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Design and Analysis of Turbocharger Impeller in Diesel Engine

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Abstract

The main goal of this research is to be design the turbine and compressor impeller of a turbocharger for a diesel engine. It is to increase power and efficiency of a turbocharger. It is to usage of new material is required for an investigation. The existing work turbine and compressor impeller has been designed with different materials. The investigation has been done by using ANSYS and CATIA software. The turbine and compressor impeller modeling has been done by using CATIA software. The variation of stresses, strains and deformation profile of the turbine and compressor impeller has been determined by using ANSYS software. The identifying the accurate or exactdesign features, the extended service life and long term stability has been assured. A structural analysis is used to investigate the stresses, strains and displacements of the turbine and compressor impeller. A modal analysis is used to investigate the frequency and deflection of the turbine and compressor impeller. A thermal analysis is used to investigate the total heat flux and direction heat flux. The turbine and compressor impeller of a turbocharger will be recommend based on the better material results.

Keywords: *Structural Analysis; Thermal Analysis; Modal Analysis.*

INTRODUCTION

A turbocharger is a turbine driven forced action device, which isused to allow morepower has been produced by an engine of a given size. Turbocharger engines have moreefficient 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.

Literature Review

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. [1] 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. [2]

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”. [3] 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 pre-compressing 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. [4]

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. [5] G. Wallace, A.P. Jackson, S.P. Midson, Q. Zhu and et.al, "Improvement of turbocharger impeller material". The casting process was chosen to produce the impellers as it's far able to producing castings with extremely high internal first-class. The generation used to produce the semi-stable impellers is defined in detail. The semi-strong solid impellers, made from an Al-Si-Mg-Cu alloy, are warmness treated to the T6 mood. results from testing are offered demonstrating that the impellers are free of porosity and different internal defects. both mechanical belongings and fatigue statistics are presented showing that the semi-stable impellers have better houses than impellers produced by way of traditional casting and comparable residences to cast and machined impellers. A short study is also described which identified suitable processing parameters to minimize hot tearing in the complex-shaped turbocharger impellers semi-solid cast from alloy 201. An aging study was performed to identify optimum mechanical strength. [6]

Experimental Work

Problem Identification

We had identified that the frequent damage on turbocharger impeller material due to the high stress and temperature acting on the impeller blades, an investigation shows that the implement of new material is required for the impeller. Based on this problem we have suggested a new material.

Fig. 1: *Damage of Material*

Investigated Turbocharger Specifications

Table 1: *Turbocharger Specifications*

Technical Data	Value
Type	TCR12
Material used for Compressor	Incoloy alloy 909
Material used for Turbine	Inconel alloy 740
Max. engine output per exhaust gas turbocharger: Four-stroke engine in kW	760
Max. Pressure in N/mm^2	6 x 10^5
Max. flow rate in m^3/s	1.26
Total pressure ratio: Standard version up to, High-pressure version up to	4.7, 5.2
Max. allowable rotor speed in rpm	71 300
Max. allowable turbine inlet temperature in °C	650
Weight in kg	25

Material Specifications

Compressor Impeller Materials:

Incoloy alloy A-286
Incoloy alloy 925
Incoloy alloy 909

Turbine Impeller Materials:
Inconel alloy 718
Inconel alloy N06230
Inconel alloy 740

Table 2: *Material Specifications*

S. No.	Material Used	Young's Modulus (N/mm^2)	Poisson Ratio	Density (Kg/mm^3)
1	Incoloy alloy A-286	201000	0.30	7.94 x 10^{-6}
2	Incoloy alloy 925	199000	0.293	8.08 x 10^{-6}
3	Incoloy alloy 909	159000	0.31	8.41 x 10^{-6}
3	Inconel alloy 718	158579	0.291	8.22 x 10^{-6}
4	Inconel alloy N06230	211500	0.34	8.91 x 10^{-6}
5	Inconel alloy 740	218000	0.32	8.05 x 10^{-6}

Investigated to Impeller Analysis
Thermal Analysis
A thermal analysis is tocalculate the temperature distribution and thermal quantities in an element. Typical thermal quantities are,

- The temperature distribution.
- The amount of heat lost or gained.
- Thermal fluxes.

A steady state thermal analysis is to determine the temperature distribution and other thermal quantities under the steady state loading analysis is to determinethe temperature distribution and thermal quantities under the conditions that varying over a time period.conditions. It is heat storage effects varying over a period of time have been ignored. A transient thermal

Structural Analysis
Structural analysis is the most common application of the finite element analysis. The term structural implies civil engineering structure like bridge, building and also naval, aeronautical and mechanical structure likeship hulls, aircraft bodies and machine housing such as mechanical components like piston, machine parts and tools.

Structural Static Analysis
A Structuralstatic analysis is to calculate the effect of steady loading conditions in a structure, inertia and damping effects caused by time varying loads.It can be include steady inertia loads like gravity, rotational velocityand time varying loads has been approximated as static equivalent loads like static equivalent wind and seismic loads.

Modal Analysis

- Modal evaluation is to describe a structure in terms of its natural characteristics which might be the frequency, damping and mode shapes – its dynamic houses.
- Now the two technologies are converging and powerful new tools for solving vibration problems are emerging as a result.
- It involves process of determining the modal parameters of a structure areconstruct a model of the response.
- The modal parameters are to determine by analytical finite element analysis and one of the most common reasons for experimental modal analysis is the verification of the results of the analytical approach.
- The modal parameters has been determined experimentally perform as the model for future evaluations such as structural modifications.

Impeller Dimension and Model
Dimensions of Compressor Impeller

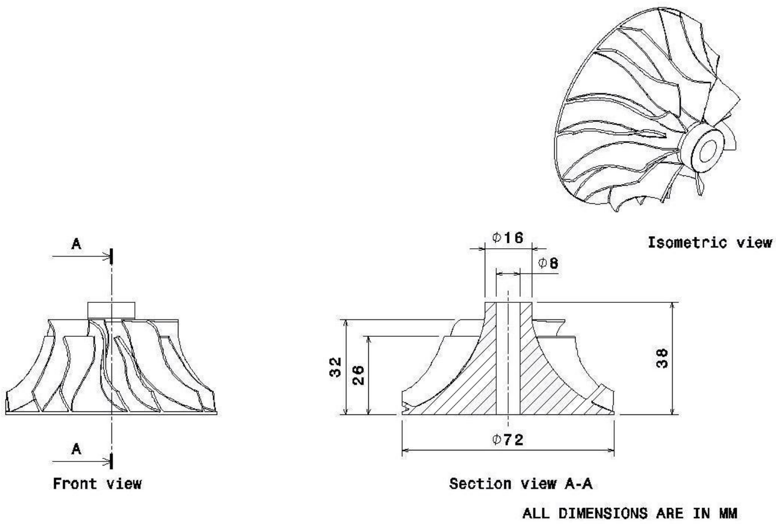

Fig. 2: *Dimensions of Compressor Impeller*

Compressor Impeller Model

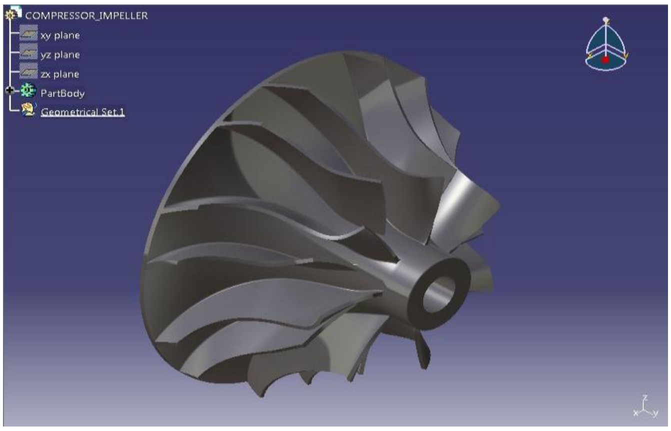

Fig. 3: *Compressor Impeller*

Dimensions of Turbine Impeller

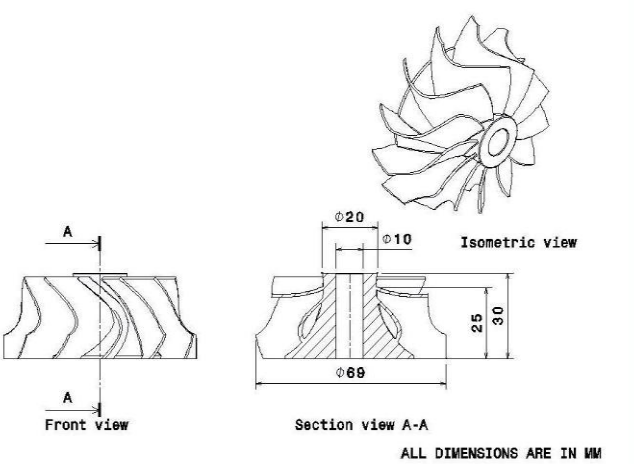

Fig. 4: *Dimensions of Turbine Impeller*

Turbine Impeller Model

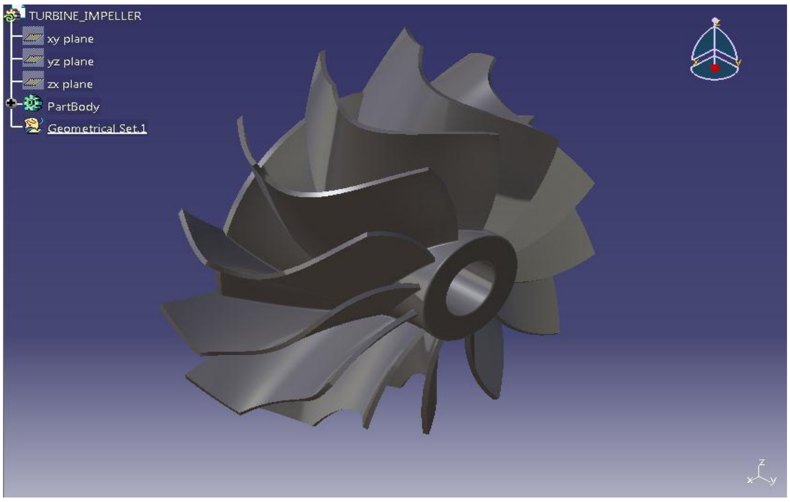

Fig. 5: *Turbine Impeller*

Analysis of Impeller

For compressor impeller 3 materials investigation is carried out the usage of structural analysis and modal evaluation for turbine impeller 3 substances research is carried out the usage of structural analysis, modal analysis and thermal evaluation

Structural Analysis of Compressor Impeller

The vonmises stress, vonmises strain and deformation for three different materials of compressor impellers by using structural analysis.

Incoloy Alloy A-286:

The result shows in Fig.6 is the structural analysis of compressor impeller for the material Incoloy alloy A-286.

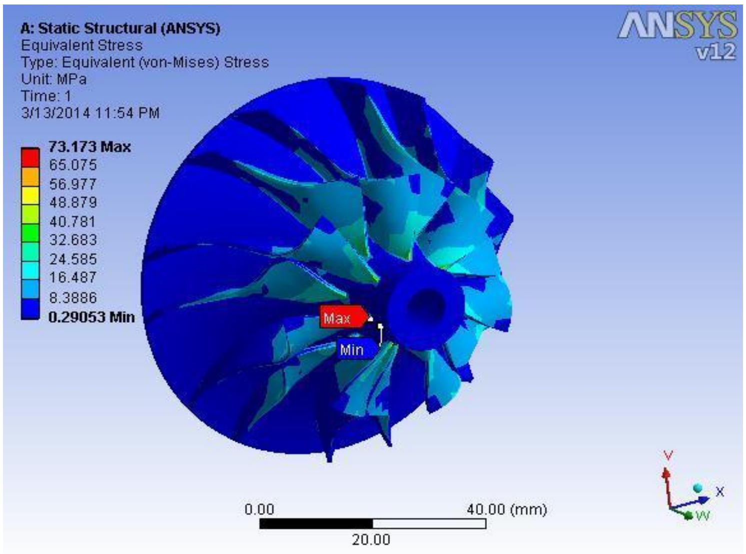

Fig. 6: *Structural Analysis for Incoloy Alloy A-286*

Incoloy Alloy 909:

The result shows in Fig. 7 is the structural analysis of compressor impeller for the material Incoloy alloy 909.

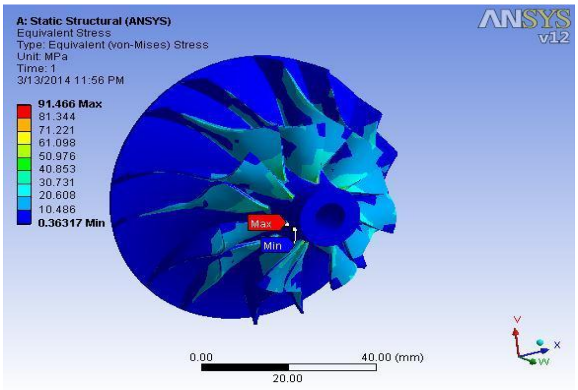

Fig. 7: Structural Analysis for Incoloy Alloy 909

Incoloy Alloy 925:

The result shows in Fig. 8 is the structural analysis of compressor impeller for the material Incoloy alloy 925.

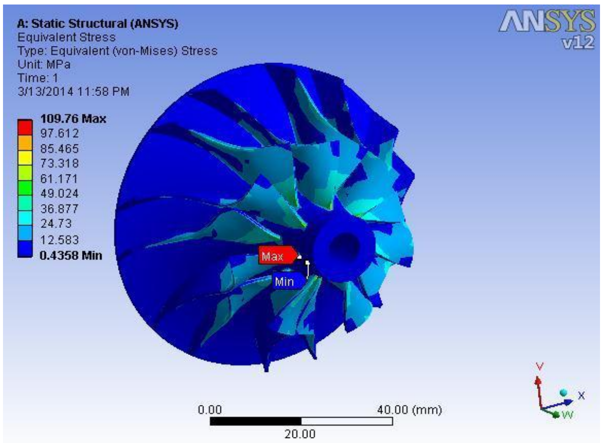

Fig. 8: Structural Analysis for Incoloy Alloy 925

Structural Analysis of Turbine Impeller

The variation of vonmises stress, vonmises strain, and deformation for three different materials of Turbine impellers, using structural analysis.

Inconel Alloy N06230

The result shows in Fig. 9 is the structural analysis of turbine impeller for the material Inconel alloy N06230.

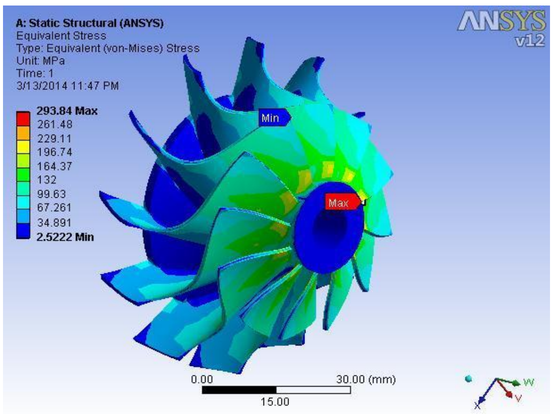

Fig. 9: Structural Analysis for Inconel Alloy N06230

Inconel Alloy 740:
The result shows in Fig. 10 is the structural analysis of turbine impeller for the material Inconel alloy 740.

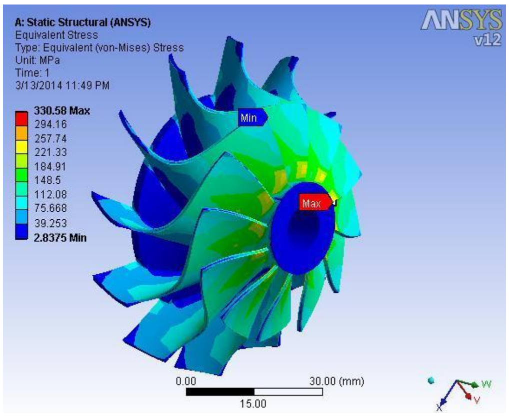

Fig. 10: *Structural Analysis for Inconel Alloy 740*

Inconel Alloy 718:
The result shows in Fig. 11 is the structural analysis of turbine impeller for the material Inconel alloy 718.

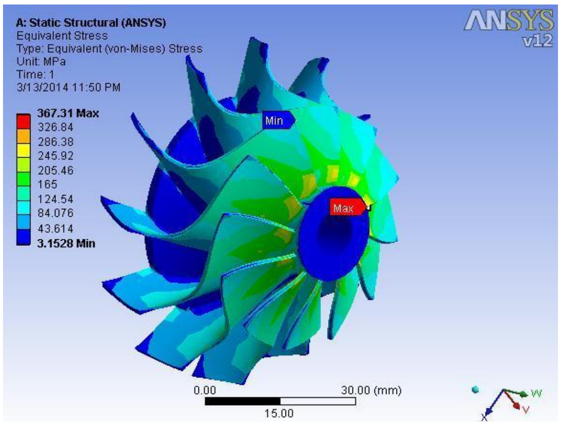

Fig. 11: *Structural Analysis for Inconel Alloy 718*

Thermal Analysis of Turbine Impeller
The total heat flux of a turbine impeller in three different materials by using thermal analysis.

Inconel Alloy N06230
The result shows in Fig. 12 is the thermal analysis of turbine impeller for the material Inconel alloy N06230.

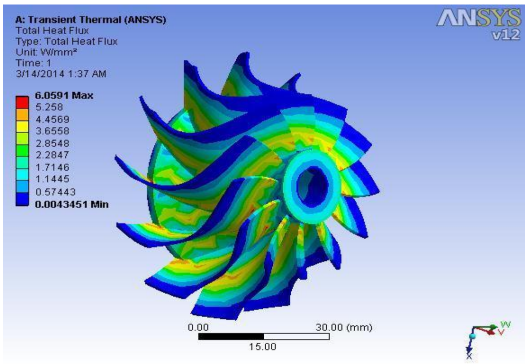

Fig. 12: *Total Heat Flux for Inconel Alloy N06230*

Inconel Alloy 740

The result shows in Fig. 13 is the thermal analysis of turbine impeller for the material Inconel alloy 740.

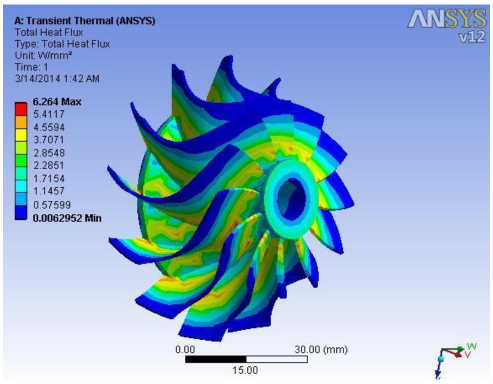

Fig. 13: *Total Heat Flux for Inconel Alloy 740*

Inconel Alloy 718

The result shows in Fig. 14 is the thermal analysis of turbine impeller for the material Inconel alloy 718.

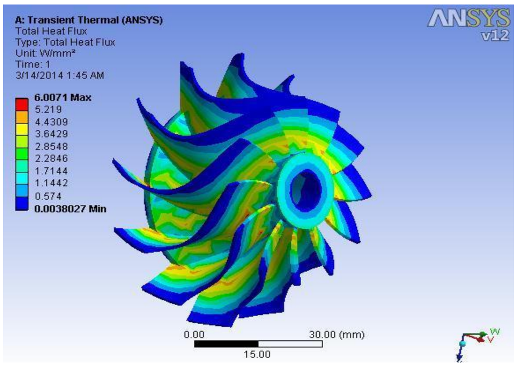

Fig. 14: *Total Heat Flux for Inconel Alloy 718*

RESULT AND DISCUSSIONS

Structural Analysis for Compressor Impeller

For compressor the minimum von mises stress is obtained for the Incoloy alloy A-286 and the maximum von mises stress is obtained for the Incoloy alloy 925.

Table 3. *Structural analysis for compressor impeller*

Properties	**Incoloy alloy A-286**	**Incoloy alloy 909**	**Incoloy alloy 925**
Max. von mises stress (N/mm^2)	73.173	91.466	109.76
Displacement (mm)	0.016966	0.021208	0.025449

Axis Materials

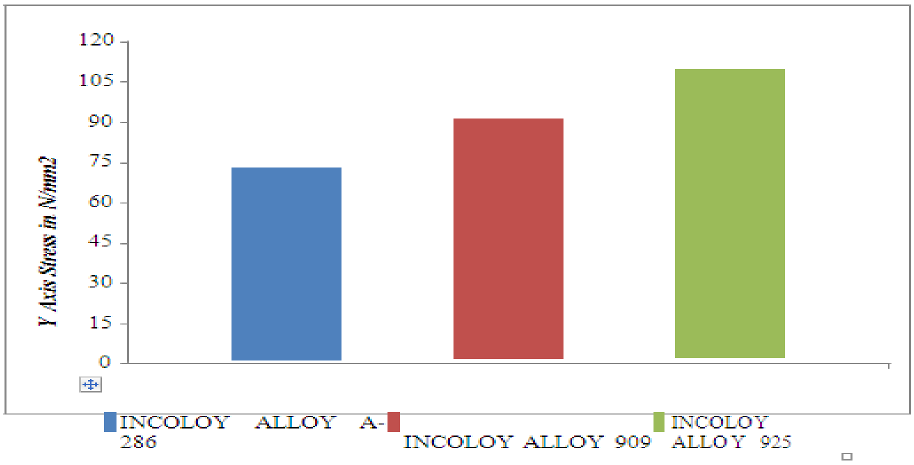

Fig.15. *Stress distribution Vs materials*

Structural Analysis for Turbine Impeller

For turbine impeller the minimum von mises stress is obtained for the Inconel alloy N06230 and the maximum von mises stress is obtained for the Inconel alloy 718.

Table 4. *Structural analysis for Turbine impeller*

Properties	**Inconel alloy N06230**	**Inconel alloy 740**	**Inconel alloy 718**
Max. von mises stress (N/mm^2)	293.84	330.58	367.31
Displacement (mm)	0.2596	0.2921	0.32455

X Axis Materials

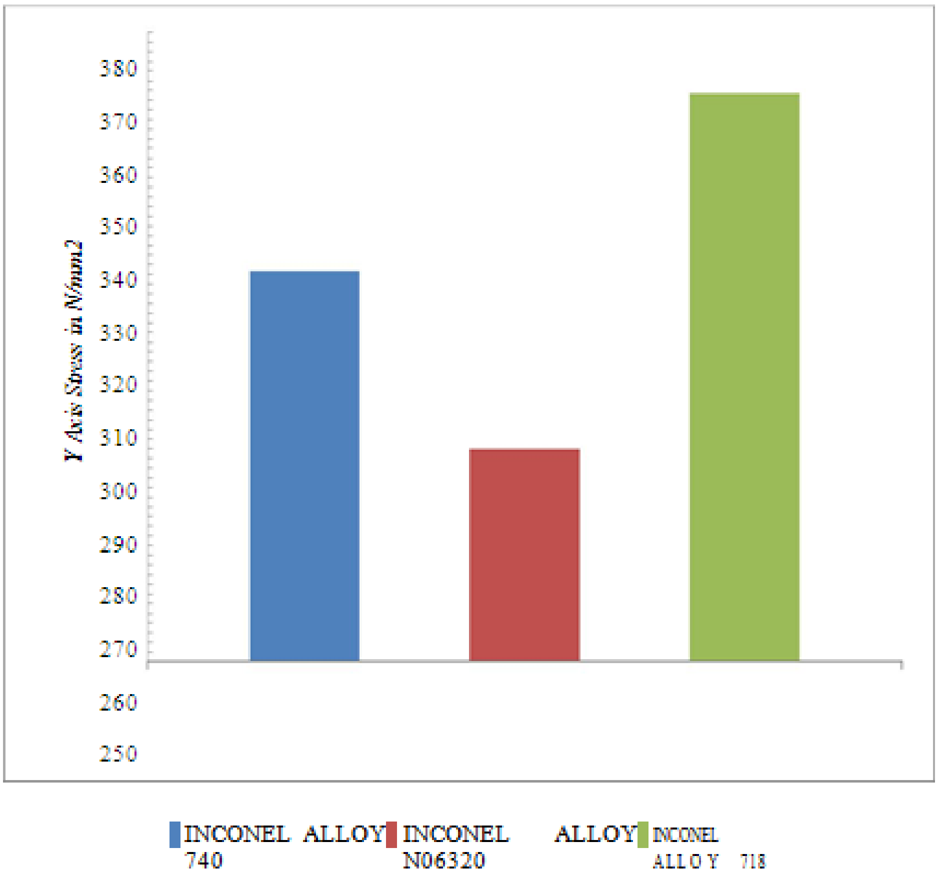

Fig.16. *Stress distribution Vs materials*

Modal Analysis of Compressor Impeller

For compressor the maximum frequency is obtain for the material Incoloy alloy A-286 and the minimum frequency is obtain for the material Incoloy alloy 909.

Table 5. *Modal analysis for compressor impeller*

Type of material	Frequency (Hz)			Deflection(mm)		
	1	2	3	1	2	3
Incoloy alloy A-286	672.36	641.26	600.32	28.432	31.45	29.89
Incoloy alloy 925	519.67	586.23	612.12	35.567	40.34	42.037
Incoloy alloy 909	432.12	467.45	505.03	39.46	44.98	45.678

X Axis Materials

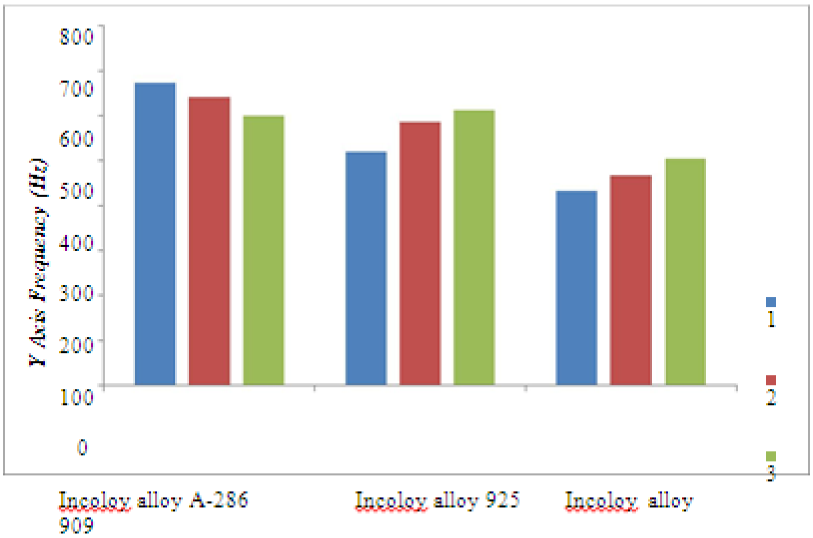

Fig.17. *Frequency Vs Material*

Modal Analysis of Turbine Impeller

For Turbine the maximum frequency is obtain for the material Inconel alloy N06230 and the minimum frequency is obtain for the material Inconel alloy.

Table 6. *Modal analysis for Turbine impeller*

Type of material	Frequency (Hz)			Deflection(mm)		
	1	**2**	**3**	**1**	**2**	**3**
Inconel alloy 718	776.2	780.27	782.4	176.86	134.56	163.11
Inconel alloy N06230	889.23	854.45	890	236.77	267.57	232.12
Inconel alloy 740	789.34	768.37	712.34	145.44	164.2	156.45

X Axis Materials

Thermal Analysis of Turbine Impeller

The total heat flux of a turbine impeller in three different materials, the maximum total heat flux is occurred in Inconel alloy N06230, the minimum total heat flux is occurred in Inconel alloy740.

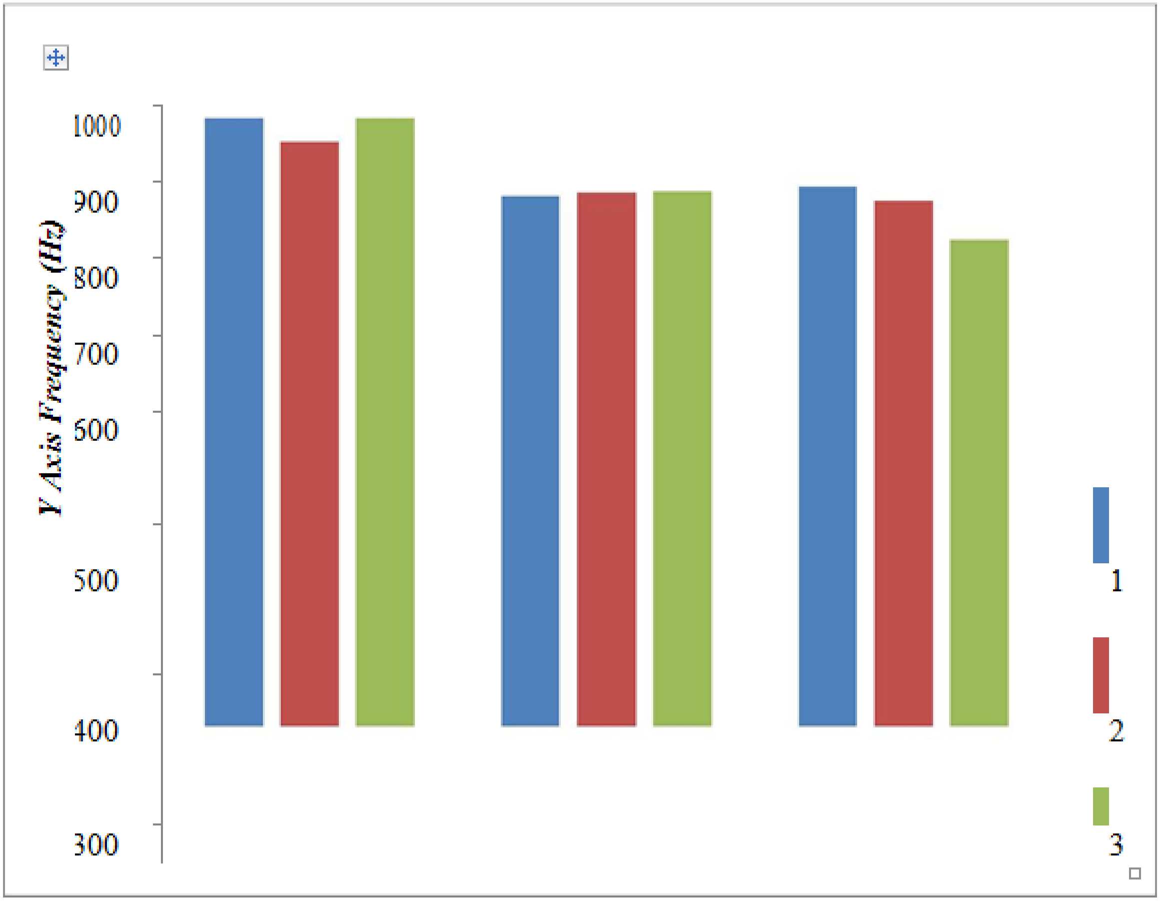

Fig.18. *Frequency vs Materials*

Table 7. *Thermal analysis for Turbine impeller*

Properties units : w/mm^2		**Inconel alloy 718**	**Inconel alloy N06230**	**Inconel alloy 740**
Total heat flux		6.0591	6.264	6.0071
Direction heat flux	**Axis**			
	X	5.5313	5.629	5.05
	Y	3.3766	3.479	3.3493
	Z	5.5321	5.6299	5.5059

X Axis Materials

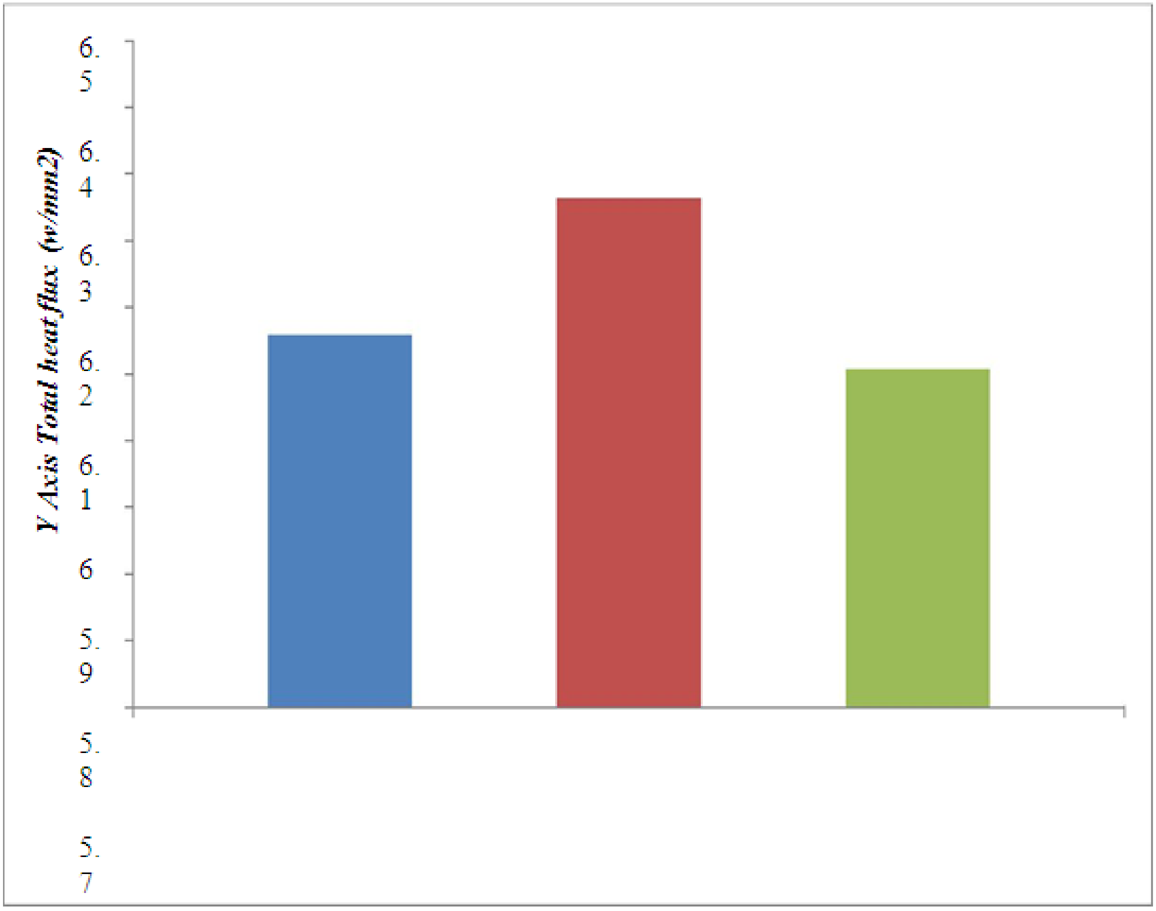

Fig.19. *Total heat flux Vs Materials*

CONCLUSIONS

- The present cloth used for compressor impeller is Incoloy alloy 909 and Turbine impeller is Inconel alloy 740 is subjected to excessive pressure, so the impeller material get broken. in this assignment, three special substances for both compressor and turbine impeller are taken into analysis.
- As per the analysis result, for Compressor impeller the minimum von mises stress and maximum frequency is obtained for the material Incoloy alloy A-286. So we conclude that among these three different materials Incoloy alloy A-286 is the best material.
- For Turbine impeller the minimum von mises stress, maximum frequency and maximum total heat flux is obtained for the material Inconel alloy N06230. So we conclude that among these three different materials Inconel alloy N06230 is the best material.

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