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DESIGN AND ANALYSIS OF RADIAL FLOW TURBO CHARGER TURBINE USING DIFFERENT MATERIALS

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ABSTRACT:- *A turbocharger is a mechanical device which is driven by exhaust gases and it increases engine power by pumping compressed air into the combustion chambers. The main parts of the turbocharger are turbine and central housing assembly. This present work is aimed to analyze the Static and thermal conditions of radial flow turbocharger turbine wheel for three different materials. A single blade in the turbine wheel has been considered for analysis. Finally find out strength based on static conditions (stress, strain, deformation, shear stress). In thermal point of view temperature distribution and total heat flux is calculated the heat flux values are predicted by performing numerical analysis for Inconel 740, Inconel 625 and Incoloy 909 materials finally concluded the suitable material on these three materials. Turbine blade of 170 mm length is also predicted to have the maximum heat flux.*

Keywords— *Turbocharger turbine, radial flow, static and thermal analysis, material modification.*

INTRODUCTION

1.1INTRODUCTION

A turbocharger is a turbine driven forced action device, which issued to allow more power has been produced by an engine of a given size. Turbocharger engines have more efficient than a naturally aspirated engine due to the turbine forces more fuel into the combustion chamber. The conventional supercharger is mechanically driven from the engine, frequently from a belt connected to the crankshaft. The turbocharger is powered by a turbine that is driven by the engine's exhaust gas. Twin charger refers to an engine which is both a supercharger and a turbo charger. Turbo is commonly used on truck, car, train, aircraft, and construction equipment engines. Turbo are popularly used with diesel cycle internal combustion engines. It is also found useful in automotive fuel cells. It is used extensively in modern diesel engines and also to improve fuel economy and minimize emissions. It comprises a turbine wheel, housing, compressor wheel, housing, and a central cast bearing housing between the wheels. It drives a compressor to compress the engine combustion airis greater than the rate the engine can naturally aspirate. The pressure output of the turbocharger is a function of component efficiency, mass flow through the turbine and compressor. One problem that occurs with turbochargers is that acceleration of an engine from relatively low rpm is accompanied by a noticeable delay in the pressure increase from the turbocharger resulting in a noticeable delay in acceleration of vehicle due to the reason is that the inlet area of the turbine is designed for maximum rated conditions. The velocity of the gases passing through the turbine wheel at low engine rpm allow the turbocharger rpm to drop low level substantial increase in gas velocity is required to increase the turbocharger rpm. It is to overcome this efficiency of schemes has been proposed to provide the turbo charger with a variable inlet area at low engine rpm. The area can be increase the velocity of the exhaust gases, which is maintaining the turbocharger at a sufficiently high rpm to minimize delay.

CHAPTER 2 LITERATURE REVIEW

kamlesh bachkar et al[1] conducted static and thermal analysis of turbine blade of turbocharger. the analysis was done using inconel 718 and the effect of induced stresses on turbine blade was investigated.z.

mazur et al [2] presented a failure analysis of a 70 mw gas turbine first stage blade of inconel nickel-base alloy 738lc material. a detailed analysis of all elements which had an influence on the failure initiation was carried out.

kishore ajjarapu et al [3]performed design and analysis of the impeller of a turbocharger for a diesel engine. finite element model of the blade was generated by meshing using the solid brick element in the ansys 11.0 software and thereby applying the boundary condition.

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alessandro romagnoli et al [4] performed experimental and computational heat transfer analysis in a turbocharger turbine. steady state thermal & structural performance of the blade for n 155, haste alloy x was examined. from the above literature review, it is understood that most of the research works have been concentrated on thermal stress concentration of the turbine blade. the rotor unbalancing causes high thermal stresses on the turbine blade reducing the efficiency. this present work aims to modify the blade geometry and increasing the thermal efficiency of turbine

[5]V.R.S.M. Ajjarapu Kishore1, K.V.P.P. Chandu, D.M. Mohanthy Babu, et.al, “Design and analysis of the impeller of a turbocharger”. In this study turbochargers are a class of turbo machinery intended to increase the power of internal Combustion engines. For Compressor the minimum vonmises stress (32.981 MPA) is obtained for the material incolol alloy 909 and the maximum frequency (482.61 HZ) is obtained for the material incolol alloy 909. For Turbine the minimum vonmises stress (171.01 MPA) is obtained for the material in conel alloy 740 and in the frequency comparing to the compressor maximum frequency (482.61 HZ) for incolol alloy 909.

[6] S.N. Al-Zubaidyet and et.al, “A proposed design package for centrifugal impellers”. A scheme for the laptop Aided layout and manufacture of radial impellers is described. beginning with a one-dimensional calculation, the foremost dimensions (for given overall performance necessities) are optimized the usage of a suitable optimization algorithm. Then, employing a direct design system, the exact geometry of the impeller is hooked up. these geometrical facts are then processed as input facts to a host of separate programs which take a look at the go with the flow distribution characteristics, blade stress and vibration. interaction among fashion designer and layout package changed into stored to minimum. The final output can be received inside the shape of tabulated statistics for direct manufacturing via N.C. machine.

[7] Gunter, E. G. and Chen, W. J, “Dynamic analysis of a Turbocharger in Floating Bushing Bearings”. Because of this, their research have been based on the output overall performance of the turbochargers with recognition on the thermodynamics of the manner. Even though rotor dynamic analysis is now an crucial a part of the design procedure, a thorough rotor dynamic research become then very hard and comparatively few research were posted. via 1938, the first turbocharged car engine was manufactured through “Swiss gadget Works Saurer”.

[8] Holmes, R., Brennan, M. J. and Gottrand, B, Vibration of an automotive turbo charger”. turbo chargers are a class of rapid equipment supposed to boom the electricity of internal Combustion engines. this is achieved through increasing the stress of intake air, permitting greater gas to be combusted. inside the overdue 19th century, Rudolf Diesel and Gottlieb Daimler experimented with precompressing air to increase the energy output and fuel efficiency. the first exhaust gasoline turbocharger become finished in 1925 by means of the Swiss engineer Alfred Buchi who introduced a prototype to boom the strength of a diesel engine by way of a suggested forty%. The concept of rapid charging at that point turned into now not widely usual. however, inside the last few decades, it has come to be vital in nearly all diesel engines aside from very small diesel engines.

[9] V. Ramamurti, D.A. Subramani, K. Sridhara and et.al, “Analysis and Determination of Eigen pairs of a typical turbocharger compressor”. In this study of analysis and determination of Eigen pairs of a typical turbocharger compressor impeller have been carried out using the concept of cyclic symmetry. A simplified model treating the blade and the hub as isolated members has also been attempted. The limitations of the simplified model have been brought out. The results of the finite element model using the cyclic symmetric approach have been discussed.

CHAPTER 3 OVER VIEW OF PROJECT

3.1 OBJECTIVES OF STUDY:

[1] To check strength of turbo charger turbine blade by static analysis using various material like INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY 625

[2] To reduce weight of turbine by using different material.

[3] To determine static and thermal analysis of INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY 652

[4] Observe the stresses ,shear stress, strain, deformations, temperature distribution, heat flux.

[5] Finally conclude the suitable material for turbo charger turbine blade.

3.2. Methodology

Step 1: Collecting information and data related to turbo charger turbine

Step 2: A fully parametric model of the turbine is created in catia software.

Step 3: Model obtained in igs. analyzed using ANSYS 14.5(workbench), to obtain stresses ,shear stress, strain, deformations, temperature distribution, heat flux.

Step 4: Taking boundary conditons.

Step 5: Finally, we compare the results obtained from ANSYS and compared with different materials.

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3.3 MATERIAL PROPERTIES:

Properties	Materials		
	Incoloy alloy 909	*Inconel alloy 740*	*Inconel alloy 625*
Tensile strength(MPa)	1034.21	1209	940
Yield strength(MPa)	861.84	818.4	1030
Density(kg/m^3)	8193.25	8050	8400
Poisson ratio	0.29	0.29	0.3
Modulus of elasticity(GPa)	230	158	150
Thermal conductivity(W/mK)	14.8	9.8	10.2
Specific heat capacity (J/g-C)	0.427	0.449	0.410
Coefficient of thermal expansion α (/°C)	16.6 x10^{-6}	16.8x10^{-6}	15 x 10^{-6}

Table 1 Material properties

3.4 LOAD CALCULATION:
$F = M \times Vm$
M= Air flowing through turbine
Vm=velocity m/s
M=1000kg/hr
Vm=1310m/s
F=362.87N
Blade area=23319.1mm^2
Pressure =F/A
P=0.01556N/mm^2

3.5 TURBOCHARGER TURBINE BLADE DIMENSION :

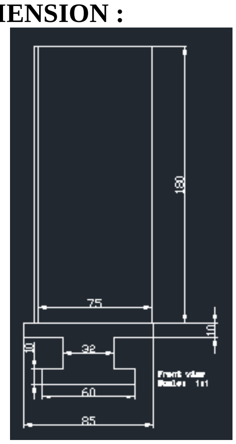

Figure 1 Dimensions of turbine

3.6 PRESENT WORK:
The objectives of the present work are depicted below: To predict the heat flux distribution of turbine blade numerically by varying the geometrical parameters and materials.
• To calculate the turbine thermal efficiency.
To accomplish the above objectives, the working conditions and specifications of turbocharger are studied. A single blade of the turbocharger turbine is modeled. The length and angle of the blade is varied and thermal analysis is performed in ANSYS. The values of heat flux are predicted. To calculate the thermal efficiency of the turbine (equation.1), the working conditions of the turbine is considered as constant value except the heat flux value. The heat flux value values are predicted in ANSYS and the same is used for calculating the turbine efficiency. As a result of analysis the heat flux value is increased and correspondingly the turbine efficiency ρ

$$\rho_{turbine} = \frac{(T_{in} - T_{out}) + (Q/m\,c_p)}{T_{in}\,(1 - VR^{(1-k)/k})} \quad (1)$$

$\rho_{turbine}$	=	Efficiency of turbine	
T_{in}	=	Temperature Inlet	= 1100 ° C
T_{out}	=	Temperature outlet	= 950 ° C
Q	=	Heat flux (analysis)	
m	=	mass flow rate	= 0.7 [6]
c_p	=	Constant specific heat	= 1.005 kJ/kg.K
VR	=	Velocity ratio	= 0.75 [6]
k	=	Ratio of specific heats	= 1.4

4. DESIGN PROCEDURE IN CATIA:

Go to the sketcher workbench create profile blade shape by using arcs Blade angle at inlet β1 = 45° Blade angle at outlet β2 = 22° after go to the part design workbench apply fpad Length of the blade L = 180 mm pad as shown below figure

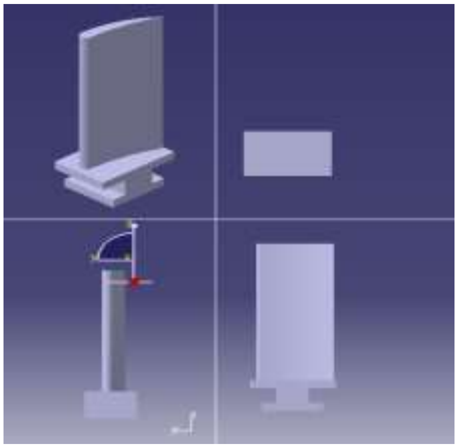

Figure 2TURBINE BLADE MULTI VIEWS IN CATIA

5 ANALYSIS PROCEDURE IN ANSYS:

Designed component in CATIA V5 workbench after imported into ANSYS workbench now select the steady state thermal ANALYSIS.

1. ENGINEEERING MATERIALS (MATERIAL PROPERTIES).
2. CREATE OR IM3d4PORT GEOMENTRY.
3. MODEL (APPLY MESHING).
4. SET UP (BOUNDARY CONDITIONS).
5. SOLUTION.
6. RESULT.

6.1 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:

6.2 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.

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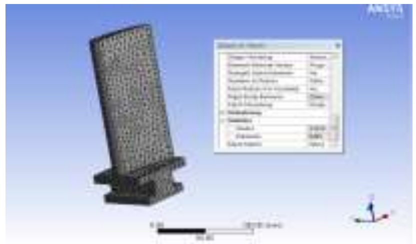

Figure 3MESH: NODES: 12225,ELEMENTS:6493

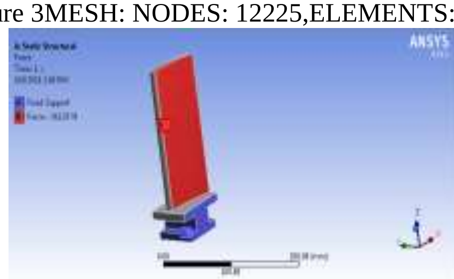

Figure 4BOUNDARY CONDITIONS IN STATIC ANALYSIS

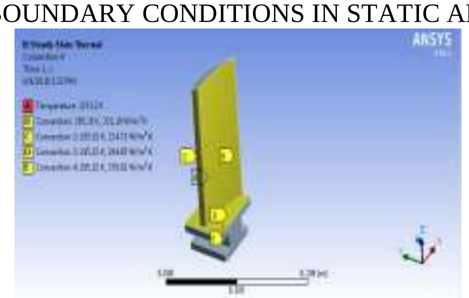

Figure 5BOUNDARY CONDITIONS IN THERMAL ANALYSIS

CHAPTER 7 RESULT AND DISCUSSION

Here the stresses, total deformations, strain, shear stress, temperature distribution total heat flux are obtained by analyzing the turbocharger turbine by using different materials **INCONEL 909, INCONEL 625, INCONEL 740** material, as shown in below figures.

7.1STATIC ANALYSIS:

7.1.1INCONEL 909 MATERIALS:

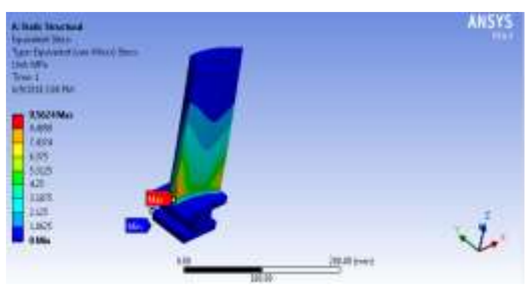

Figure 6VON-MISES STRESS OF INCONEL 909 MATERIAL

Figure 7 TOTAL DEFORMATION OF INCONEL 909 MATERIAL

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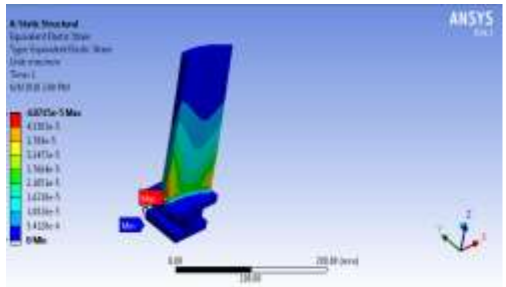

Figure 8 STRAIN OF INCONEL 909 MATERIAL

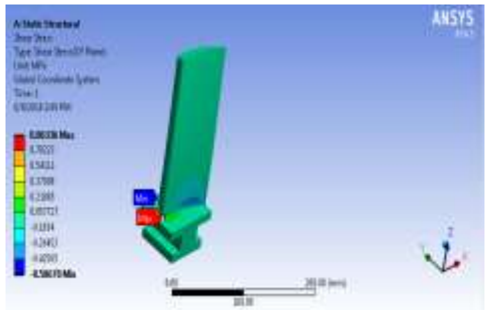

Figure 9SHEAR STRESS OF INCONEL 909 MATERIAL

7.1.2INCONEL 625 MATERIALS:

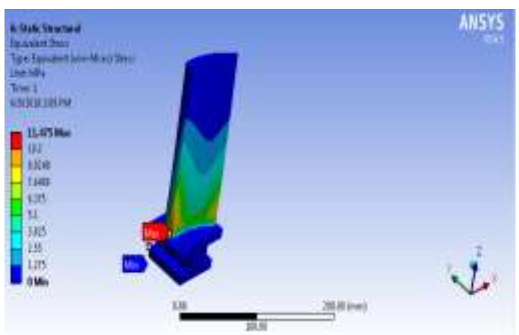

Figure 10VON-MISES STRESS OF INCONEL 625 MATERIAL

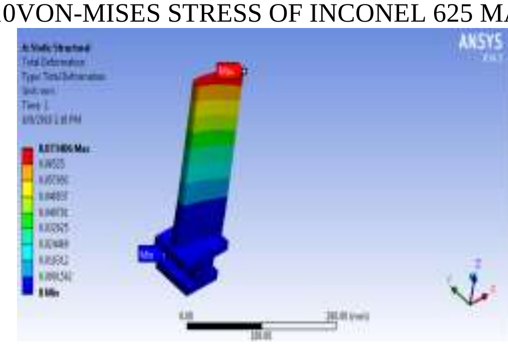

Figure 11TOTAL DEFORMATION OF INCONEL 625 MATERIALS

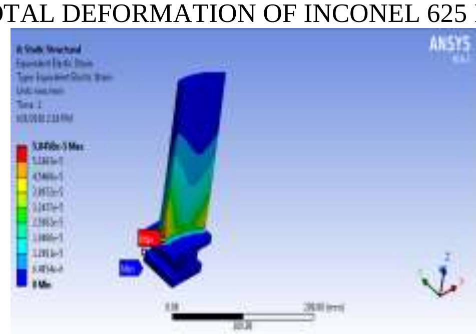

Figure 12STRAIN OF INCONEL 625 MATERIAL

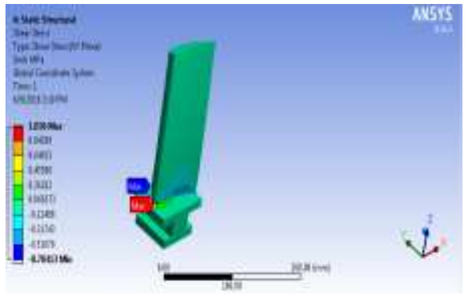

Figure 13SHEAR STRESS OF INCONEL 625

7.1.3INCONEL 740 MATERIAL:

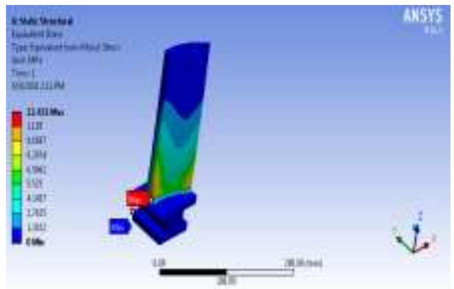

Figure 14VON-MISES STRESS OF INCONEL 740

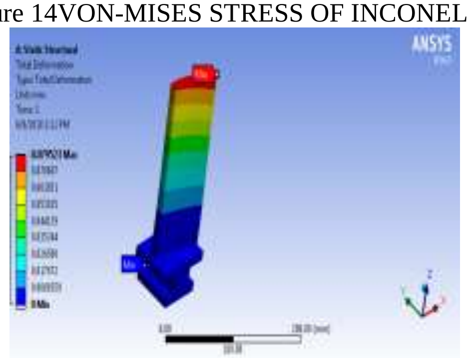

Figure 15TOTAL DEFORMATION OF INCONEL 740

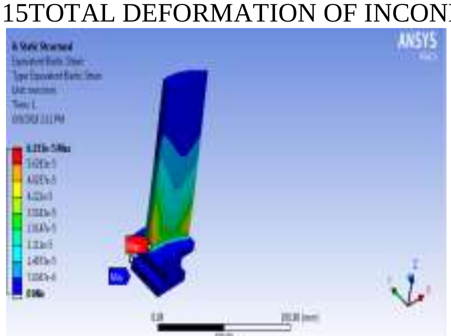

Figure 2STRAIN OF INCONEL 740

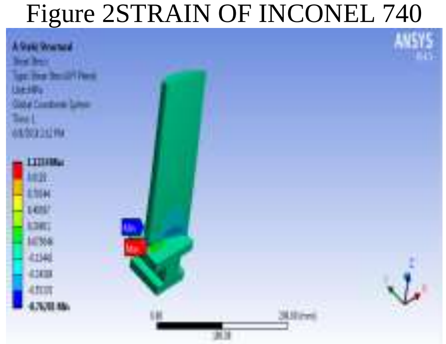

Figure 17SHEAR STRESS OF INCONEL 740

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7.2THERMAL ANALYSIS:

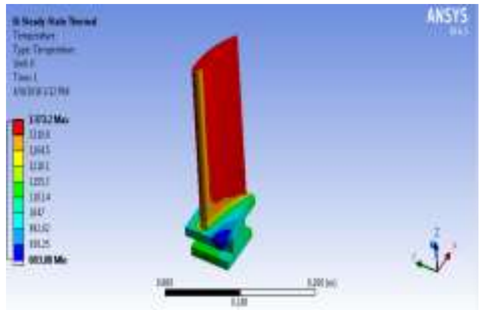

Figure 18]TEMPERATURE DISTRIBUTION OF INCONEL 909

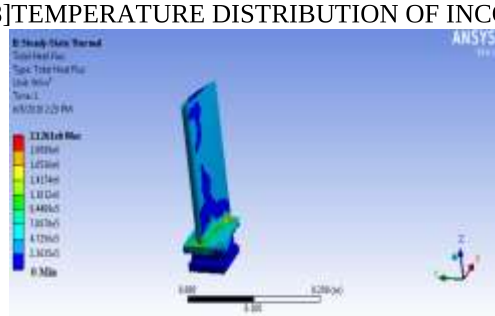

Figure 19TOTAL HEATFLUX OF INCONEL 909

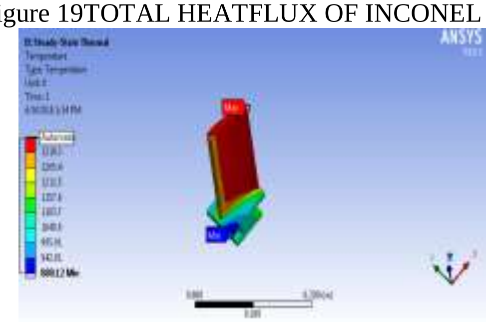

Figure 20TEMPERATURE DISTRIBUTION OF INCONEL 625

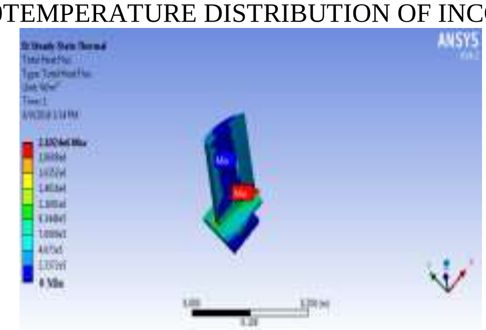

Figure 21TOTAL HEATFLUX OF INCONEL 625

TEMPERATURE DISTRIBUTION OF INCONEL 740:

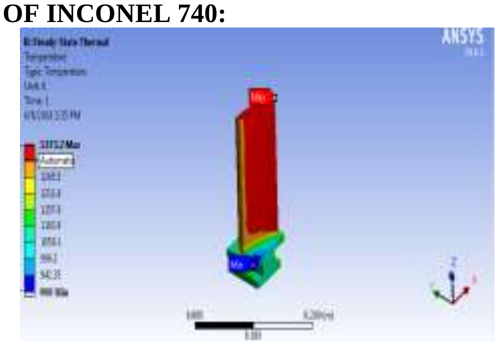

Figure 22TEMPERATURE DISTRIBUTION OF INCONEL 740

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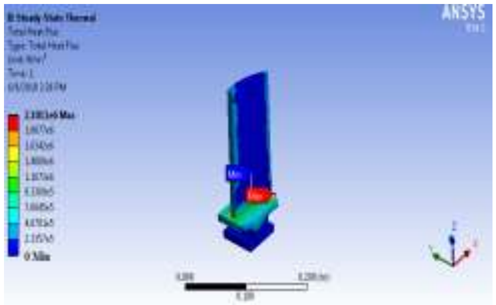

Figure 23TOTAL HEATFLUX OF INCONEL 740

7.3 GRAPHS:

7.3.1GRAPH BETWEEN VON-MISES STRESSES:

This graph shows the different stress values in different materials, INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY 625 materials finally INCOLOY ALLOY 909 have least stress value compared to another two materials as shown below graph

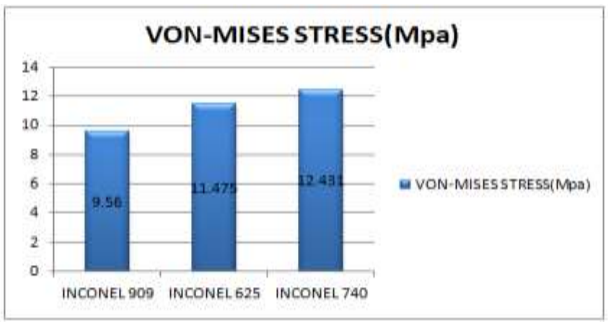

Figure 24VON-MISES GRAPH

7.3.2GRAPH BETWEEN SHEAR STRESSES :

This graph shows the different shear stress values in different materials, INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY 625 materials finally INCOLOY ALLOY 909 have least shear stress value compared to another two materials as shown below graph

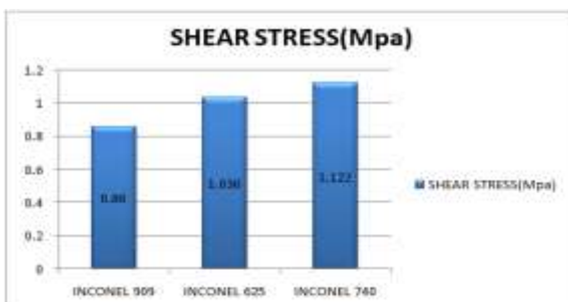

Figure 25SHEAR STRESS GRAPH

7.3.3GRAPH BETWEEN TOTAL DEFORMATION :

This graph shows the different Total deformation values in different materials, INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY 625 materials finally INCOLOY ALLOY 909 have least Total deformation value compared to another two materials as shown below graph

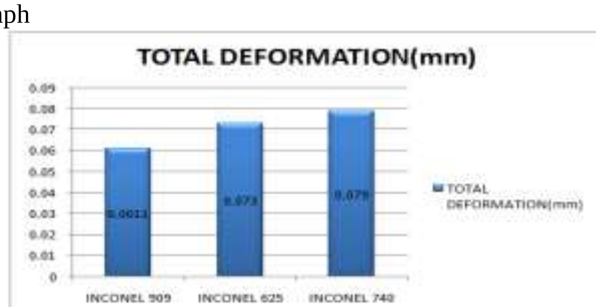

Figure 26TOTAL DEFORMATION GRAPH

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7.3.4GRAPH BETWEEN STRAIN :

This graph shows the different Strain values in different materials, INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY 625 materials finally INCOLOY ALLOY 909 have least strain value compared to another two materials as shown below graph

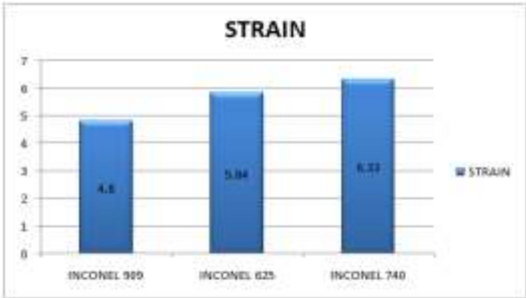

Figure 27STRAIN GRAPH

7.3.5 GRAPH BETWEEN TEMPERATURE DISTRIBUTION :

This graph shows the different Temperature distribution values in different materials, INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY 625 materials , finally INCOLOY ALLOY 909 have reached early compared to another two materials as shown below graph

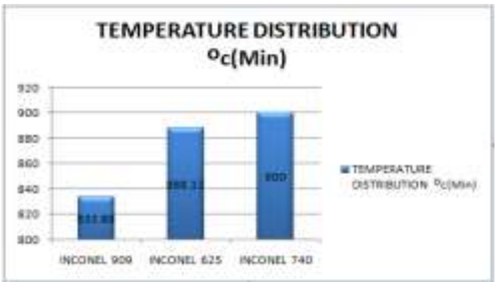

Figure 28TEMPERATURE DISTRIBUTION GRAPH

7.3.6 GRAPH BETWEEN TOTAL HEAT FLUX :

This graph shows the different Total heatflux values in different materials, INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY 625 materials finally INCOLOY ALLOY 909 have better heat transfer compared to another two materials as shown below graph

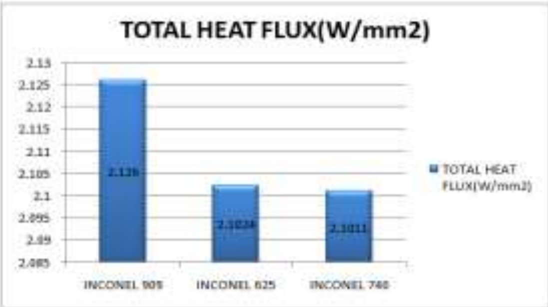

Figure 3TOTAL HEATFLUX GRAPH

CHAPTER 8 CONCLUSION

Modeling and simulation of turbocharger turbine Blade has done by using catia software. After observing the static analysis and thermal analysis values we can conclude that inconel 909 better stress capacity compared with the other materials and its showing better strength values when loads are applied, static analysis and thermal analysis of turbocharger turbine blade it is clear that, the von-mises Stress,shear stress,strain, deformations, temperature distribution,Total heat flux are induced in inconel 740, inconel alloy 909, inconel alloy 625. materials compared to other materials. If we compare material Inconel 909 material above result finally concluded because of tailor-made coefficient of thermal expansion, high thermal conductivity, light weight and strong, precision surface treatment, cost effective production. less values compared to remaining materials as suitable material For turbocharger turbine impeller and manufacturing the turbocharger turbine impeller we can proceed inconel 909 material because it has high stress bearing capacity and reasonable manufacturing cost.

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