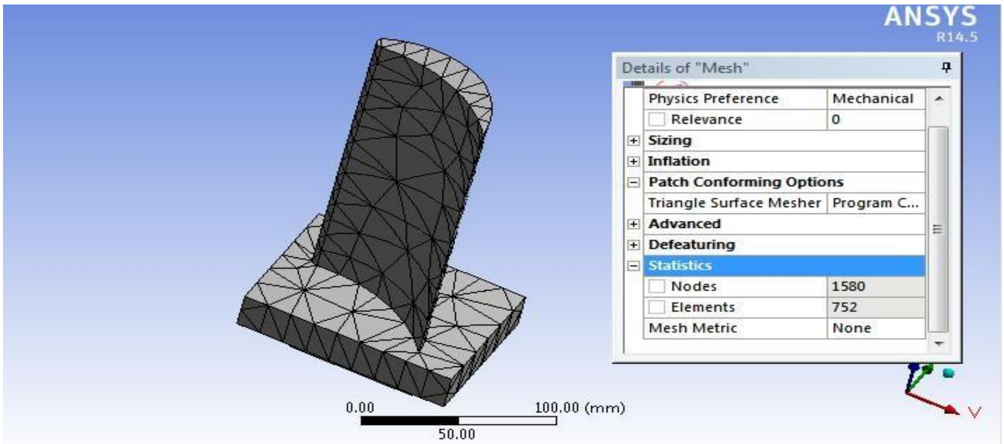


Fig 3. Meshing

10.3. Boundary Condition in Static Analysis

In static analysis fixed the bottom side after apply pressure on blade face

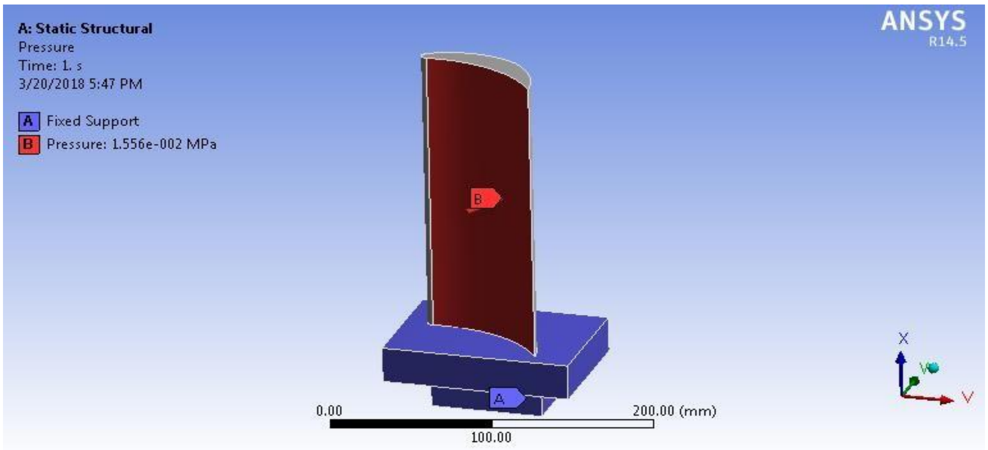


Fig 4. Boundary Condition in Static Analysis

10.4. Boundary condition in steady state thermal analysis

Apply temperature 229^{0}C, apply convection 22^{0}C film coefficient is 0.0025w/mm2^{o}c

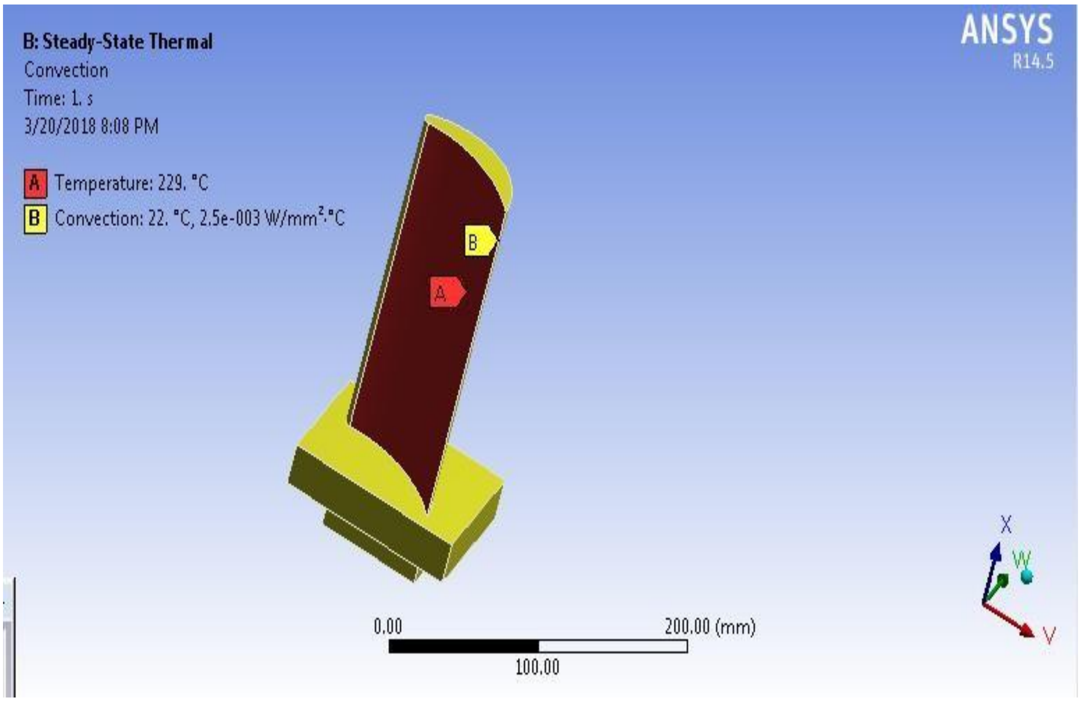


Fig 5. Boundary Condition in Steady State Thermal Analysis

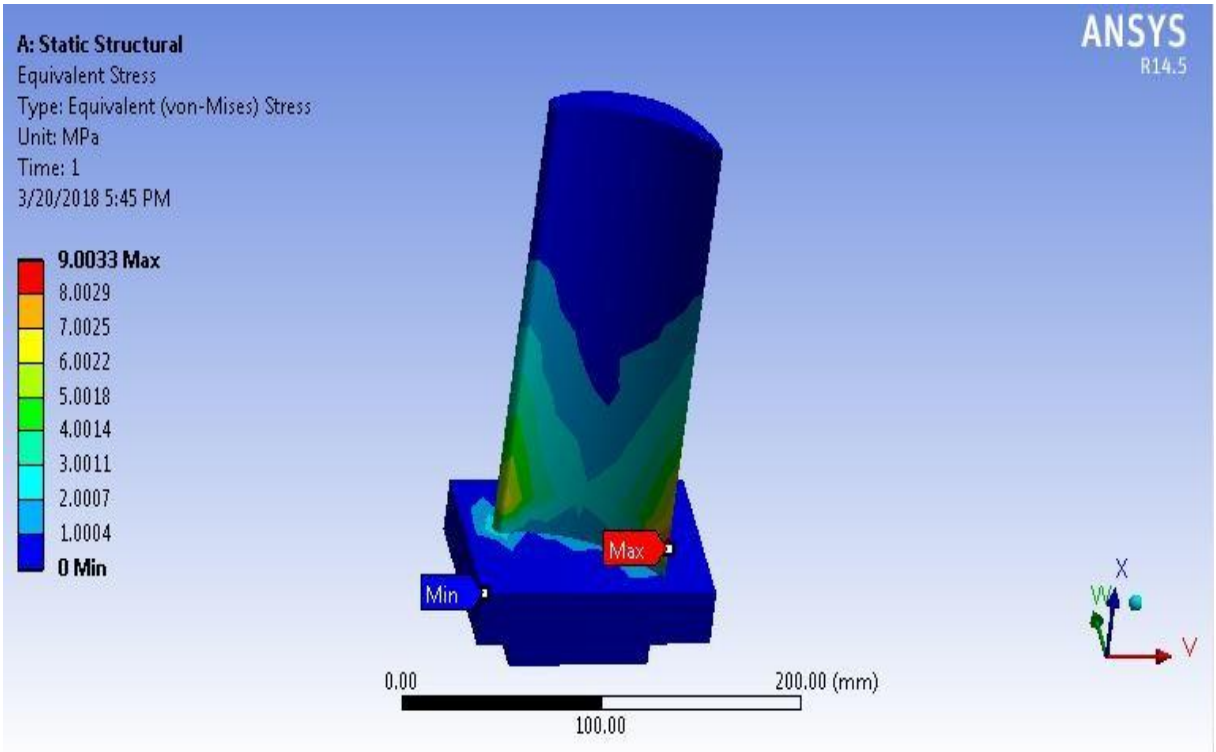
XI. RESULTS AND DISCUSSION

11.1. Static Analysis

This analysis is performed to find Structural parameters such as Stresses, shear stress, Deformation, Here we observed results on three materials namely chrome steel, hastelloy, and Inconel as shown below figures

11.1.1. Chrome steel

Fig 6. Stresses on Chrome Steel



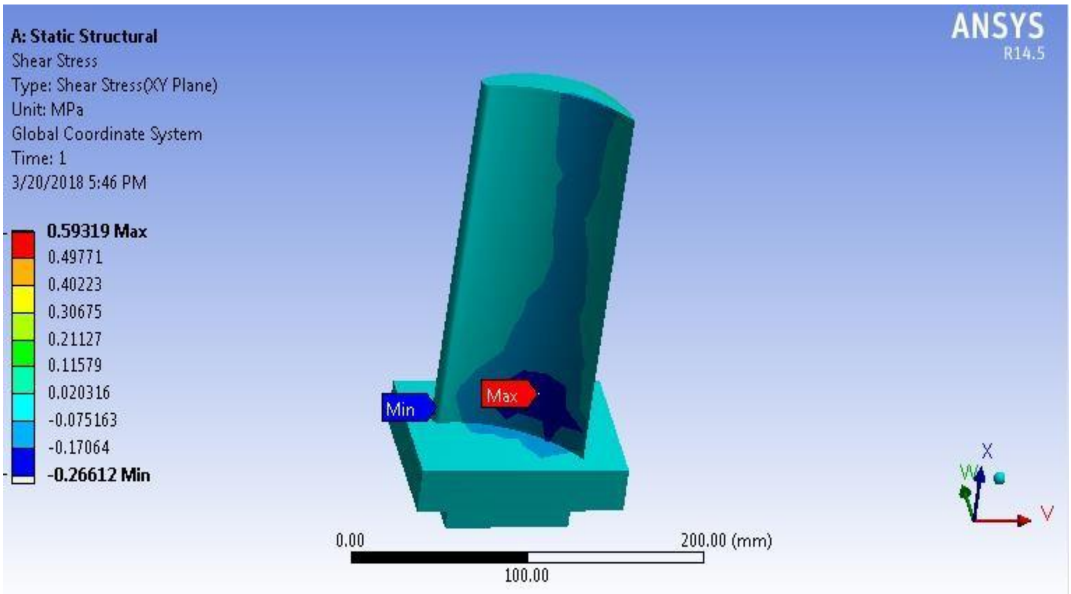


Fig 7. Shear Stress on Chrome Steel

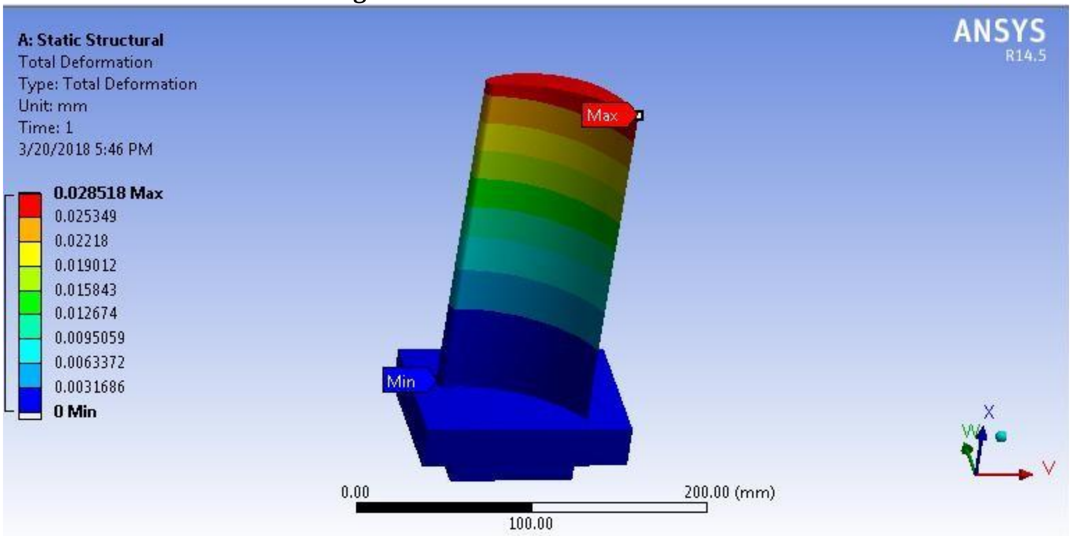


Fig 8. Deformation on Chrome Steel

11.1.2. Inconel material:

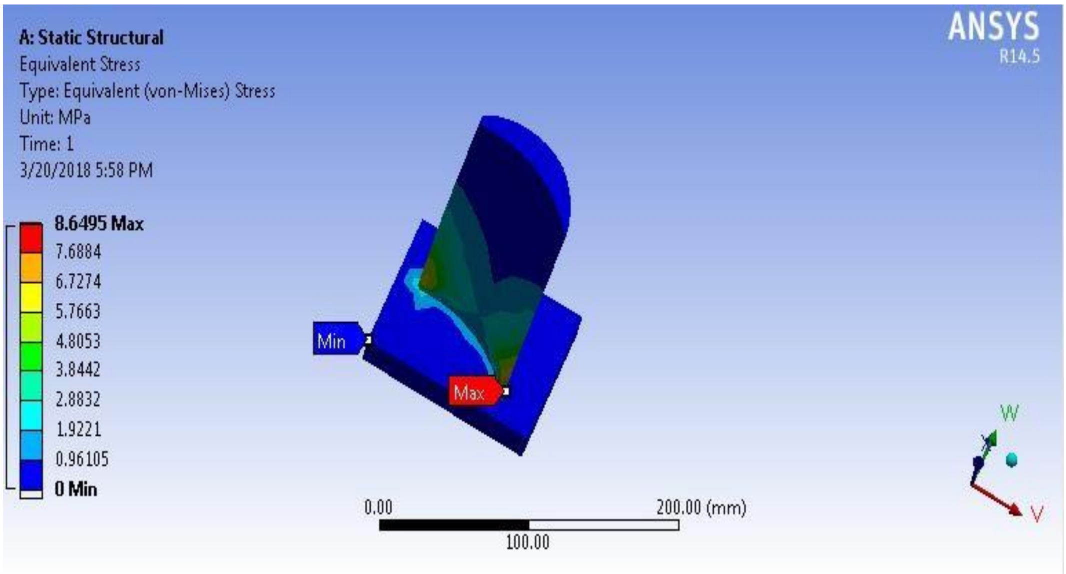


Fig 9. Stress on Inconel

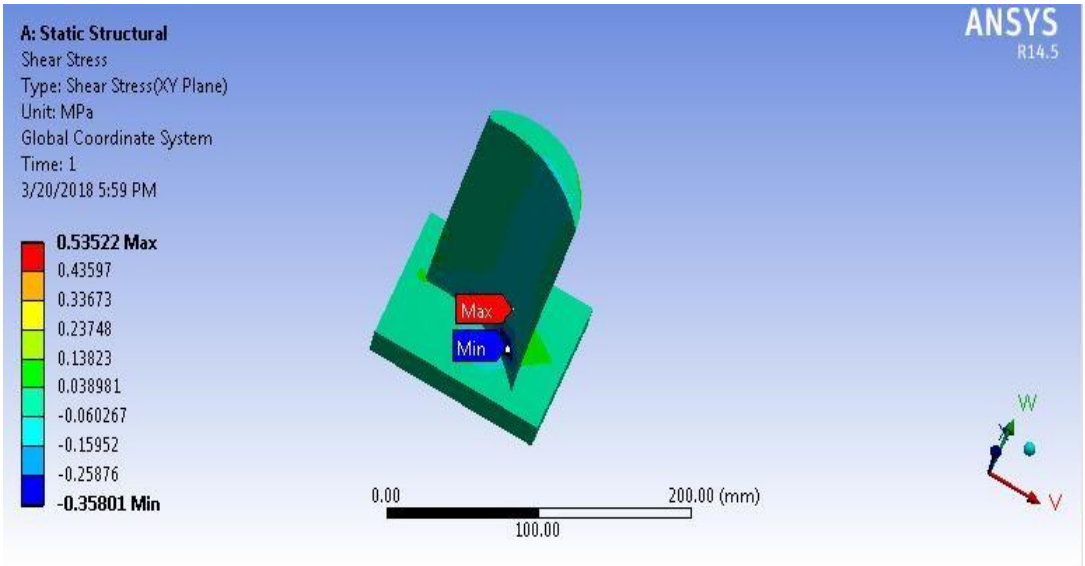


Fig 10. Shear Stress on Inconel

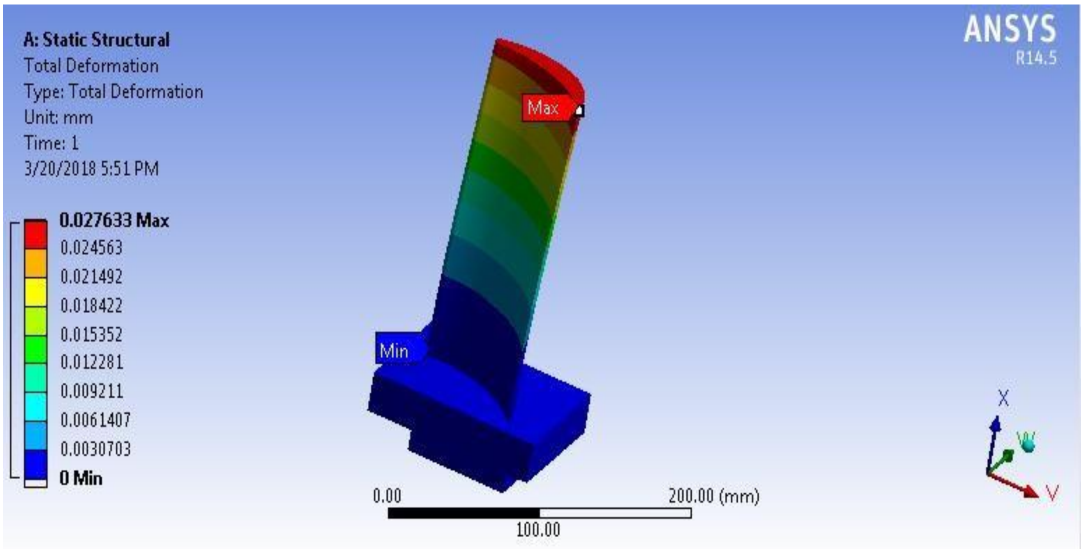


Fig 11. Deformations on Inconel

11.1.3. Hastealloy

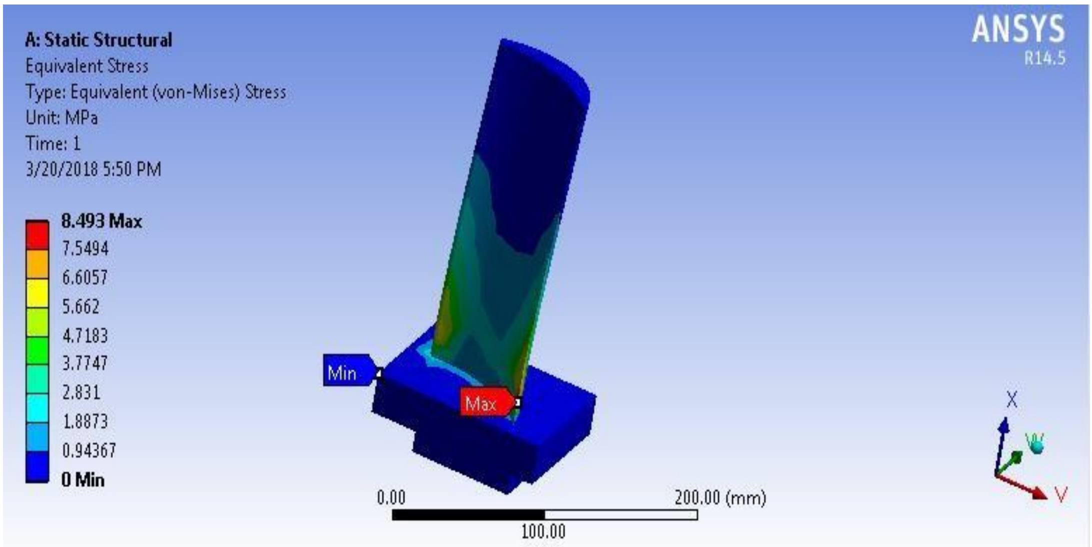


Fig 12. Stresses on Hastealloy

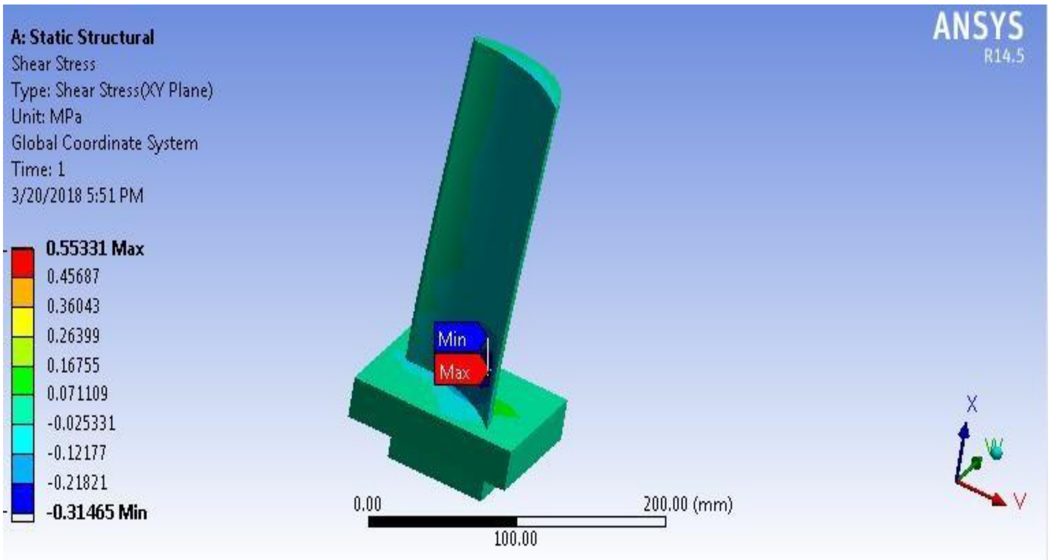


Fig 13. Shear Stress on Hastealloy

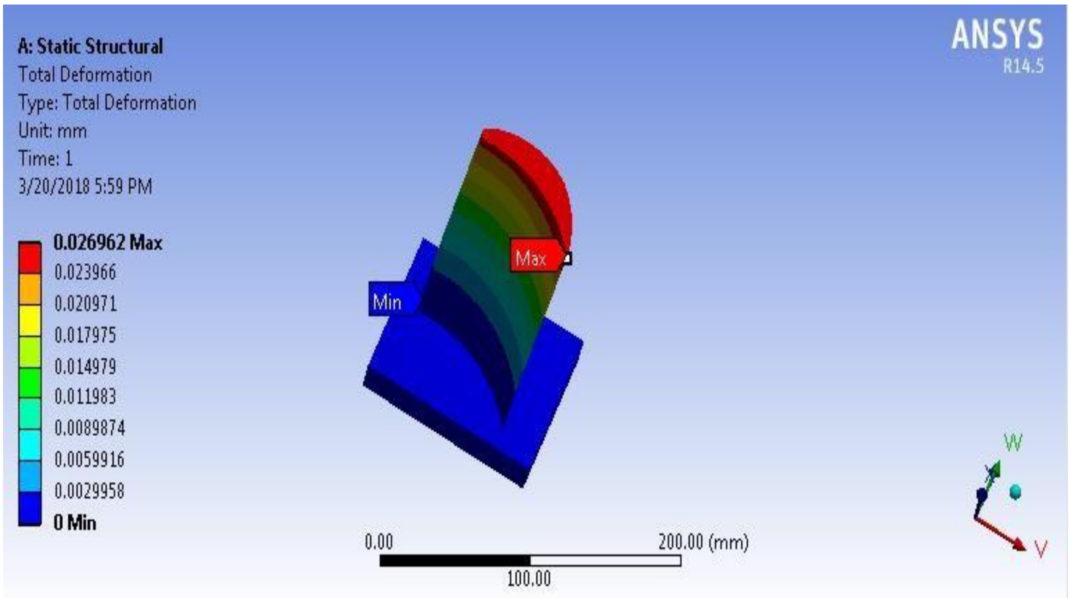


Fig 14. Deformations on Hastealloy

11.2. THERMAL ANALYSIS
11.2.1. Chrome Steel

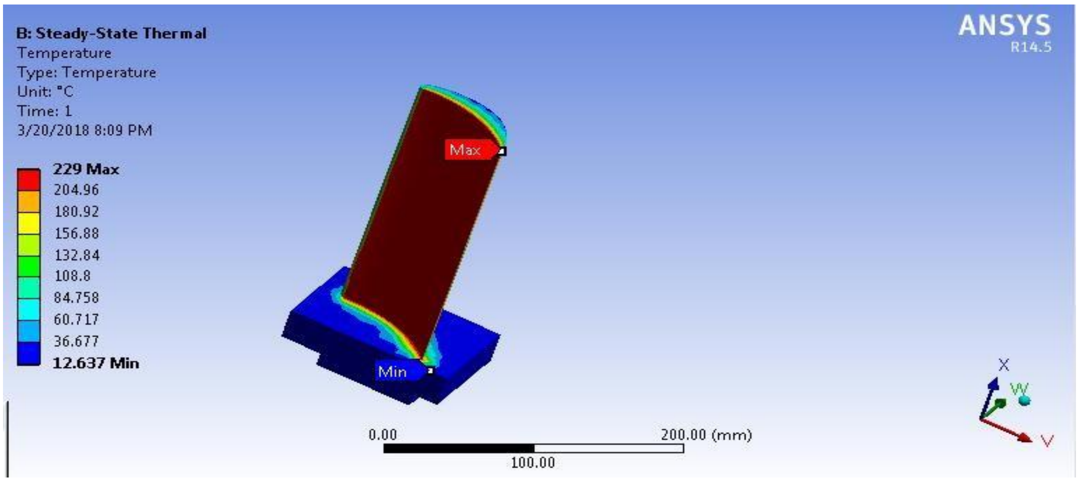


Fig 15. Temperature Distribution Chrome Steel

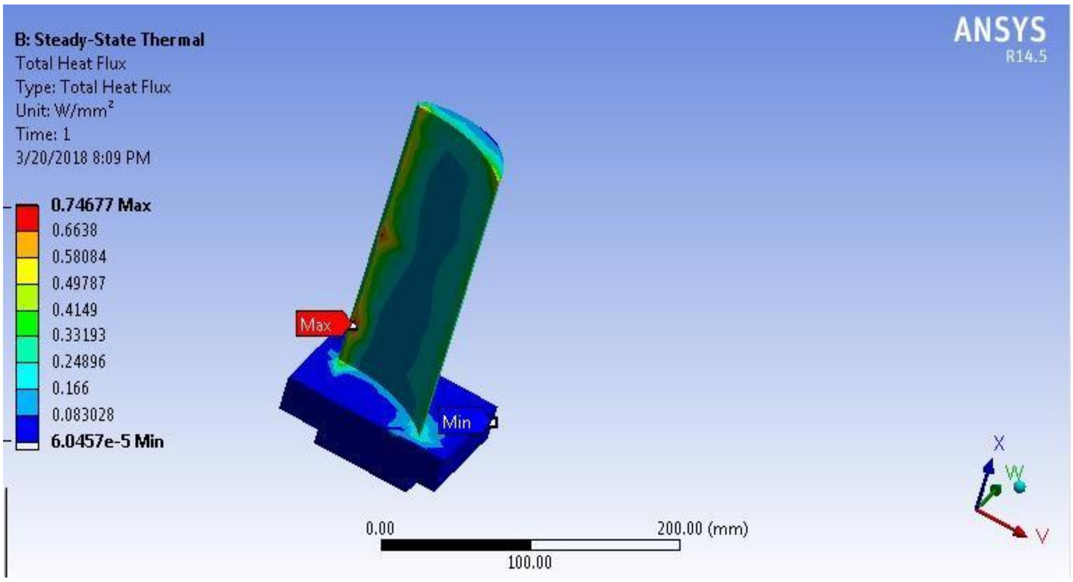


Fig 16. Heat Flux on Chrome Steel

11.2.2. Hastealloy

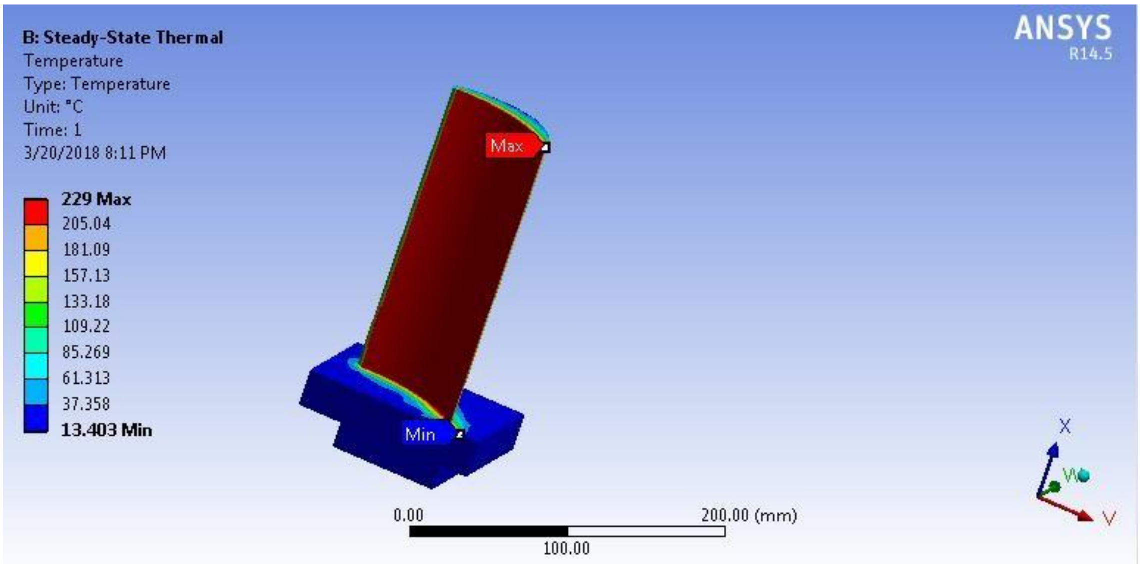


Fig 17. Temperature Distribution on Hastealloy

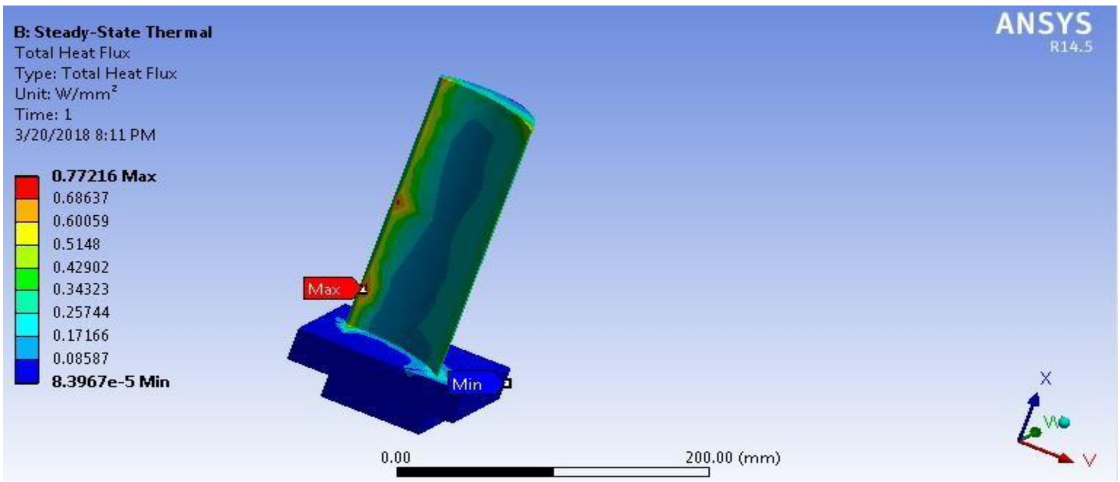


Fig 18. Heat Flux on Hastealloy

11.2.3. Inconel 600

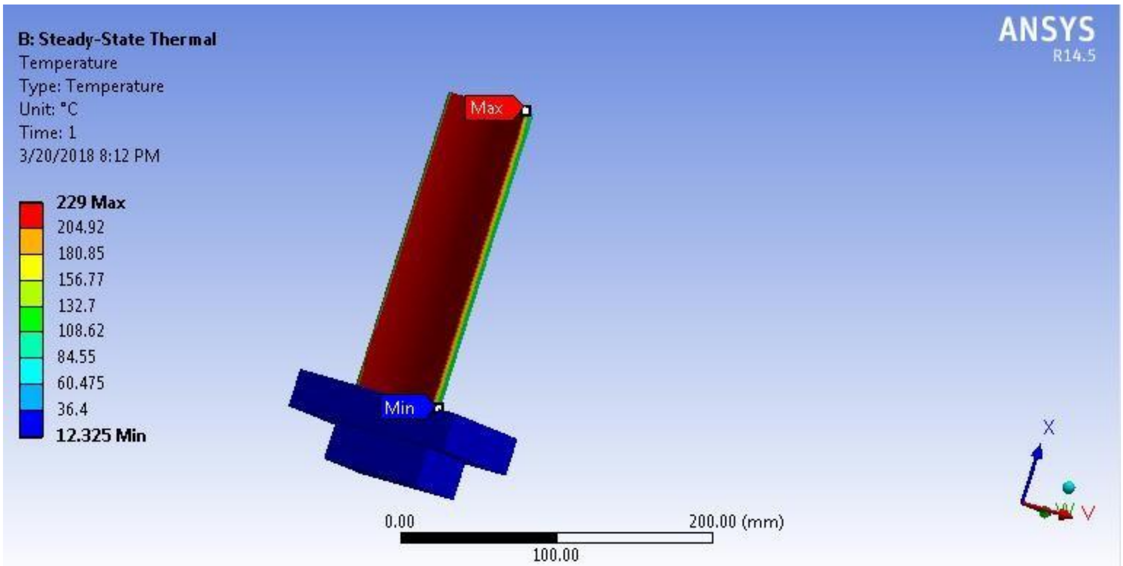


Fig 19. Temperature Distribution on Inconel 600

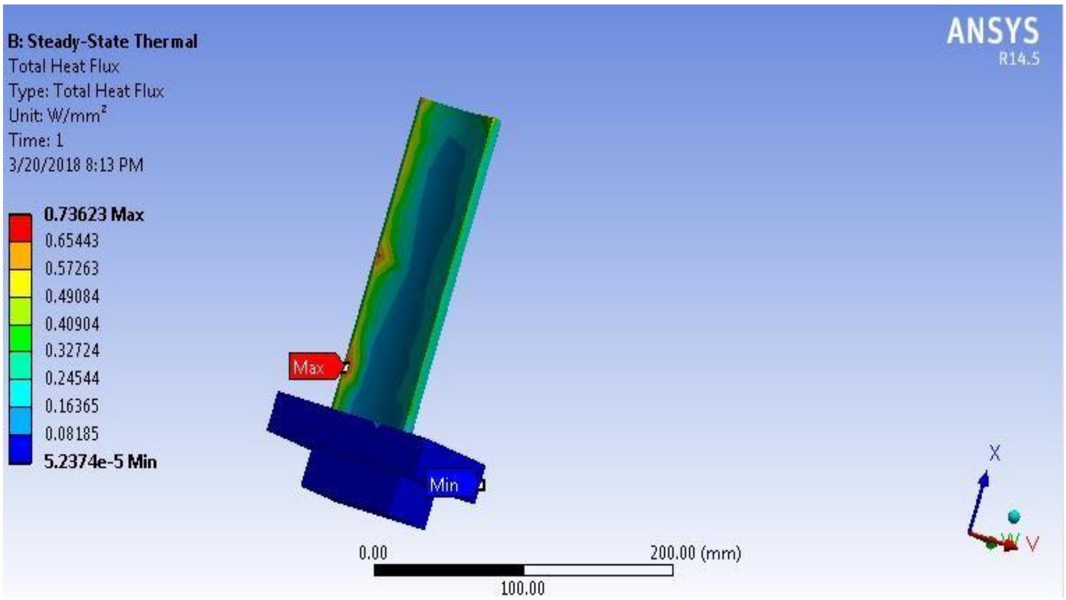
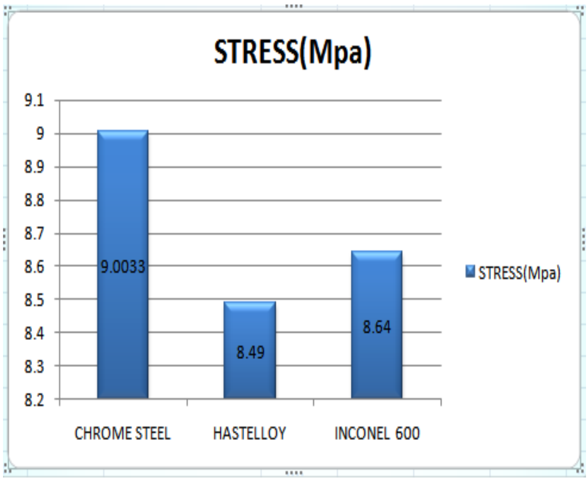
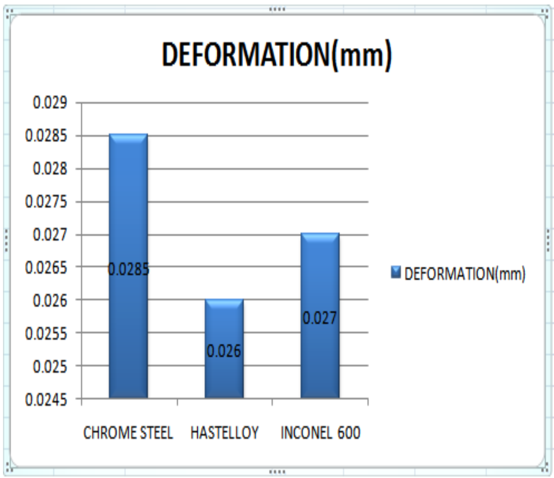


Fig 20. Heat Flux on Inconel 600

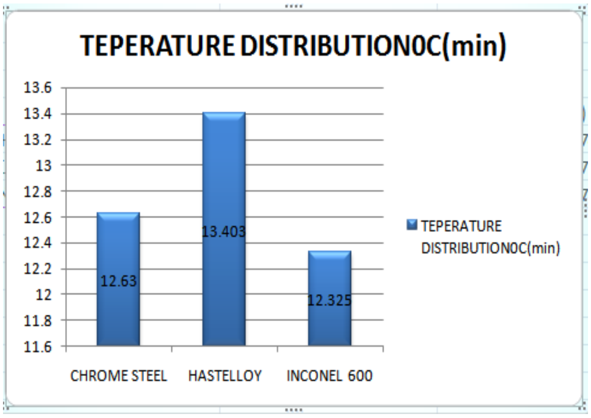
XII. GRAPHS

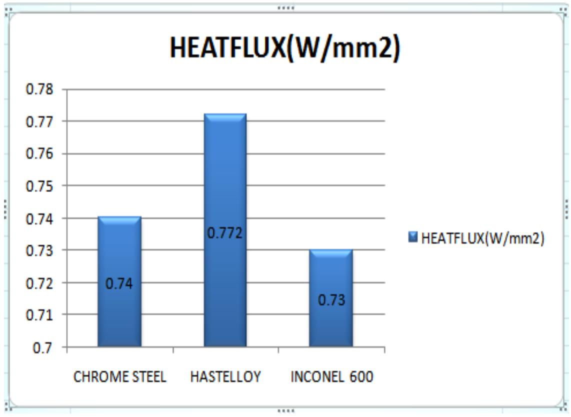


Graph 1. Stress



Graph 2. Total Deformation





Graph 3.Temperature Distribution **Graph 4.Heat Flux**

XIII. CONCLUSION

Modeling and analysis of steam turbine blade is done by using CATIAV5 Software and then the model is imported into ANSYS Software for Structural analysis on the steam turbine blade to check the quality of materials such as, chrome steel, haste alloy, and Inconel. From the obtained Von-misses stresses, shear stress, deformation, temperature distribution and heat flux for the materials, respectively Compared with all materials haste alloy material have less stresses, deformations, and High temperature distribution and heat flux values.

Finally from structural analysis and thermal analysis based on results it is concluded that haste alloy material is suitable material for stream turbine.

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