DESIGN, STATIC AND THERMAL ANALYSIS OF GAS TURBINE BLADE USING VARIOUS MATERIALS

[1]**E Venkateswara Rao,** Assistant professor, evenkat15@gmail.com, Sir C R Reddy College of engineering.
[2]**K V P P Chandu,** Assistant professor, kakarala.chandu@gmail.com, Sir C R Reddy College of engineering

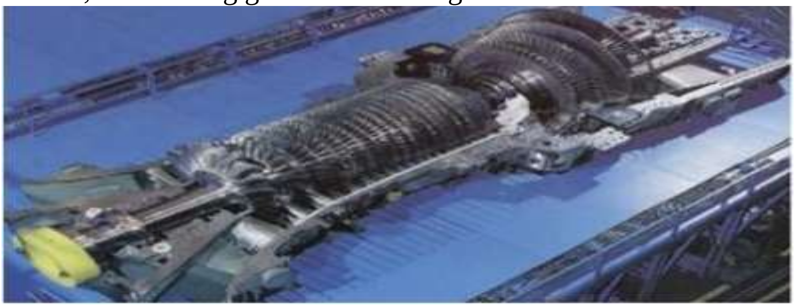
ABSTRACT: A turbine blade is the individual component which makes up the turbine section of a gas turbine or steam turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. In such a responsibility, the failure of the blade can cause a dramatic effect on the safety and performance of the gas turbine. Turbine blades are subjected to very strenuous environments inside a gas turbine. Therefore, the turbine blade failure might be caused by multiple failure mechanisms such as hot corrosion, erosion and fatigue. Hot corrosion could have reduced the thickness of the blade material and thus weakened the blade. This reduction of the blade thickness decreases the fatigue strength which ultimately leads to the failure of the turbine blade. They face high temperatures, high stresses, and a potentially high vibration environment. All these factors can lead to blade failure, resulting in catastrophic failure of turbine. The external and internal surface damages include corrosion, oxidation, crack formation, erosion, foreign object damage and fretting. Therefore, it is required to choose high abrasive resistance, low corrosion and high thermal resistance material and also requires modifications in blade design. In this project, our aim is to design the gas turbine blade using CATIA software and Static thermal analysis will be done using ANSYS software by design with various materials like NIMONIC 80A,CHROME STEEL,INCONEL 600. Finally the best material will be decided based on the results of von-misses stress, strain, deformation, shear stress, Temperature distribution and heat flux.

KEYWORDS : Gas turbine blade NACA6409,Catia, Ansys, static, Thermal,

INTRODUCTION OF GAS TURBINE The turbine is a rotary mechanical device that extracts energy from a fluid flow and converts into useful work and purpose of turbine technology are to extract the maximum quantity of energy from the working fluid to convert it into useful work with maximum reliability, minimum cost, minimum supervision and minimum starting time. Gas turbine are used extensively for aircraft propulsion, land-based power generation and industrial application. Thermal efficiency and power output of gas turbine increases with increasing turbine rotor inlet temperature. The current rotor inlet temperature level in advanced gas turbine is far above the melting point of the blade material. Therefore, along with high temperature development, sophisticated cooling scheme must be developed for continuous safe operation of gas turbine with high performance. Losses on the turbine consist of mechanical losses due to the friction of rotating parts or bearings, tip clearance losses due to the flow leakage through tip gap, secondary flow losses due to curved passages, and profile losses due to the blade shape, etc. More than 60% of total losses on the turbine is generated by the two latter loss mechanisms. These losses are directly related with the reduction of turbine efficiency. Turbine efficiency is the most important factor on the performance of heavy-duty gas turbines for power plants, air turbines, or turbo expanders, etc. This efficiency is related very closely with losses in the passage.

GAS TURBINE:

A Gas turbine is used as a prime mover for power generation in various fields of mechanical and aeronautical engineering. In gas turbine engine fuel is constantly burnt with compressed air to harvest a jet of hot, fast-moving gas. These hot gases impinge on the turbine blade which will rotate the gas turbine. The gas turbine is spooled or coupled with compressor. The turbine uses the power generated to rotate compressor. The turbine extracts power by using the energy of combusted gases and air which is at high temperature and high pressure by expanding through several stages of stator vanes and rotor blades. After compression, the air will be expanded in the turbine, then supposing that there were no losses in both the components, the power extracted by the turbine can be augmented by augmenting the volume of hot gases at continual pressure or alternatively increasing the pressure at continual volume. To get an elevated temperature of the working fluid, a combustion chamber is required where burning of air and fuel takes place giving temperature intensification to the working fluid. A gas turbine blade is the main part which makes the turbine division of a gas turbine. The blades are the main component accountable for extracting energy from high pressure, high temperature gas produced by the burner. Due to the huge number of stresses produced on the turbine blade from the effect of centrifugal force (due to the rotation of turbine disc at high RPM) and the forces exerted by the hot gases on the turbine blade can cause yielding, fracture or creep failures. In addition to the forces exerted on the turbine blade, the first stage turbine of advanced engines will face temperatures of around 820 oC to 1,370 oC. One of the most important and critical components of the gas turbine engine is turbine blade. The complete performance of the engine depends on the ability of turbine blade to extract energy from the hot gases. The major cause of failure in gas turbine engine is the breakdown of rotor blade. The failure of the rotor blade may lead to catastrophic consequences both physically and economically. Due to this a proper design must be done for gas turbine blade, which plays an important role in gas turbine engine. The purpose of turbine technology are to extract the maximum quantity of energy from the working fluid to convert it into useful work with maximum efficiency by means of a plant having maximum reliability, minimum cost, minimum supervision and minimum starting time. The gas turbine obtains its power by utilizing the energy of burnt gases and the air which is at high temperature and pressure by expanding through the several rings of fixed and moving blades. To get a high pressure of order 4 to 10 bar of working fluid where fuel is continuously burnt with compressed air to produce a steam of hot, fast moving gases shown in figure



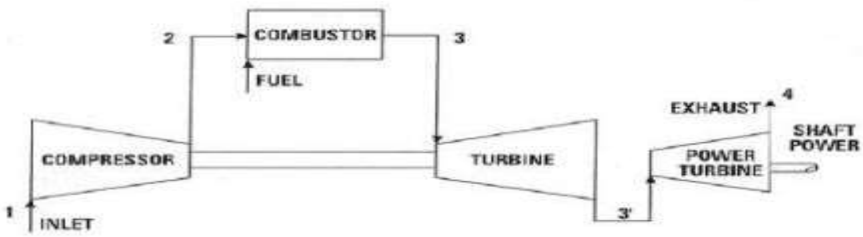


FIGURE 1 GAS TURBINE SIMPLE OPEN CYCLE

This gas stream is used to power the compressor that supplies the air to the engine as well as providing excess energy that may be used to do other work, which is essential for expansion a compressor, is required. The quantity of the working fluid and speed required are more so generally a centrifugal or an axial compressor is required. The turbine drives the compressor so it is coupled to the turbine shaft. If after compression the working fluid were to be expanded in a turbine, then assuming that there were no losses in either component, the power developed by the turbine can be increased by increasing the volume of working fluid at constant pressure or alternatively increasing the pressure at constant volume.

LITERATURE REVIEW

Soo-Yong Cho [1] Heat transfer analysis of gas turbine blade is carried out with different models consisting of blade with without holes and blade with varying number of cooling holes. It is found that total heat transfer rate is maximum and the temperature of the blade leading edge is minimum for the blade consisting of 13 holes. The thermal and structural analysis is studied for two different materials constructions that is Chromium steel and Inconel718. By observing the graphs the thermal flux is maximum of Inconel718 blade with consisting of 13 number of holes, and the induced von misses stress and strain are within allowable limits. It is found that inconel718 is better than Chromium steel.

John.V, T. Ramakrishna [2] as turbine blade cooling is studied for two different materials of constructions that is N 155 & Inconel 718. It is found that Inconel 718 has better thermal properties as the blade temperatures and thermal stresses induced are lesser. The provision of cooling passages in the blades is found to alleviate the problem of high temperatures and thermal stresses. It is observed that as the no. of holes increases the temperature distribution increase. The structural analysis is carried out after the thermal analysis in SOLID WORKS SIMULATION TOOL. It is observed that blade with 10 holes has showing more stresses than the remaining blades. Finally the blade with 9 holes has giving optimum performance for prescribed loading conditions with average temperature of 514.1K at the trailing edge and von misses stresses as 17.7 Mpa. B. Deepanraj [3] The finite element analysis for structural and thermal analysis of gas turbine rotor blade is carried out using. Solid 95 element. The temperature has a significant effect on the overall turbine blades. Maximum elongations and temperatures are observed at the blade tip section and minimum elongation and temperature variations at the root of the blade. Maximum stresses and strains are observed at the root of the turbine blade and upper surface along the blade roots three different materials of construction i.e., N-155, Inconel It is seen from above results both the materials are giving the considerable results; finally the conclusion can be one on the basis of the cost and the availability of the materials. If cost of the materials is not a primary issue we can select the titanium T6 which have lesser density, lesser value of deformation at a same time it will have lower value of yield strength and young modulus at higher temperature, which will have a lower strength. On the other hand if cost of the material is a primary issue then we can select Inconel 718, it will have little higher deformation at high temperature as compare to titanium T6. But at the same time it will have higher value of elastic strength, higher values of yield strength which will induce lesser value of the stress on the blade. It is also seen Inconel 718 have good material properties at higher temperature has compare to that of the titanium T6.

PROBLEM STATEMENT

Due to high centrifugal forces and high temperature working conditions the gas turbine blades are experiencing high stresses. Due to the high stresses in turbine blade there may be chance of failure or change in the shape of turbine blade. To prevent the failure or change in the shape of the turbine blade we should know the amount of stresses and deformation acting on the blade. The main intention of this work is to know the amount of stresses acting on the first stage gas turbine blade and to come up with an idea to minimize the stresses and increase the life of gas turbine blade Using various materials. In the present work gas turbine blade has been analyzed for static structural, steady state thermal.

OBJECTIVE AND METHODOLOGY

To understand the loads acting on the turbine blade and to obtain the geometric details from the literature survey. To generate 3-dimensional geometry model in Catia workbench of the Gas turbine turbine blade To perform structural analysis on the model to determine the stress, deformation, temperature distribution and heat flux of the component under the thermal load conditions To compare analysis between two different designs and three materials Nimonic 80a, chrome steel, Inconel 600, of gas turbine blade. To mesh the geometry of gas turbine blade and carryout Static, thermal analysis by applying boundary conditions obtained from literature review and validating the results with literature review results. Finally concluded the suitable design and material of the gas turbine blade. To optimize the material of gas turbine blade to reduce the stresses and analyzing it for different materials using various

Suggesting the better material for the gas turbine blade with respect to these Nimonic 80a, chrome steel, Inconel 600 Materials for turbine blade.

METHODOLOGY

The Gas turbine blade geometry was created using commercially available CAD software CATIA V5.

The geometry was imported to Design modeler of Ansys Workbench V16.2.

The geometry was meshed using Mechanical of Ansys Workbench V16.2.

The boundary conditions were applied to the turbine blade which was obtained from literature review

The results obtained were validated with literature review results.

The blade is Analyzed for Static and Thermal analysis

GAS TURBINE BLADE MATERIAL PROPERTIES:

MATERIAL	NIMONIC 80A	CHROME STEEL	INCONEL 600
Density g/cc	8.19	7.31	8360
Young's modulus(Gpa)	144	200	214
Poisson's ratio	0.348	0.3	0.324
Tensile strength ultimate(Mpa)	1120	485	570
Tensile strength yield(Mpa)	980	275	340
Melting point(oc)	1380	1365	1370
Thermal conductivity (W/m/k)	33.5	14.0	13.6
Specific heat capacity(J/go-c)	0.448	0.418	0.419

TABLE 1 GAS TURBINE BLADE MATERIAL PROPERTIES

FOLLOWING PARAMETER HAS BEEN TAKEN FOR CALCULATION OF FORCES APPLYING ON THE BLADE: -

Blade height (H) = 0.12m Rotor diameter (D) = 0.51m Mean diameter (Dm) = 0.63m Temperature (T) = 1000K No. of blade=120

Mass flow rate (M) = 31.6 kg/sec

For max diagram efficiency nozzle angle(

for max diagram efficiency nozzle angle (α) should be as small as possible. Due to manufacturing constraint it is taken as 14° Velocity of blade

$(V\ \ ) = \frac{\pi i}{6} = 659.7344m/s$

since $\frac{V}{V1} = \frac{c}{2} \Rightarrow A$ v $(V1) =$ $1359.8625m/s.$

Inlet bladeangle

$(t\ \ 1) = (V1\,s\ \ 1)/(V1\,c\ \ 1 - V\ \ ) = 0.4986 \Rightarrow \beta 1 = 26.5034°$
$= \beta 2(f\ \ i\ \ t\ \ )$

$V2 = V\ 2 + V\ \ = \frac{1\ \ 8\ \ m}{s}$

$\frac{V2}{s\ \ 2} = \frac{V\ 2}{s} \Rightarrow \delta = 13.2825°$

$V\ \ 1 = V1\,c\ \ 1 = \frac{1\ \ 4\ \ m}{s}$

$V\ 1 = V\ 2 = V1 - V = 700.1281m/s/$ $V\ \ 2 = V2\cos(180 - \delta) = -\frac{1\ \ 4\ \ m}{s}$ Tangential

$V\ \ 1 = V1\,s\ \ 1 = \frac{3\ \ 9\ \ m}{s}$

$V\ \ 2 = V2\sin(180 - \delta) = 312.4317m/s$

Force (Ft) $=\dot{M}\times \Delta V\ \ = 83517.33376N;$ Ft/blade=695.97N

Axial force (Fa) $=\dot{M}\times \Delta V\ \ = 522.94208N$
Fa/blade=4.35785N
Power generated=$\dot{M}$ (Vw1+Vw2) U=55.09MW

Centrifugal Force (Fc) $=\rho\ \ \omega^2(\frac{R2^2-R1^2}{2})$

RPM	20000
Fa/Blade	4.3578 N
Ft/Blade	695.97 N
Power	55.0MW

RESULTS AND DISCUSSIONS

This Static and thermal analysis is performed using the Catia and Ansys software to find Structural and thermal parameters such as Von-misses Stresses, Deformation, shear stress, Total heat flux, temperature distribution of gas turbine blade using three materials Namely Nemonic 80A, Chrome steel, Inconel 600. finally observed results as shown below figures.

NIMONIC 80A MATERIAL:

Von-misses stress of Nimonic 80 A Material:

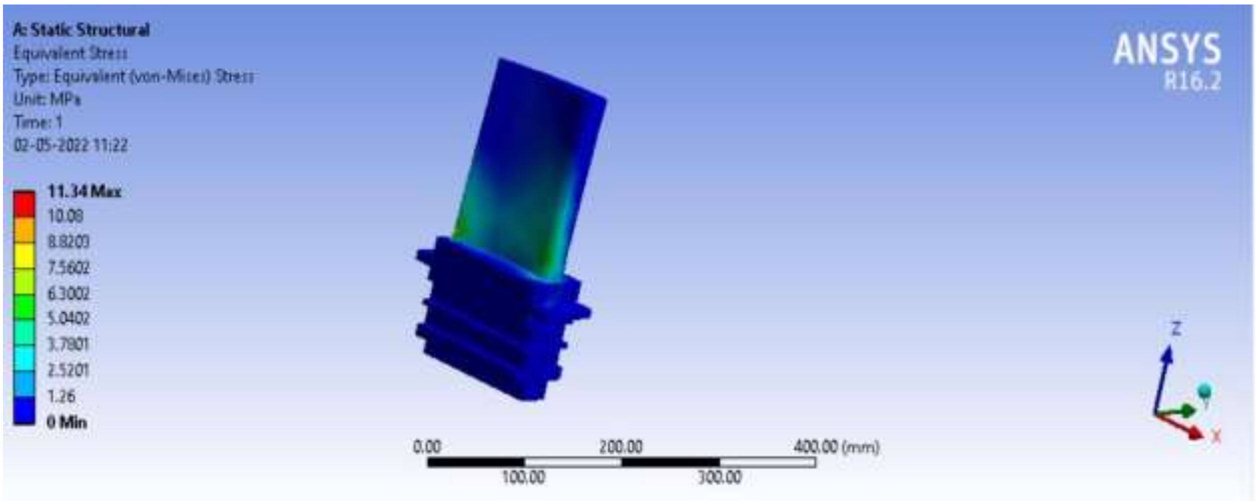


FIGURE2 VON-MISSES STRESS OF NIMONIC 80 A MATERIAL

Total deformation of Nimonic 80 A Material:

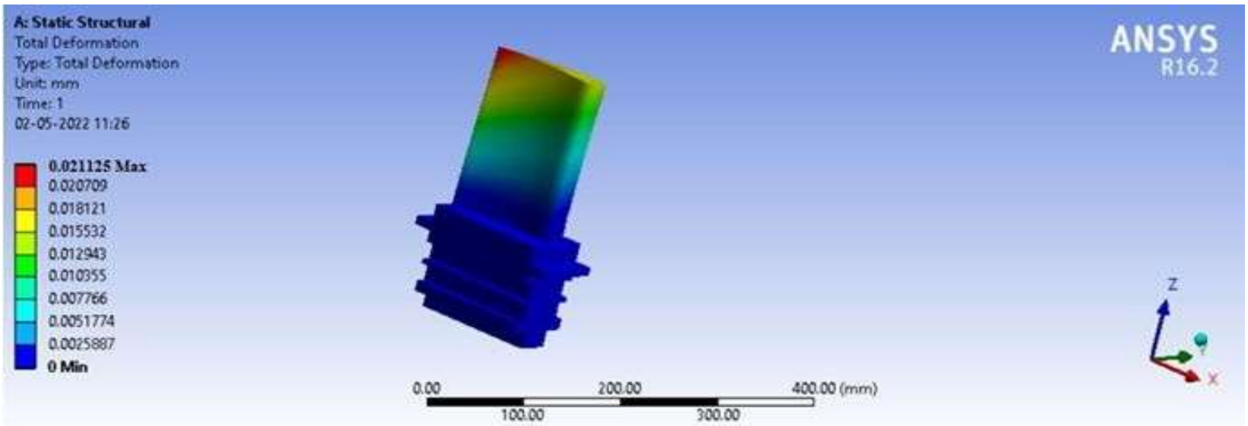


FIGURE3 TOTAL DEFORMATION OF NIMONIC 80 A MATERIAL

Shear stress of Nimonic 80 A Material:

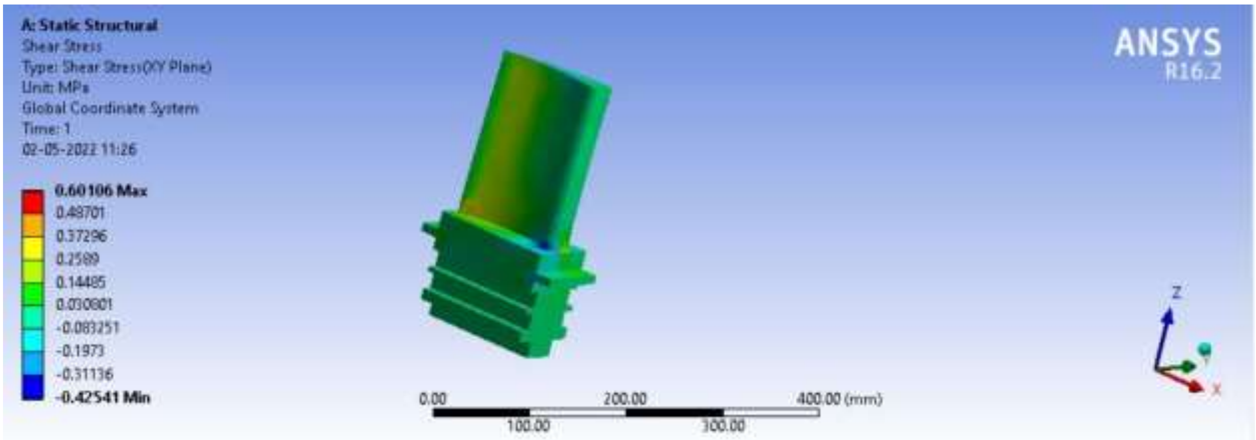


FIGURE4 SHEAR STRESS OF NIMONIC 80 A MATERIAL

Temperature distribution of Nimonic 80 A Material:

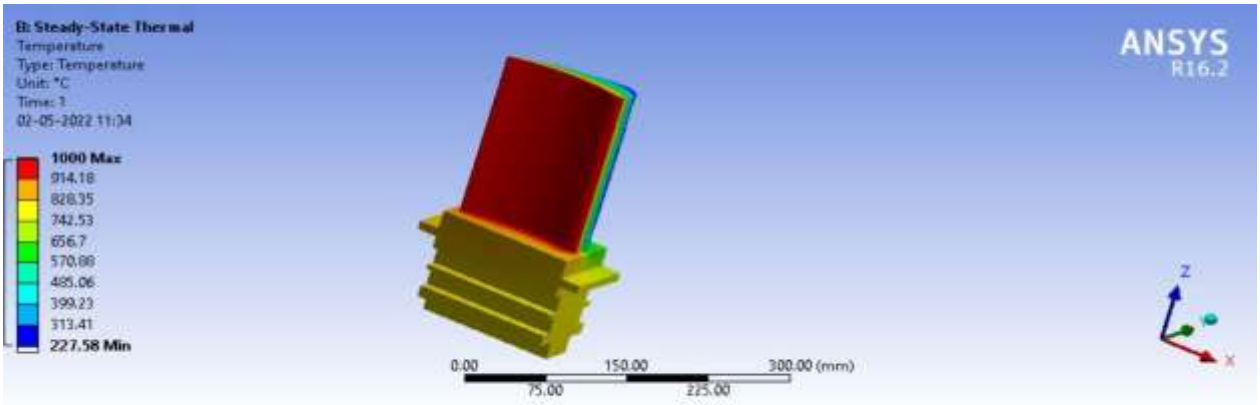


FIGURE5 TEMPERATURE DISTRIBUTION OF NIMONIC 80 A MATERIAL

Total heat flux of Nimonic 80 A Material:

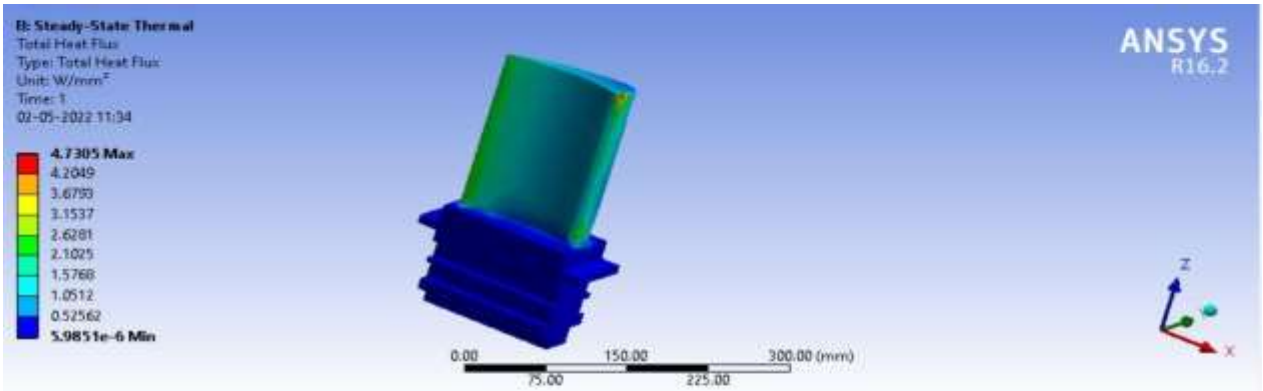


FIGURE6 TOTAL HEAT FLUX OF NIMONIC 80 A MATERIAL

CHROME STEEL MATERIAL:

Von-misses stress of Chrome steel Material:

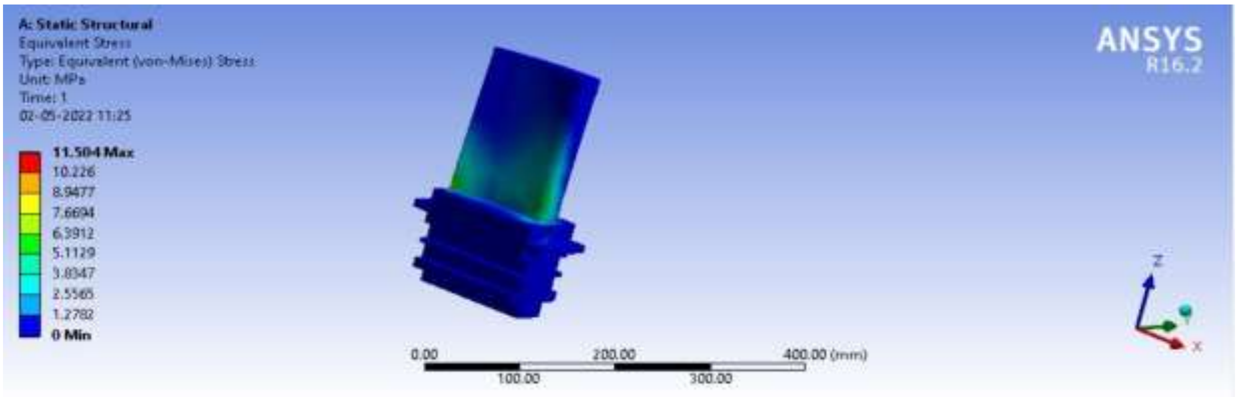


FIGURE7 VON-MISSES STRESS OF CHROME STEEL MATERIAL

Total deformation of Chrome steel Material:

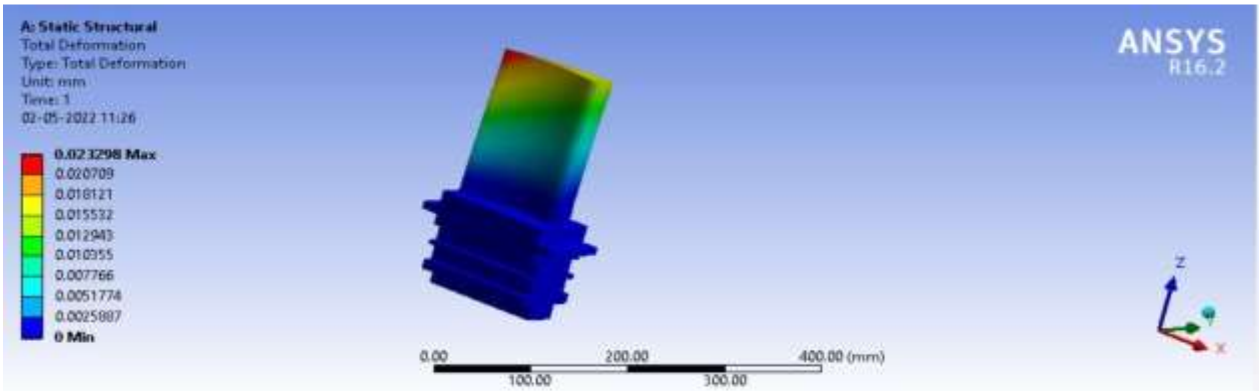


FIGURE8 TOTAL DEFORMATION OF CHROME STEEL MATERIAL

Shear stress of Chrome steel Material:

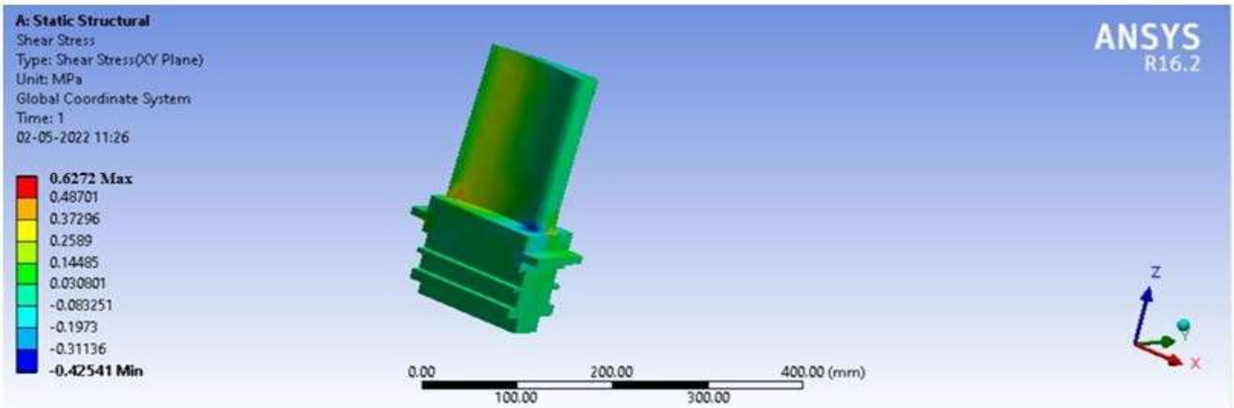


FIGURE9 SHEAR STRESS OF CHROME STEEL MATERIAL

Temperature distribution of Chrome steel Material:

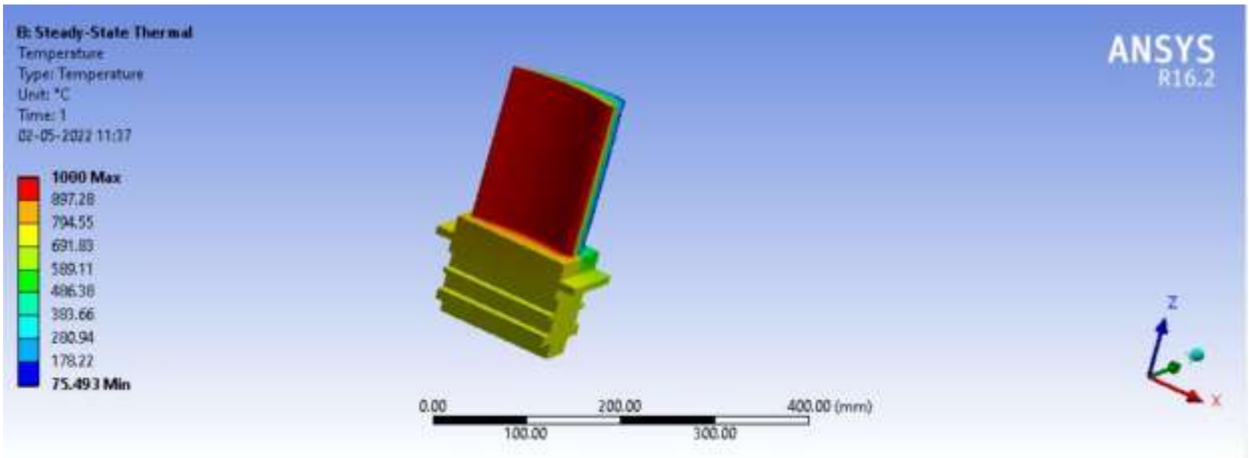


FIGURE10 TEMPERATURE DISTRIBUTION OF CHROME STEEL MATERIAL

Total heat flux of Chrome steel Material:

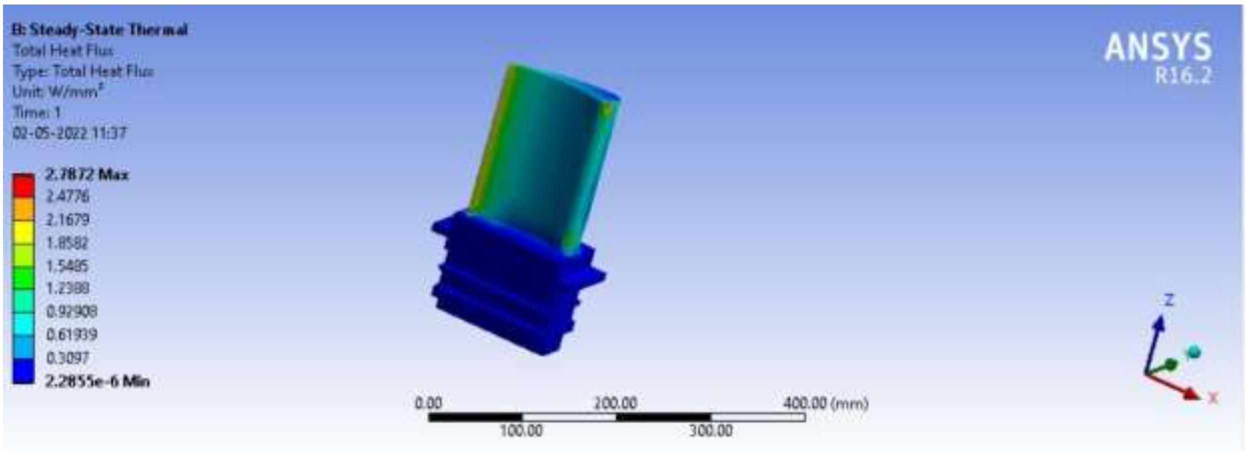


FIGURE11 TOTAL HEAT FLUX OF CHROME STEEL MATERIAL

INCONEL 600 MATERIAL:

Von-misses stress of Inconel 600 Material:

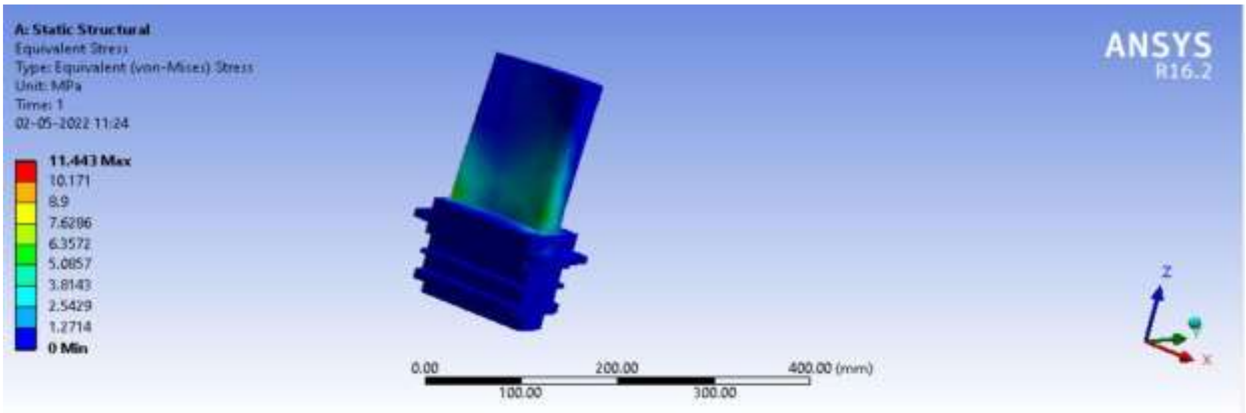


FIGURE12 VON-MISSES STRESS OF INCONEL 600 MATERIAL

Total deformation of Inconel 600 Material:

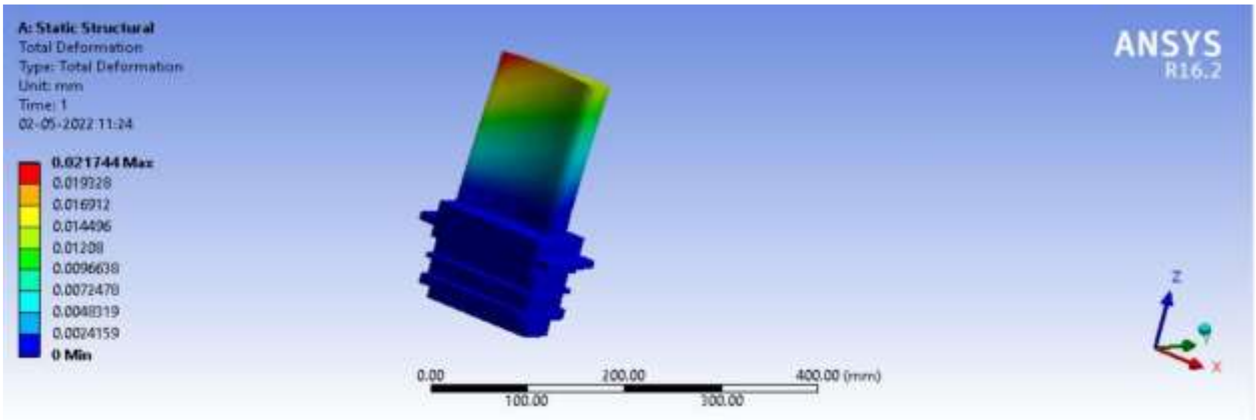


FIGURE 13 TOTAL DEFORMATION OF INCONEL 600 MATERIAL

shear stress of inconel 600 material:

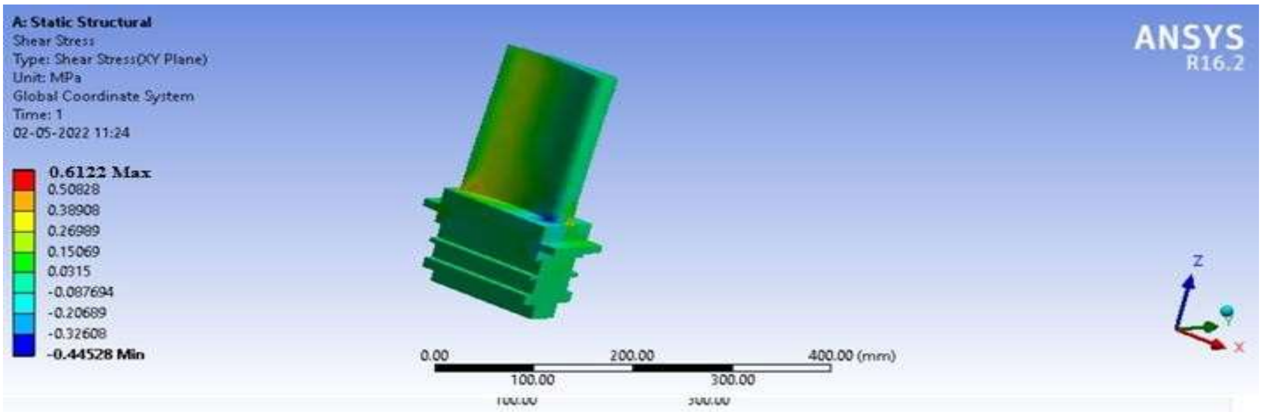


FIGURE14 SHEAR STRESS OF INCONEL 600 MATERIAL

Temperature distribution of Inconel 600 Material:

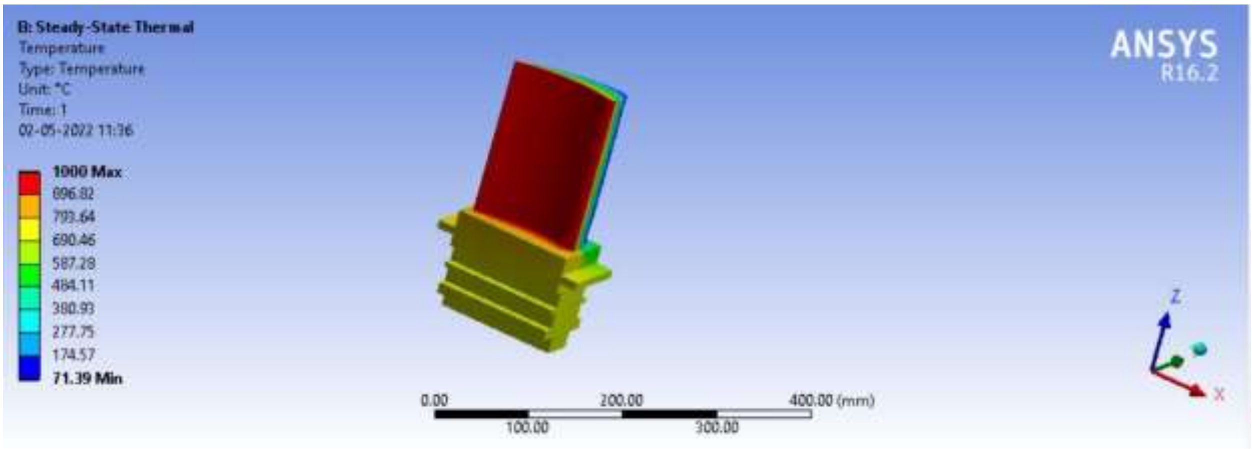


FIGURE 15 TEMPERATURE DISTRIBUTION OF INCONEL 600 MATERIAL

Total heat flux of Inconel 600 Material:

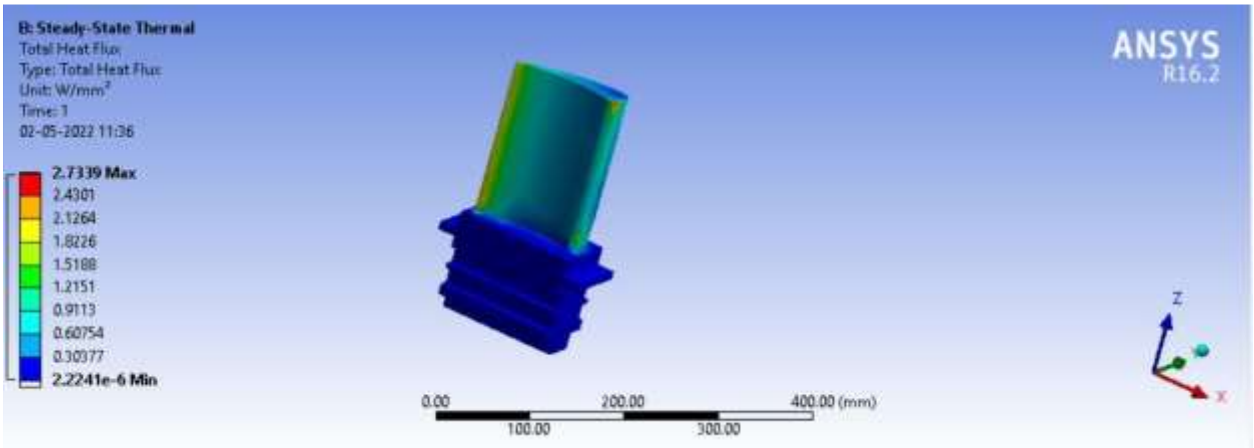


FIGURE 16 TOTAL HEAT FLUX OF INCONEL 600 MATERIAL

VON-MISSES STRESS GRAPH:

The below graph shows that Gas turbine blade Observed the Von-misses stresses using 3 different materials Nimonic 80A, Chrome steel, Inconel 600 like has least stress is Nimonic 80A(11.34 Mpa) material.

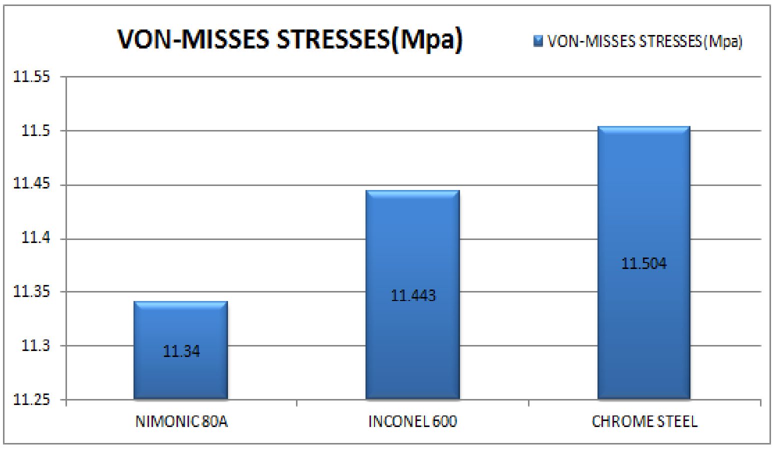


FIGURE 17 VON-MISSES STRESS GRAPH

TOTAL DEFORMATION GRAPH:

The below graph shows that Gas turbine blade Observed the Von Total deformation using 3 different materials Nimonic 80A, Chrome steel, Inconel 600 like has least Total deformation is Nimonic 80A(0.221mm) material.

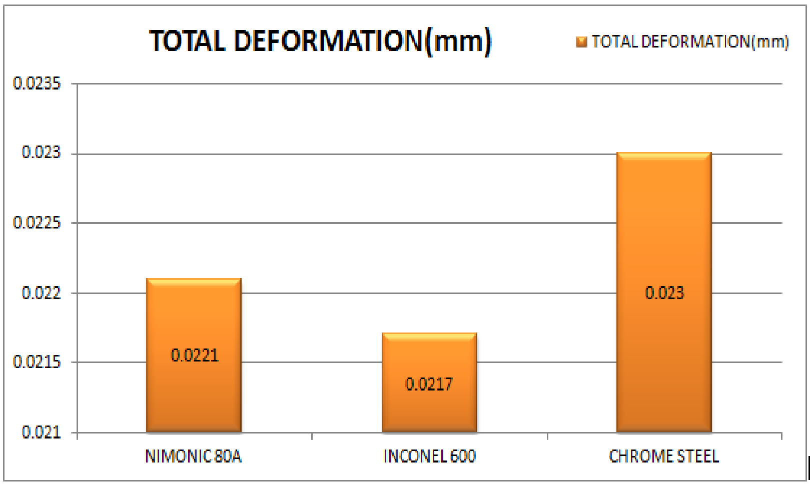


FIGURE 18 TOTAL DEFORMATION GRAPH

SHEAR STRESS GRAPH:

The below graph shows that Gas turbine blade Observed the shear stress using 3 different materials Nimonic 80A, Chrome steel, Inconel 600 compared to three materials observed has least shear stress is Nimonic 80A(0.601Mpa) material.

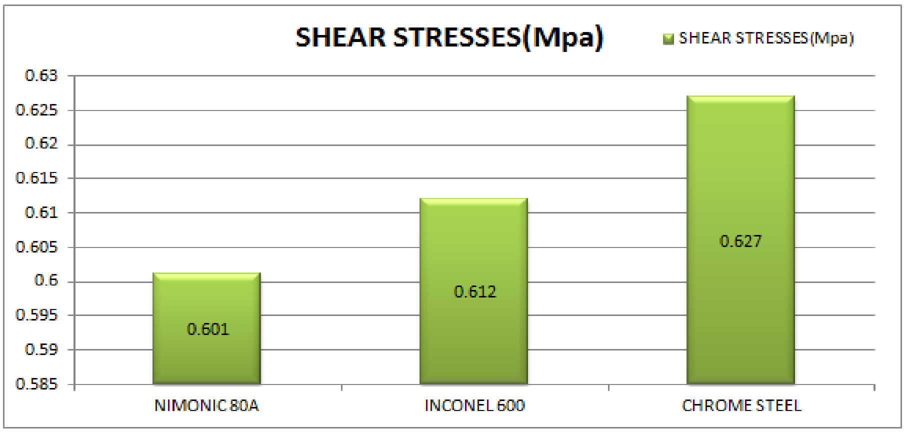


FIGURE 19 SHEAR STRESS GRAPH

TEMPERATURE DISTRIBUTION:

The below graph shows that Gas turbine blade Observed the Temperature distribution using 3 different materials Nimonic 80A, Chrome steel, Inconel 600 compared to three materials observed has least temperature distribution is Nimonic 80A (71.39) material.

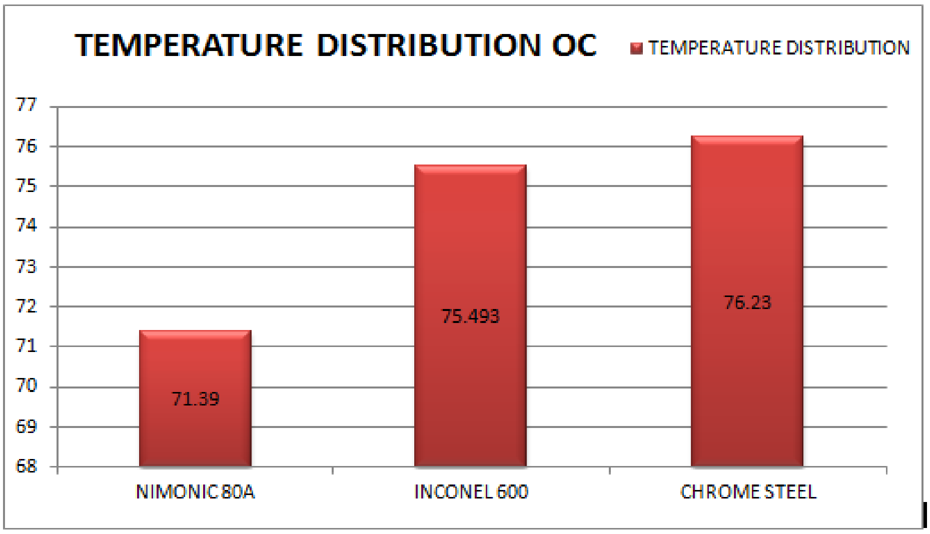


FIGURE 20 TEMPERATURE DISTRIBUTION

TOTAL HEAT FLUX:

The below graph shows that Gas turbine blade Observed the Total heat flux using 3 different materials Nimonic 80A, Chrome steel, Inconel 600 compared to three materials observed has highest Total heat flux is Nimonic 80A(4.73w/mm2) material.

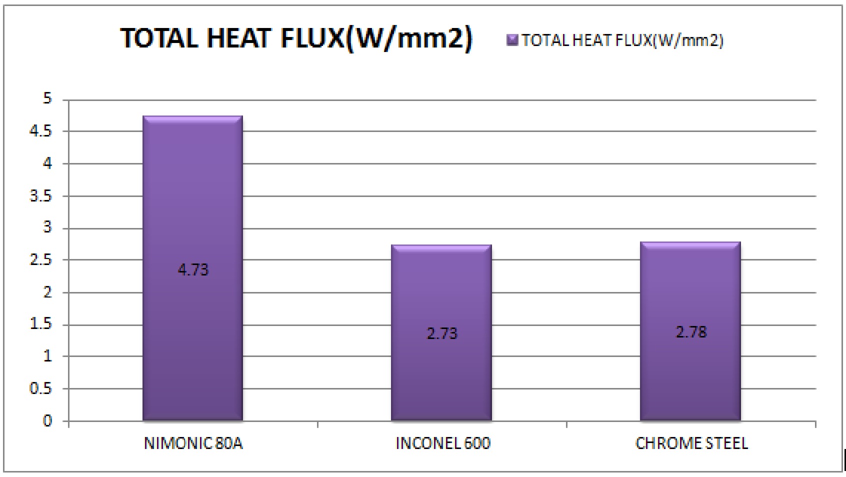


FIGURE 21 TOTAL HEAT FLUX

CONCLUSION

Design and static & Thermal analysis of gas turbine is done Generally gas turbine blade is a fluid flow machine that translates enthalpy of the operational agent, also preferred to as the thermodynamic agent (stream of exhaust gas) into mechanical work that effects in the turning round of the gas turbine rotor along with blade. The essential advantages of gas turbines contain possibility to develop more power at quite compact dimensions and less bare weight, quite high efficiency of the energy conversion procedure, simple design and high consistent of operation. In that time Improper material leads to the failure than in this project we choose the right material for the gas turbine blade. Modeling and analysis on gas turbine rotor blade is done. Modeling of turbine blade is done in catiav5. Then the file is saved as igs to import in Ansys software. The gas turbine blade model is imported to Ansys work bench software. steady thermal analysis is carried out on turbine blade by applying different materials such as chrome steel, Inconel 600, Nimonic 80A. Temperature distribution and heat flux values are noted. From the analysis results we noticed that the Nimonic 80A is showing efficient heat flux compared to remaining material. Thus, from the study we can conclude that Nimonic 80A is more preferable compared to remaining two materials.

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