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A TYPICAL OVERVIEW ON STATIC & THERMAL ANALYSIS OF GAS TURBINE IMPELLER

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Abstract: The individual component that makes up the turbine section of a gas turbine is the gas turbine blades. The main objective of this work is to investigate the thermal stress and thermal distribution over a turbine impeller. The static and thermal study of a gas turbine impeller is the main subject of this analytical research. The main framework includes the modelling and analysis of the impeller in CATIA V5 and ANSYS Workbench software (Static and Steady state thermal workspace standalone) packages respectively. To examine the turbine impeller at a specific pressure and temperature and determine various parameters such as Total Heat Flux, Equivalent Stress, Equivalent Elastic Strain, Total Deformation, and Maximum principal stress of gas turbine impeller and by varying different materials such as Titanium alloy (Ti-6Al-4V), INCONEL 617 alloy, NIMONIC 80 A and making an attempt to compare these materials and propose the best suitable material at sever conditions.

Key words: Gas turbine impeller, Materials (Titanium alloy (Ti-6Al-4V), INCONEL 617 alloy, NIMONIC 80A), Static and Thermal Properties.

1. INTRODUCTION:

A Turbine is a rotational mechanical device that transfers energy from a fast- moving flow of water, steam, gas, air, or other fluids into productive work. A turbine is a turbomachine having at least one moving component, the rotor assembly, which consists of a shaft or drum with blades attached. Moving fluids operate on the blades, causing them to contribute rotational energy to the rotor. The working fluid is air which is obtained from the atmosphere and compressed. The compressed air is heated as it passes through combustion chamber. The pressure and temperature of the air rises as the combustion chamber heats up. High pressure hot air is allowed to flow over the moving blades of turbine's rotating blades causing the turbine to whirl. The blade and components of rotary device are affected when it is subjected to high temperatures and pressure. As a result, materials used for manufacturing should be able to withstand extreme environment. [2]

2. MATERIAL CHARACTERISTICS & MODELLING:

Turbine generates continuous power for a variety of applications. Impeller is subjected to high loads and significant heat impacts, which are the primary reasons of failure. In terms of shear and young modulus, an appropriate material for turbine impeller should have good mechanical properties. Therefore, Materials must be tough and ductile. Gas turbine impeller traditionally been built of pure metals such as cast iron and steel. However, metal alloys and composites are being used to replace metals because of their high strength to weight ratio. In this study three different types of materials have been consider i.e, Titanium alloy (Ti-6Al-4V), INCONEL 617, NIMONIC 80A. [1]

2.1 MATERIAL CHARACTERISTICS:

2.1.1 TITANIUM ALLOY (Ti-6Al-4V): The tensile strength and toughness of alloys are extremely high. They are low in weight, have excellent corrosion resistance and can sustain high temperatures. Table1,[4]

2.1.2 INCONEL 617: INCONEL617 is a high-temperature alloy with outstanding oxidation resistance. In reducing and oxidizing circumstances, it has excellent resistance to pitting and crevice corrosion, as well as general corrosion. Carburization, spalling, and crevice corrosion are all prevented. Table1,[6]

2.1.3 NIMONIC 80A: Nickel and chromium are the main components of NIMONIC alloys. These alloys are well-known for their high performance and reduced creep at high temperatures. Aluminum, carbon, and titanium are injected into the alloy as additives. Alloy 80 A is a wrought nickel- chromium alloy that can be age-hardened. Table 1, [5]

Table 1: Mechanical properties of material

Properties	Titanium alloy (Ti-6Al-4V)	NIMONIC 80A	INCONEL 617
Density (Kg/m^3)	4620	8190	8300
Thermal conductivity(W/m.◦K)	21.9	11.2	13.6
Specific heat (J/kg.◦K)	533	448	419
Modulus of elasticity (G.Pa)	114	222	211
Poisson ratio	0.33	0.3	0.33

2.2 MODELLING:

The modelling of turbine impeller is entirely carried out in CATIA V5 software predominantly. Model is developed by using Boolean operations like trim, remove, intersect in part drawing with required dimensions. The base diameter of the impeller is 200 mm, height of shaft is 70 mm and diameter 10mm, no of blades of impeller is 8 with 1 mm thickness as shown in Figure 1. The developed catia model is imported in Ansys workbench. Analysis is done in static structural and steady state thermal analysis to find different parameters. Where different steps are involved to examine the analysis. First, meshing of model is takes place then boundary conditions are applied to the model as shown in Figure 2.

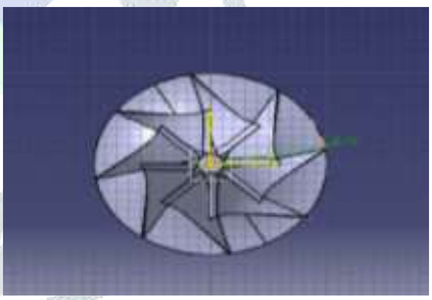

Figure 1: Catia model of turbine impeller

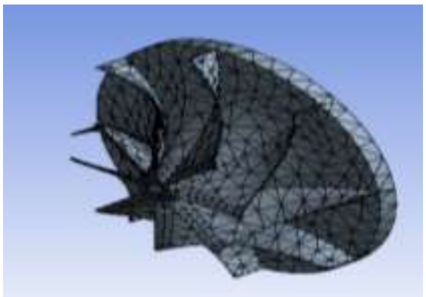

Figure 2: Meshing of the turbine impeller geometry

3. RESULTS AND DISCUSSIONS:

3.1 STATIC STRUCTURAL ANALYSIS:

First structural analaysis is performed on the impeller under the specified boundary conditions i.e,the shaft portion of the impeller is fixed and pressure is applied to the blades of the impeller.the maximum deformation and Equivalent elastic strain are calculated on the turbine impeller. The results for titanium alloy turbine impeller are shown in figure (3-6) For Titanium alloy (Ti-6Al-4V) turbine impeller, maximum deformation and equivalent elastic strain are 3.97mm and 10.59,respectively. Similarly,the results of maximum deformation and equivalent elastic strain for nimonic 80A and inconel 617 alloy are shown in figure (7-14) respectively.For nimonic 80 A, the maximum deformation and equivalent elastic strain are 3.25mm and 5.87,respectively.For inconel 617 alloy, the maximum deformation and equivalent elastic strain are 1.859 mm and 4.949,respectively.

Based on the results of the static structural analysis , three materials are compared for their respective deformation under the applied boundary conditions. The material showing the lower value of the maximum deformation will be more suitable material for impeller. From the obtained results,the decending order of the maximum deformation is as follow: titanium alloy (Ti-6Al-4V) > NIMONIC 80A > INCONEL 617 alloy. Hence, INCONEL 617 is the most suitable material from the static structural analysis of the three selected materials at that boundary conditions as shown in figure (15-18).

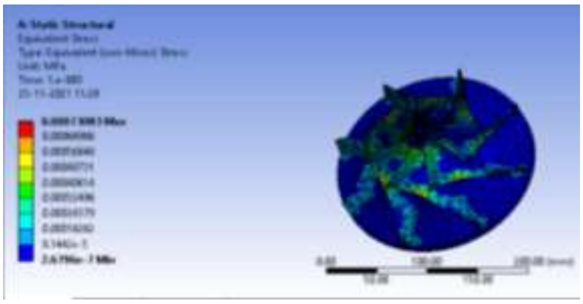

Figure 3:Equivalent stress of turbine impeller made of Titanium alloy (Ti-6Al-4V)

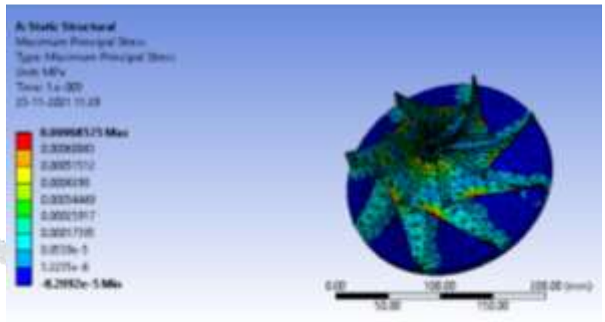

Figure 4: Maximum prinicipal stress of turbine impeller made of Titanium alloy (Ti-6Al-4V)

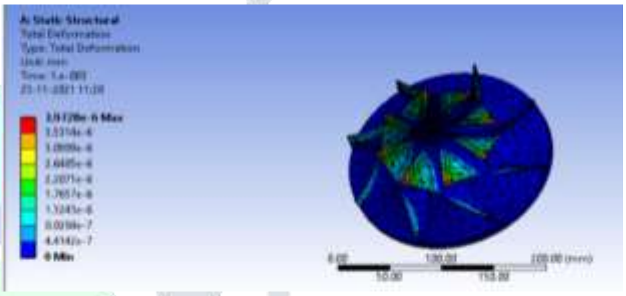

Figure 5: Total deformation of turbine impeller made of titanium alloy (Ti-6Al-4V)

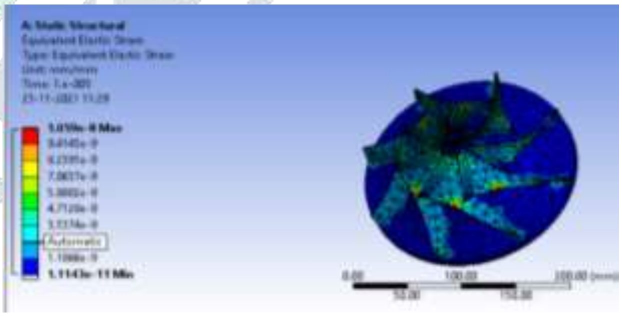

Figure 6: Equivalent elastic strain of turbine impeller made of Titanium alloy (Ti-6Al-4V)

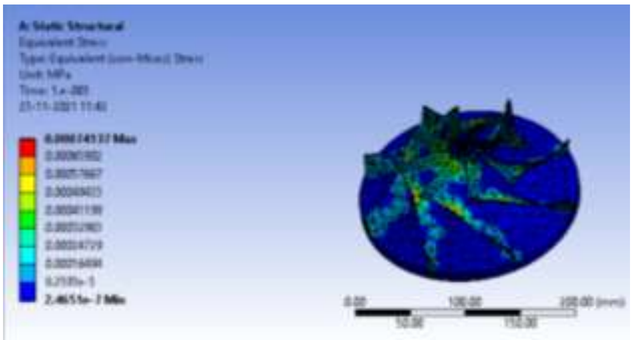

Figure 7: Equivalent stress of Turbine impeller made of INCONEL 617 alloy

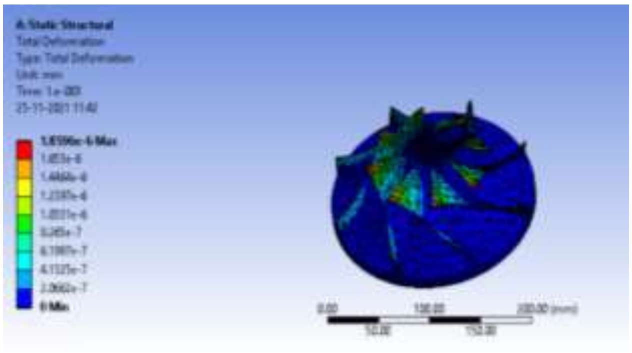

Figure 9: Total deformation of turbine impeller of INCONEL 617alloy

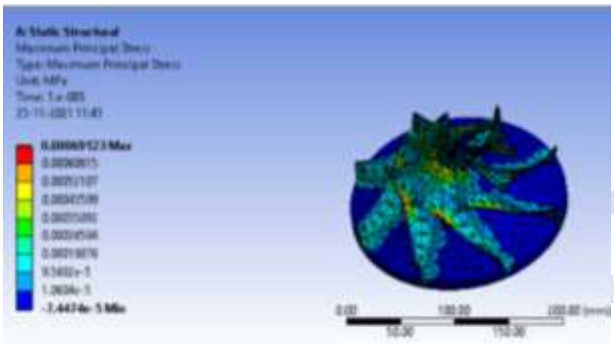

Figure 8: Maximum principal stress of Turbine impeller of INCONEL 617 alloy

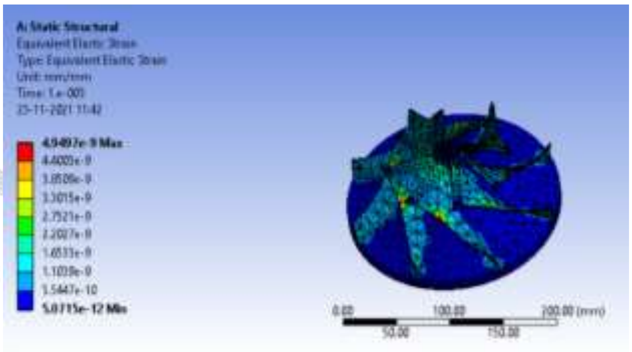

Figure 10: Equivalent elastic strain of turbine impeller of INCONEL 617alloy

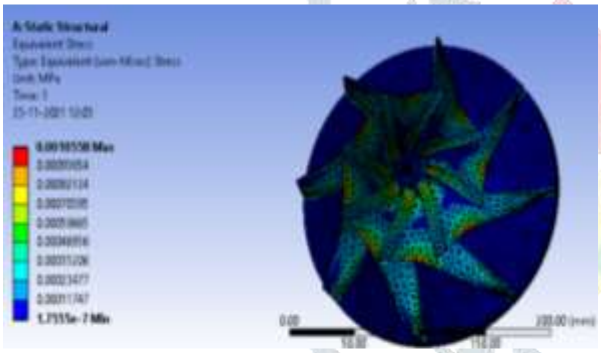

Figure11: Equivalent stress of turbine impeller made of NIMONIC 80A

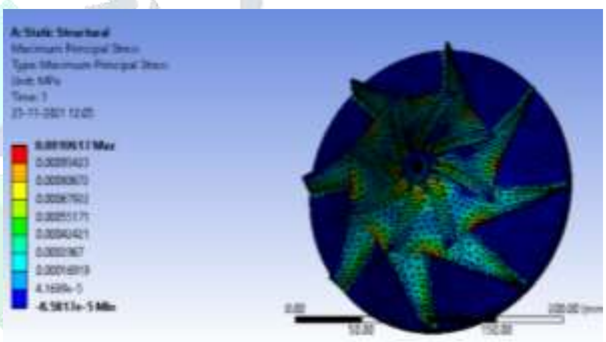

Figure 14: Maximum principal stress of turbine impeller made of NIMONIC 80 A

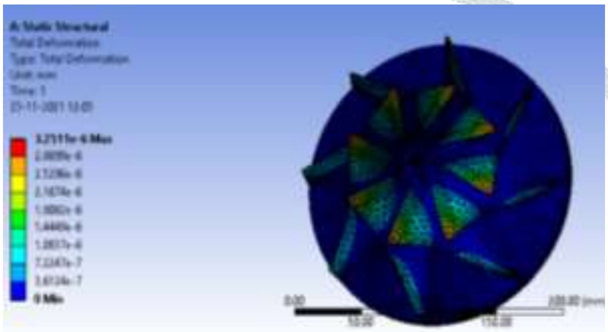

Figure 12: Total Deformation of turbine impeller made of NIMONIC 80A

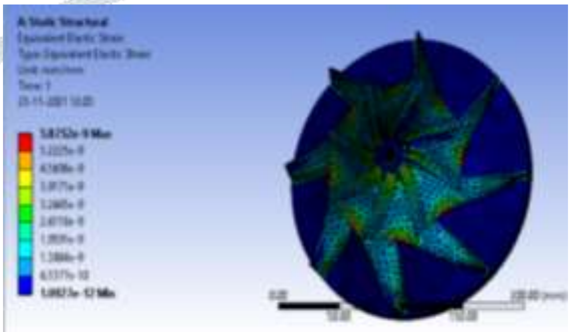

Figure13: Equivalent elastic strain of turbine impeller made of NIMONIC 80A

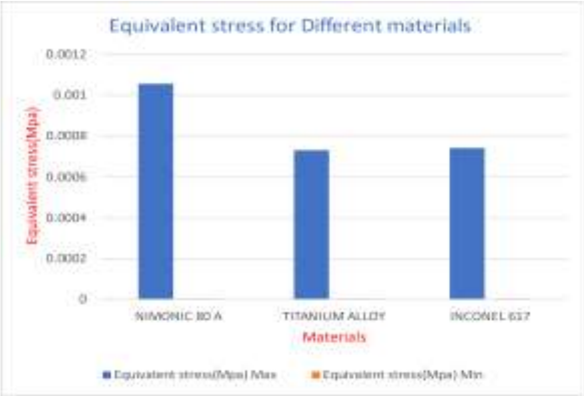

Figure15: Comparision graph of Equivalent Stress for different material

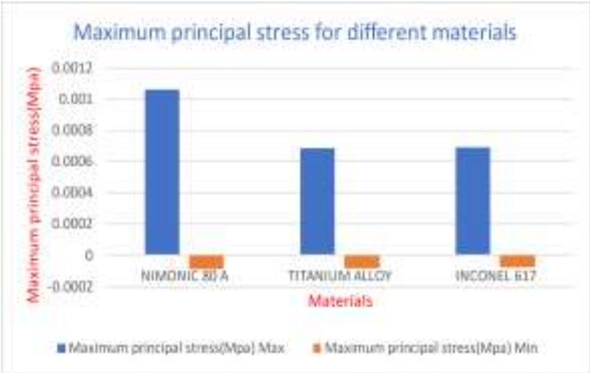

Figure16: Comparison graph of maximum principal stress for different material

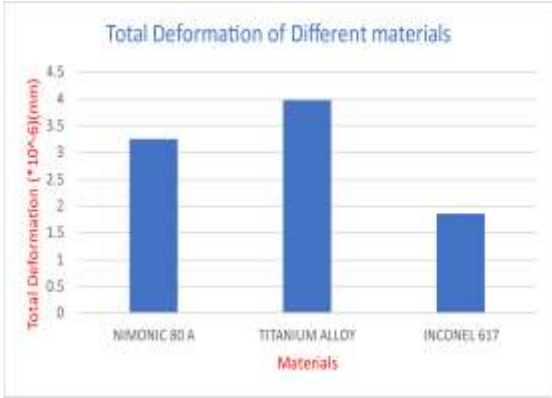

Figure 17: Total Deformation of different materials

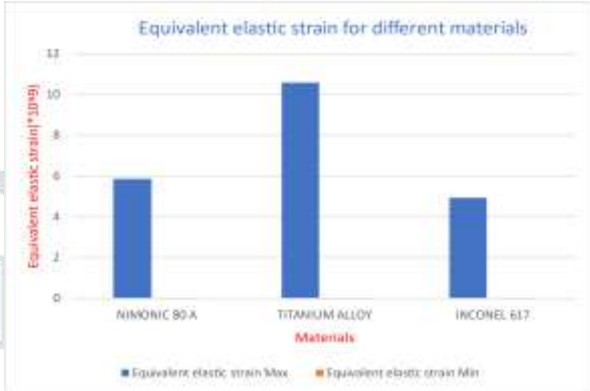

Figure18: Equivalent elastic strain for different materials

3.2 STEADY STATE THERMAL ANALYSIS:

For steady state thermal analysis is performed on the impeller at 700°Ci.e, the shaft portion of the impeller is fixed and intial temperature as 22°C. The total heat flux is calculated on the turbine impeller. The results for titanium alloy (Ti-6Al-4V) turbine impeller are shown in fig(19-20). for titanium alloy turbine impeller,total heat flux is 0.2542 W/mm^2. similarly, the results of total heat flux for nimonic 80A and inconel 617 are shown in figure (21-24) respectively. for nimonic 80 A,the total heat flux is 0.2516 W/mm^2 and the total heat flux for inconel 617 is 0.23102 W/mm^2.

Based on the results of the steady state thermal analysis, three materials are compared for their respective heat flux under the applied temperature 700 °Cand film coeffient 2.36 e^{-004}w/mm^2 °C.The material showing the lower value of heat flux will be more suitable material for impeller.from the obtained results the decending order of the heat flux is as follow: tianium alloy (Ti-6Al-4V) > NIMONIC 80A > INCONEL 617 alloy. Hence , INCONEL 617 alloy is the most suitable material from the steadt state thermal analysis of the three selected materials as shown in figure (25-26).

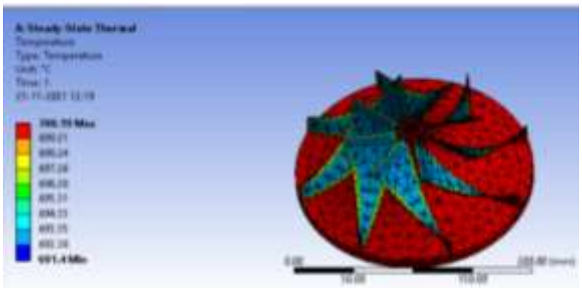

Figure 19: temperature of turbine impeller made of titanium alloy (Ti-6Al-4V)

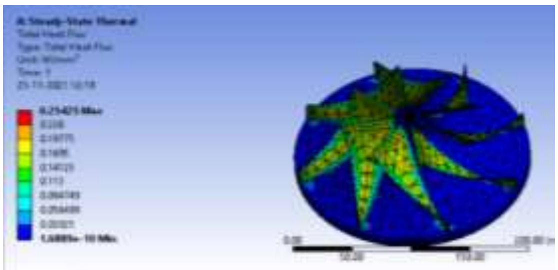

Figure 20:Total heat flux of turbine impeler made of titanium alloy (Ti-6Al-4V)

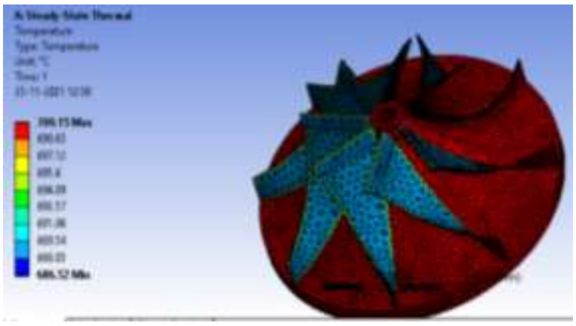

Figure 21: Temperature of turbine impeller made of INCONEL617 alloy

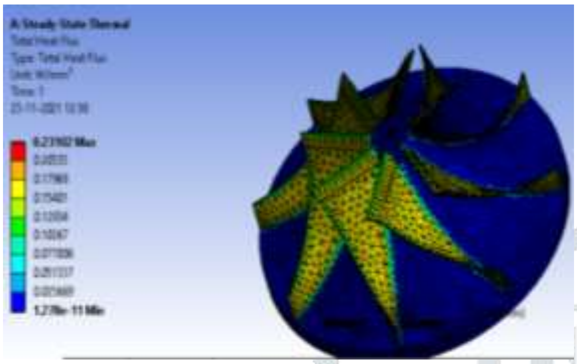

Figure 22: Total heat flux of turbine impeller made of INCONEL 617 alloy

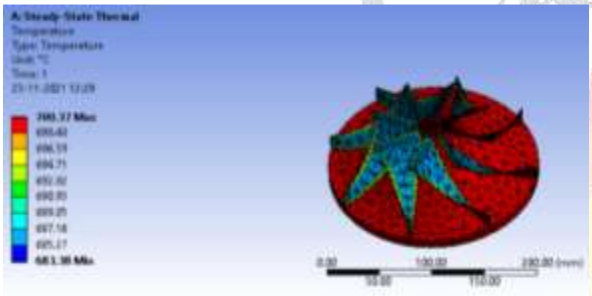

Figure 23: Temperature of turbine impeller made of NIMONIC 80A

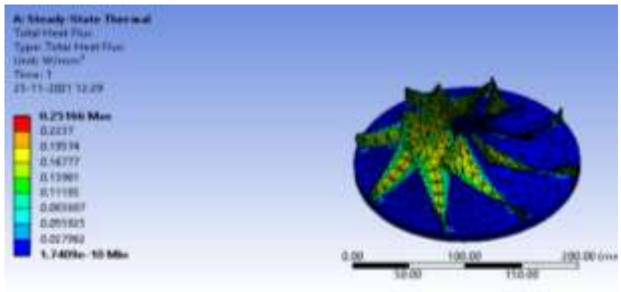

Figure 24: Total heat flux of turbine impeller made of NIMONIC 80 A.

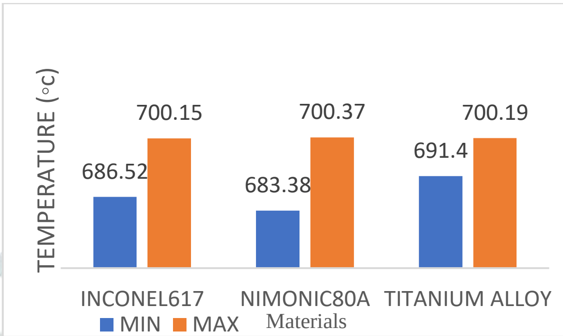

Figure 25: Comparision graph of temperature for three materials

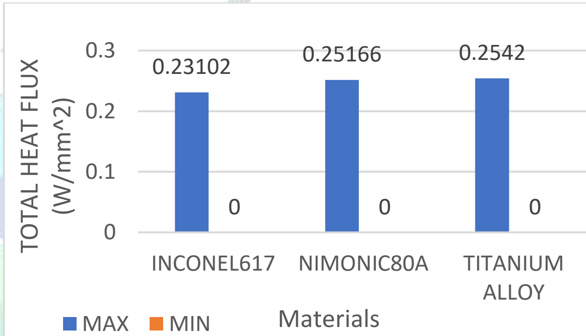

Figure 26:Comaprision gragh of heat flux for three materials

4. CONCULSION:

In this paper the static structural analysis and steady state thermal analysis is done with three materials i.e, titanium alloy (Ti-6Al-4V), INCONEL 617 alloy and NIMONIC 80A ,the following conclusions are drawn. Comparing the deformation and strain values with three materials ,INCONEL 617 showed less deformation.When compared with heat flux values inconel showed less compared to others.Turbine impeller model designed with INCONEL 617 alloy provides better life and more effiency compared to the titanium alloy (Ti-6Al-4V) and NIMONIC 80A.

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