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MODELLING AND GEOMETRICAL OPTIMIZATION OF TURBO CHARGER COMPRESSOR USING DIFFERENT MATERIALS

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ABSTRACT:
The automotive industry uses turbochargers because they may boost an internal combustion engine's output without requiring the engine's cylinder capacity to be increased. turbocharger to increase the amount of air compressed into the engine's cylinder. The oxygen molecules in compressed air are crammed closer together. For a normally aspirated engine of the same size, more fuel may be injected due to the increase in air. in order to enhance the engine's pressure by the use of traditional turbocharger compressors. By using a mechanical mechanism of this kind, the car manufacturing industry may implement "engine downsizing," or the use of reduced displacement engines. The project's goal is to use Ansys software for static and modal analysis and Catia v5 for simulating a turbo charger compressor wheel. Ultimately, use these materials to determine the Von-misses stresses, total deformations, shear stress, and strain in both static and dynamic analysis. INCOLOY A-286, INCOLOY 740, AND INCOLOY ALLOY 909. Determine the Frequencies at various total deformation levels. To increase the compressor's performance, I propose changing the compressor's design.

Keywords: horsepower, turbocharger, ANSYS, Catia, Ansys

I.INTRODUCTION

An internal combustion engine's intake air pressure may be increased with the use of a turbocharger, which is made up of an exhaust gas turbine wheel and compressor wheel connected by a solid shaft. In order to power the compressor and reduce friction, the exhaust gas turbine absorbs energy from the exhaust gas. The compressor and turbine wheel in the majority of automotive-type applications are radial flow types. In some situations, an axial flow turbine wheel may be used in place of a radial flow turbine, such as medium- and low-speed diesel engines.

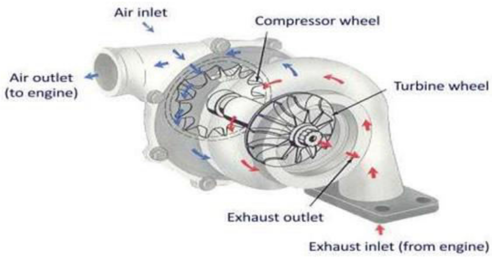

Figure: Turbocharger Construction and Flow of Gases

Turbo Charger Operating Principle:

In naturally aspirated piston engines, intake gases are drawn or "pushed" into the engine by atmospheric pressure filling the volumetric void caused by the downward stroke of the piston (which creates a low-pressure area), similar to drawing liquid using a syringe. The amount of air actually inspired, compared with the theoretical amount if the engine could maintain atmospheric pressure, is called volumetric efficiency. The objective of a turbocharger is to improve an engine's volumetric efficiency by increasing density of the intake gas (usually air) allowing more power per engine cycle. The turbocharger's compressor draws in ambient air and compresses it before it enters into the intake manifold at increased pressure. This results in a greater mass of air entering the cylinders on each intake stroke. The power needed to spin the centrifugal compressor is derived from the kinetic energy of the engine's exhaust gases. In automotive applications, 'boost' refers to the amount by which intake manifold pressure exceeds atmospheric pressure. This is representative of the extra air pressure that is achieved over what would be achieved without the forced induction. The level of boost may be shown on a pressure gauge, usually in bar, psi or possibly Kpa. The control of turbocharger boost has changed dramatically over the 100-plus years of their use. Modern turbochargers can use waste gates, blow-off valves and variable geometry, as discussed in later sections. To check strength of turbocharger Compressor creating the geometry using Catia software with and 6 blades and 5 blades after static analysis and Modal analysis using various material like INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY A-286.

Objectives:

- To Increase the strength of Compressor by using different materials
- To determine static analysis of INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY A-286
- To determine the modal analysis and find out the Total deformation at different frequencies.
- Finally conclude the suitable design and material for Compressor

II.LITERATURE REVIEW

D. Ramesh Kumar, B. Shanmugasundaram, P. Mohanraj et, al., [2017] in this work the author used different material for the turbine and compressor impeller and investigation has been done by ANSYS and CATIA software. The variation of stresses, strains, and deformation profile of the turbine and compressor impeller has been determined by using the ANSYS software. The authors are used different analysis, to investigate stresses, strains and displacements of the turbine used structural analysis, to investigate the frequency and deflection of the turbine and compressor impeller used modal analysis, to investigate total heat flux and direction heat flux used thermal analysis

Shujie Liu, Chi Liu, Yawei Hu, SIbo Gao, Yifan Wang, Hongchao Zhang et, al., [2016] studied about the fatigue life assessment of centrifugal compressor impeller has a critical issue in the industrial practise as well as automotive application. In this study, both centrifugal load and aerodynamic load have beern considered in the analysis of the impeller life using finite element analysis (FEA). The impeller working under an alternating cycle load and a dynamic load caused by the centrifugal loads, aerodynamic loads, exciting loads, etc

CH. Satyasai Manikanta, S.D.V.V.S.B. Reddy, A. Sirishabhadrakali et, al., [2016] presents structural analysis of the turbocharger impeller by using different material under different static and dynamic condition to obtaining the stress values and strain values and deformation range. In this study the authors consider design for 30000 rpm of the impeller. The design has mainly focused to reduce the blade size according to the requirements and geometrical modelling is used when designing this impeller of turbocharger.

M.F. Moreira et, al., [2016] studied about the aluminium compressor wheel used in the turbocharged diesel engine which are made with machined AA2618 T652 alloy and installed in light truck engines. The premature failure of the wheels happened after life between 40000 km and 300000 km, while the expected life was about 1000000 km. The nine different impeller or compressor wheels were submitted to chemical analysis, microstructural characterization, X-ray diffraction, hardness testing and fractographic examinations.

B.P. Terani, Dr. K.S. Badarinarayan, Prakasha.A. Met, al., [2015] stated that turbocharger is very essential to incorporate in diesel engine. Turbocharger will feed compressed air to engine which produce more power and torque than natural aspirated engine, this process to obtained more power from engine is called engine downsizing. This study is to analyses impellers structural, modal and thermal stability with various boundary conditions and blade parameters Impeller wheel has to with stand high exhaust gas temperature and stress induced force and external pressure.

III.METHODOLOGY

Step 1: Collecting information and data related to turbocharger Compressor turbine

Step 2: A fully parametric model of the Compressor is created in Catia software.

Step 3: Model obtained in is. analyzed using ANSYS 14.5(workbench), to obtain stresses, deformation, strain, Shear stress and modal analysis at different frequencies etc.

Step 4: Taking boundary conditions static and Modal

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

Dynamic Testing: If possible, conduct a road test to observe the turbocharger's performance under real-world conditions. Pay attention to throttle response, acceleration, and boost pressure during acceleration By systematically examining these aspects of the turbocharger compressor, you can identify potential problems and determine the necessary steps for repair or replacement. If you're uncertain about any findings or need further assistance, consulting with a qualified mechanic or turbocharger specialist is advisable

Figure: Failures of Compressor

Table: Material Properties

S. NO	MATERIAL	Density (Kg/m^3)	Poisson's ratio (μ)	Youngs modulus (Mpa)	Ultimate Tensile strength (Mpa)
1	Inconel 740	8190	0.29	200000	950
2	Inconel 909	8140	0.28	220000	900
3	Inconel A286	7940	0.29	200000	930

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Design Procedure In CATIA:

Catia is a computer graphics system for modelling various mechanical designs and for performing related design and manufacturing operations

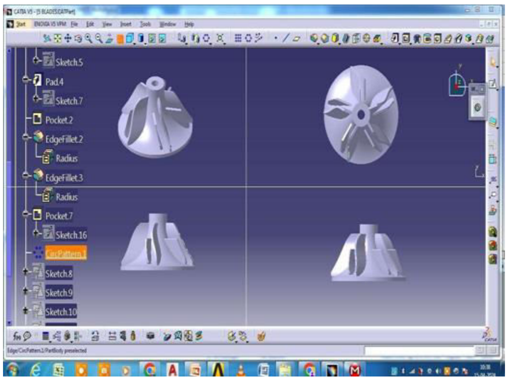


Figure: Turbocharger Compressor 5 Blades

. The system uses a 3D solid modelling system as the core, and applies the feature-based, parametric modelling method. In short, Catia Parametric is a feature-based, parametric solid modelling system with many extended design and manufacturing application

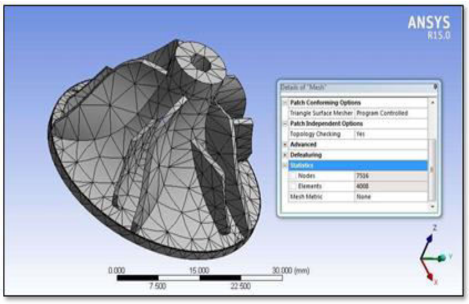


Figure: Mesh Of 5 Blades Nodes: 7516, Elements:4008

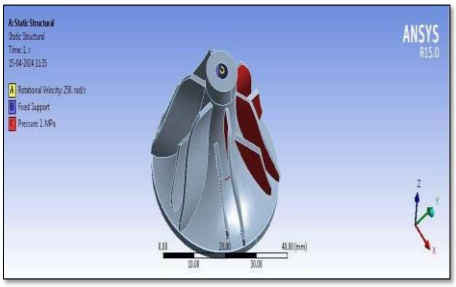


Figure: Boundary Condition At 6 Blades: Pressure 2mpa, Rotational Velocity 250rad/S

The above figure consists of 6 blades and having a rotational velocity of 250m/s and it is a fixed support and having a pressure of 2 Mpa

IV.RESULTS AND DISCUSSIONS

Design and analysis is done using with various designs 5 blades and 6 blades with different materials. Here find out the stresses, total deformations, strain, shear stresses obtained by analyzing the turbocharger compressor by using different materials Inconel 909, Inconel 740, Inconel alloy A 286 material as shown in below figures.

Inconel Material 740:

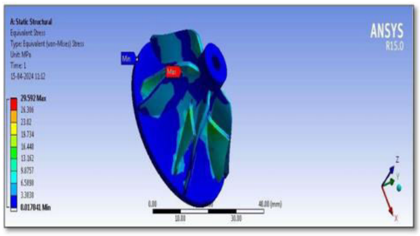


Figure: Von-Misses Stress of Inconel Material

The above figure tells us about the Von-misses stress of Inconel material 740 having a max strength of 29.592 and a min strength of 0.017840. Equivalent Stresses have been calculated by using the ANSYS software.

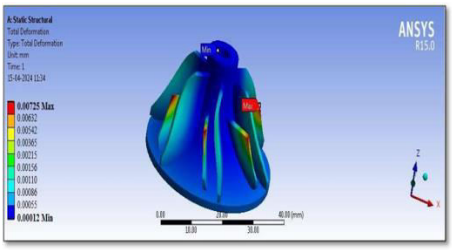


Figure: Total Deformation of Inconel Material

The above figure tells us about the Total Deformation of Inconel material 740 having a max strength of 0.00725 and a min strength of 0.00012. Total Deformation have been calculated by using the ANSYS software

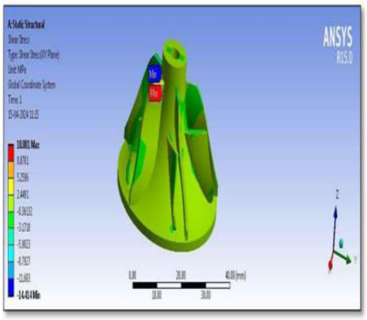


Figure: Shear Stress of Inconel Material

The above figure tells us about the Shear stress of Inconel material 740 having a max strength of 10.881 and a min strength of -14.414. Shear Stress have been calculated by using the ANSYS software

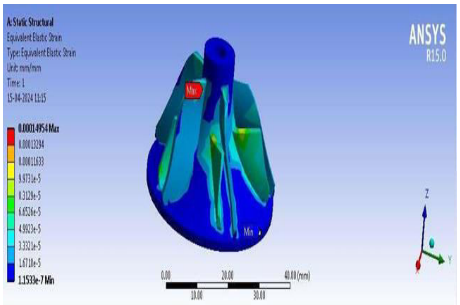


Figure: Strain of Inconel Material

The above figure tells us about the Strain of Inconel material 740 having a max strength of 0.0001495 and a min strength of 1.1533e-7. Strain have been calculated by using the ANSYS software

INCONEL ALLOY 909 MATERIAL:

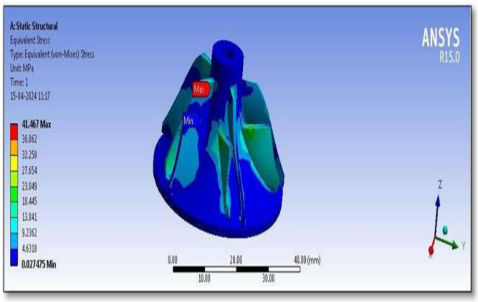


Figure: Von-Misses Stress of Inconel Alloy 909 Material

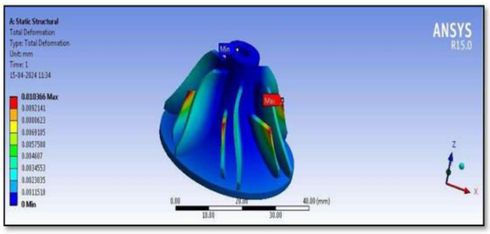


Figure: Total Deformation of Inconel Alloy 909 Material

The above figure tells us about the Total Deformation of Inconel Alloy 909 Material having a max strength of 0.010366 and a min strength of 0. Total Deformation have been calculated by using the ANSYS software

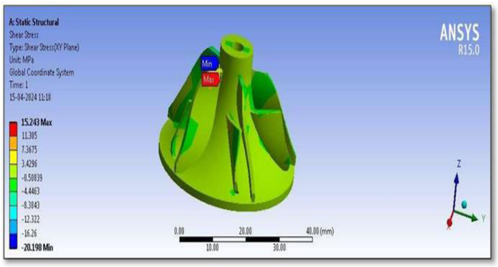
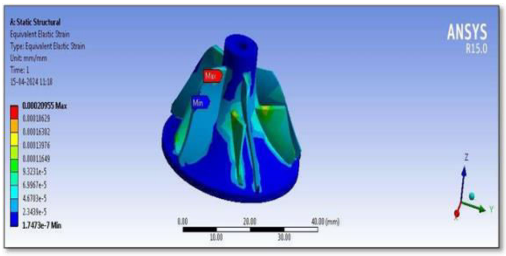


Figure: Shear Stress of Inconel Alloy 909 Material

The above figure tells us about the Shear Stress of Inconel Alloy 909 Material having a max strength of 15.243 and a min strength of -20.198. Shear Stress have been calculated by using the ANSYS software



INCONEL ALLOY A 286 MATERIAL:

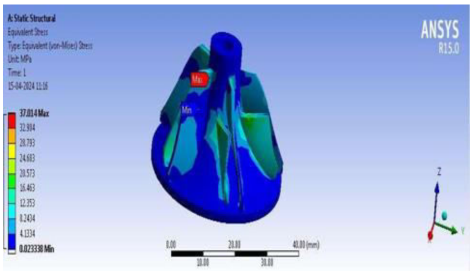


Figure 21 Von-Misses Stress of Inconel Alloy A 286 Material

The above figure tells us about the Von-Misses of Inconel Alloy 286 Material having a max strength of 37.014 and a min strength of 0.023338. Von-Misses have been calculated by using the ANSYS software

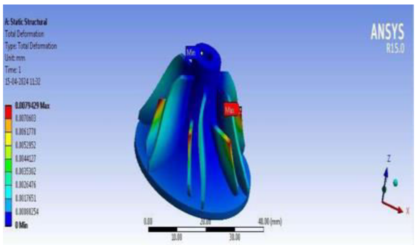


Figure: Total Deformation of Inconel Alloy A 286 Material

The above figure tells us about the Total Deformation of Inconel Alloy 286 Material having a max strength of 0.0079429 and a min strength of 0.00088254. Total Deformation have been calculated by using the ANSYS software.

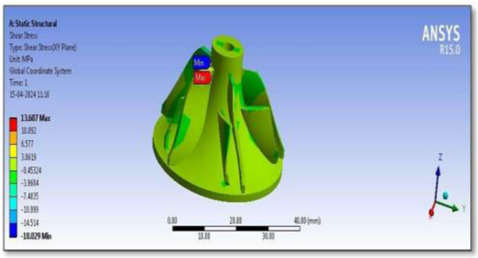


Figure: Shear Stress of Inconel Alloy A 286 Material

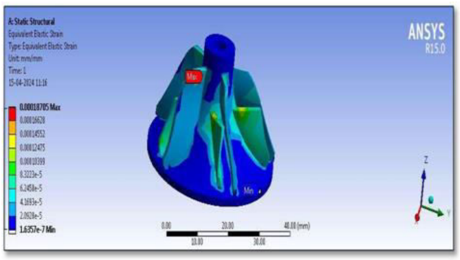


Figure: Strain of Inconel Alloy A 286 Material

The above figure tells us about the Strain of Inconel Alloy 286 Material having a max strength of 0.00018705 and a min strength of 1.6357e-7. Strain have been calculated by using the ANSYS software.

6 BLADES COMPRESSOR:

Inconel Material 740:

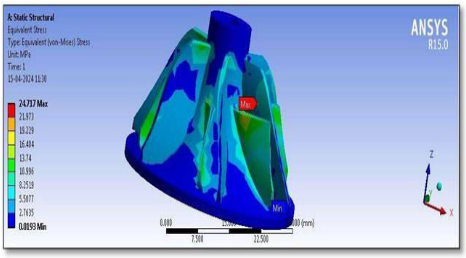


Figure: Von-Misses Stress of Inconel Material

The above figure tells us about the Von-Misses of Inconel Alloy 740 Material having a max strength of 24.717 and a min strength of 0.0193. Von-Misses have been calculated by using the ANSYS software.

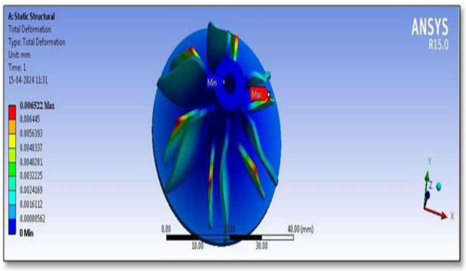


Figure: Total Deformation of Inconel Material

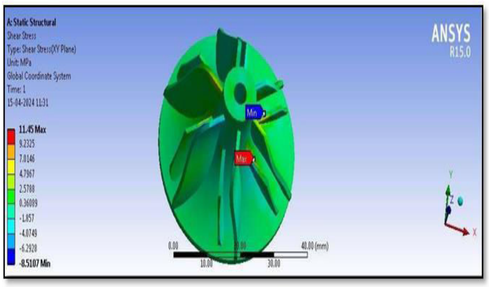


Figure: Shear Stress of Inconel Material

The above figure tells us about the Shear Stress of Inconel Alloy 740 Material having a max strength of 11.45 and a min strength of -8.5107. Shear Stress have been calculated by using the ANSYS software

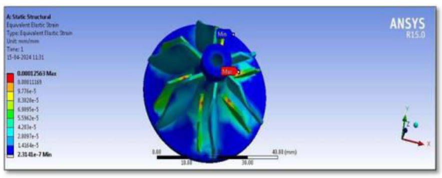


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Figure: Strain of Inconel Material

The above figure tells us about the Strain of Inconel Alloy 740 Material having a max strength of 0.00012563 and a min strength of 2.3141e-7. Strain have been calculated by using the ANSYS software

INCONEL ALLOY 909 MATERIAL:

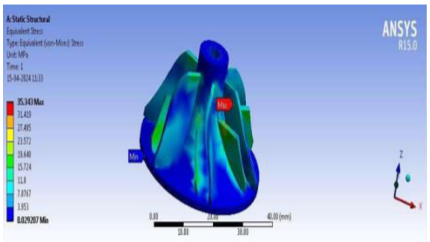

Figure: Von-Misses Stress of Inconel Alloy 909 Material

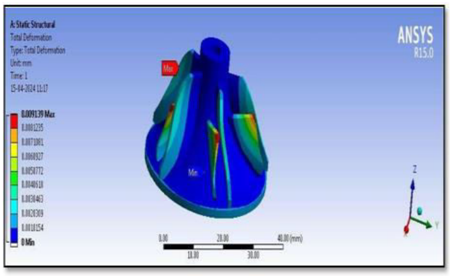

Figure: Total Deformation of Inconel Alloy 909 Material

The above figure tells us about the Total Deformation of Inconel Alloy 909 Material having a max strength of 0.009139 and a min strength of 0. Total Deformation have been calculated by using the ANSYS software

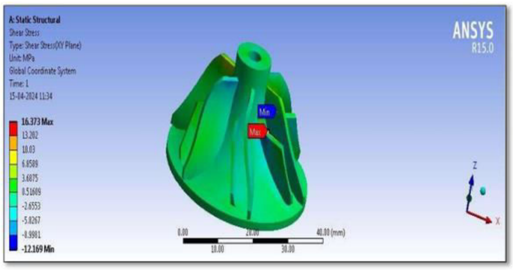

Figure: Shear Stress of Inconel Alloy 909 Material

The above figure tells us about the Shear Stress of Inconel Alloy 909 Material having a max strength of 16.373 and a min strength of -12.169. Shear Stress have been calculated by using the ANSYS software.

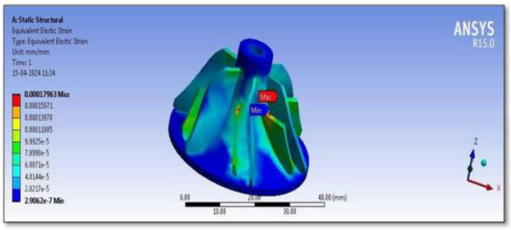

Figure: Strain of Inconel Alloy 909 Material

The below graph shows that with Variation of stresses two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286 Finally least von-mises stress is Inconel 740 material 6 Blades design have 24.717 Mpa

INCONEL ALLOY A 286 MATERIAL:

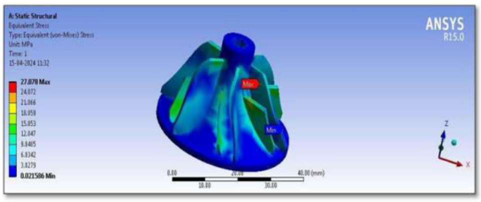

Figure: stress

The above figure tells us about the Von-Misses of Inconel Alloy 286 Material having a max strength of 27.078 and a min strength of 0.021586. Von-Misses have been calculated by using the ANSYS software

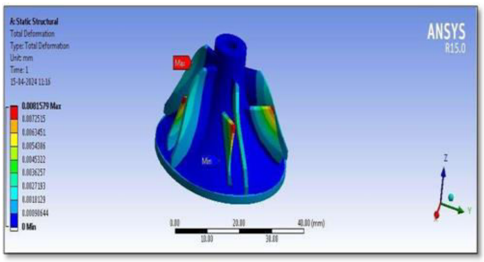

Figure: Total Deformation of Inconel Alloy A 286 Material

The above figure tells us about the Total Deformation of Inconel Alloy 286 Material having a max strength of

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0.0081579 and a min strength of 0. Total Deformation have been calculated by using the ANSYS software.

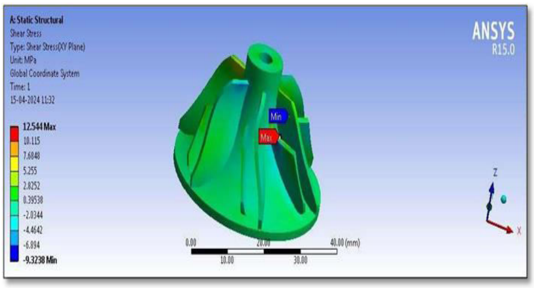


Figure: Shear Stress of Inconel Alloy A 286 Material

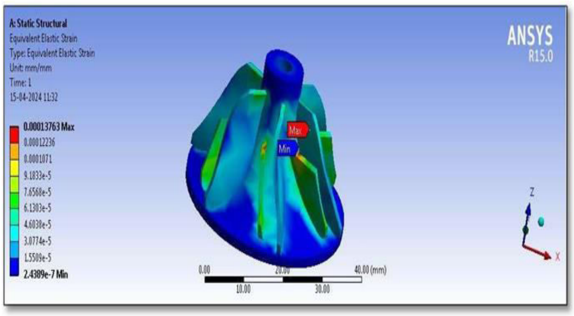
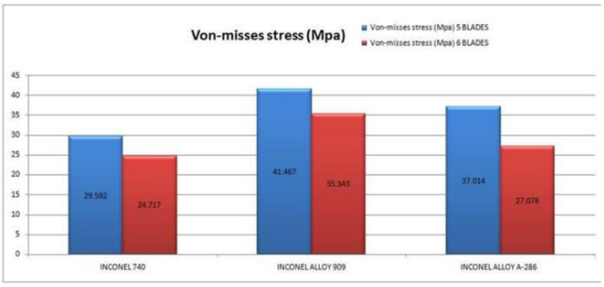


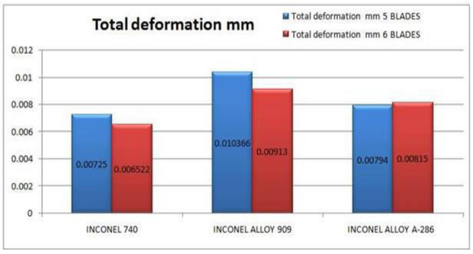
Figure: Strain of Inconel Alloy A 286 Material

The above figure tells us about the Strain of Inconel Alloy 286 Material having a max strength of 0.00013763 and a min strength of 2.4389e-7. Strain have been calculated by using the ANSYS software



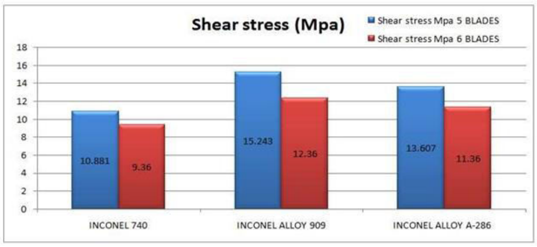
Graph:1 Von-Misses Stress

The below graph shows that with Variation of Total deformation two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally, least Total deformation is Inconel 740 material 6 Blades design have 0.0065mm.



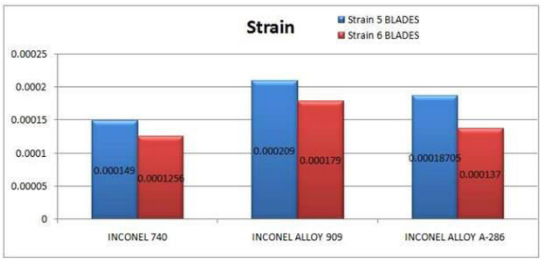
Graph 2: Total Deformation

The below graph shows that with Variation of Shear stress two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Shear stress is Inconel 740 material 6 Blades design have 9.36 Mpa



Graph3: Shear stress (Mpa)

The below graph shows that with Variation of Strain two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Strain is Inconel 740 material 6 Blades design have 0.000125



Graph 4: Strain

V.CONCLUSION

The Catia program is used in this project to create the turbo charger compressor wheel. On ANSYS Workbench, the analysis is completed. The geometry of the compressor blades 5 and 6 as well as the materials of the compressor wheels—Inconel 740, Inconel 909, and Inconel Alloy A-286—were changed for this study.Other, more stable and robust materials are taken into consideration for this project. Based on the findings above, I have concluded that blade 740 has the best material out of the six blades containing inconel.

The graph below illustrates how the variation in total deformation affects two distinct designs—one with six compressor blades and the other with five compressor blades—using various materials. Inconel Alloy A-286, Inconel 740, and Inconel 909. Finally, Inconel 740 material exhibits the least total deformation. Design for 6 Blades has 0.0065mm

The variation of emphasises two distinct designs with a compressor having six blades and a compressor having five blades that use various materials Inconel Alloy A-286, Inconel 740, and Inconel 909. Finally, Inconel 740 material has the lowest von-mises stress. The design of 6 Blades has 24.717 Mpa.

The variation in shear stress between two distinct designs employing five and six blade compressors made of various materials Inconel Alloy A-286, Inconel 740, and Inconel 909. Lastly, Inconel 740 material with six blades that have a 9.36 MPa design has the least shear stress.

The variation in strain between two distinct designs employing five and six blade compressors made of various materials Inconel Alloy A-286, Inconel 740, and Inconel 909. Last but not least, the Inconel 740 material's six blade design with 0.000125 strain.

Modal analysis from the perspective of the turbocharger compressor five blades in first mode 45.63 Hz at 1.563 mm deformation, 70.31 Hz at 2.957 mm, and 106.44 Hz at 5.44 mm in another design are the frequencies. Six Blades Mode 3 is at 113.92 Hz at 4.631 mm, frequency 50.63 Hz at total deformation of 1.311 and 80.45 Hz at 2.645 mm

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