IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

``STRUCTURAL, THERMAL AND FLUID ANALYSIS OF 3D MODEL IMPELLER OF A TURBOCHARGER IN DIESEL ENGINE`` BY VARYING DIFFERENT SUPER ALLOYS USING ANSYS.

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Abstract

In the present work the Impeller of a Turbocharger was designed with five different types of super alloy materials (Structural Steel, Cobalt super Alloy, and Inconel Alloy 718, Udimet Alloy 720, Aluminium super Alloy). Consequently, a Computer-Aided Design (CAD) model of the Impeller in Turbocharger is developed and simulated. The CAD Model and Assembly is done in Siemens NX CAD and Analysis (Static Structural, Thermal, and Fluid) is done through ANSYS Workbench.

A modest attempt has been made to investigate the effect of Temperature, Pressure, Induced stress and strain, Deformation, Strain Energy, Total Heat flux Pressure and Velocity flow path, of the impeller by varying different types of super alloys and the results were compared for above parameters aluminium super alloy having less equivalent stress & elastic strain and total deformation as compared to other four alloys finally concluded that Aluminium super alloy is the best suited material among the chosen five different super alloys.

Keywords: Impeller, Turbocharger, Modelling, Simulation, 5 Different types of Materials, Static Structural, Thermal, Fluid Modules.

1. Introduction

Turbocharger is highly utilized device in the diesel type of engines for increasing the overall efficiency. By using the turbocharger effectively, the specific fuel consumption of the engine is reduced significantly. The two types of impellers called compressor impeller and turbine impeller was fixed on either side of the turbocharger. Both the impeller has to work sequentially for compressing and expanding the air simultaneously. The Selection of material for the impeller design plays a significant role to deciding the overall efficiency. The impeller material

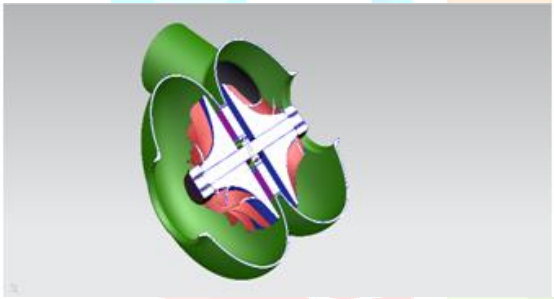
Should be withstanding the high pressure of incoming compressed air at the time of working. Many materials were experimented by the researchers for improving the performance of the impeller used in the diesel engines. The impeller blade angle plays a significant influence over the performance of the turbocharger. In the present study, the five different types of materials say Inconel Alloy 718, Structural Steel, Cobalt Alloy, Udimet Alloy 720, Aluminium Alloy were considered for the analysis. The material properties five materials were considered. The 3D model of the impeller was designed by using NX CAD Software.

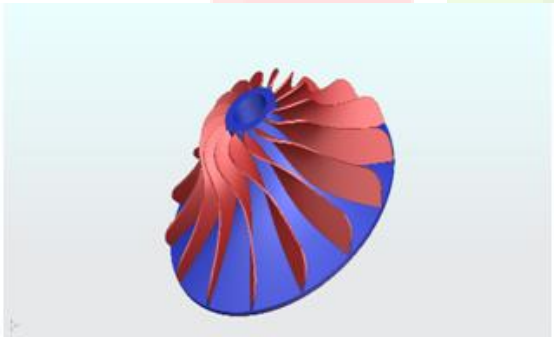
The Created Geometry was import to ANSYS Workbench where the Static Structural, Thermal, Fluid Analysis were performed by corresponding properties. The principal Stress and strain, deformation along with Heat flux, Directional heat flux, Velocity, Pressure, Temperature etc.…

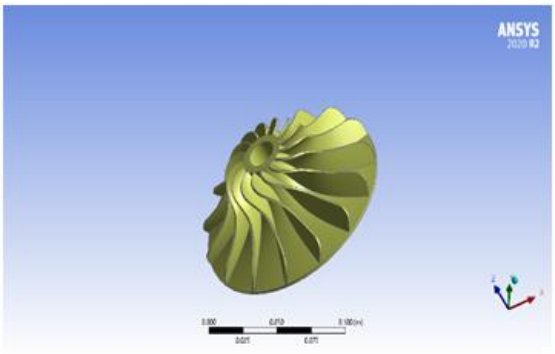
2. Geometry Model

In NX CAD Model Module, The Geometry Dimensions are drawn with this specification, The Diameter (D) and height (H) of impeller is 70mm and 50mm.

The Special tool for Blade design "Law Extension tool "angle at start 950 and end 1250. Total No. of blades is 15 with Pitch angle of 240 and thickness of blades is 1 mm. All fillets are taken as 0.15mm.







In NX CAD Model Module, The Geometry Dimensions are drawn with this specification, The Diameter (D) and height (H) of impeller is 70mm and 50mm.

The Special tool for Blade design "Law Extension tool "angle at start 95^0 and end $125^{0.}$ Total No. of blades is 15 with Pitch angle of 24^0 and thickness of blades is 1 mm. All fillets are taken as 0.15mm.

After that CAD model created to save in the .iges format (Intitial Graphics Exchange Specification) to avoid the errors like overlapping of facets, geometrical data redundancy and vertex to vertex rule between the facets. Further, for analyzing Calucations of mass properties values easily find out.

3.Materials and Properties:

In Simulation purpose, they are five different types of materials like " Structural Steel, Cobalt Alloy, Udimet Alloy 720,Inconel Alloy 718,Aluminium Alloy". Below the table 1,2,3 and 4,5 show the material properties.

Table.1 Properties of the structural steel

Sl. no	Parameters	Values
1	Density (ρ)	7850 kg/m^3
2	Young's modulus (E)	2 * 10^{11} Pa
3	Poisson's ratio (i)	0.3
4	Thermal conductivity(K)	60.5 $Wm^{-1}K^{-1}$

Table.2 Properties of the Udimet alloy 720

Sl. no	Parameters	Values
1	Density(ρ)	8080 kg/m^3
2	Young's modulus (E)	2.1 * 10^{11} Pa
3	Poisson's ratio(i)	0.27
4	Thermal conductivity(K)	25 $Wm^{-1}K^{-1}$

Table.3 Properties of the Inconel alloy 718

Sl. no	Parameters	Values
1	Density (ρ)	8220 kg/m^3
2	Young's modulus (E)	2* 10^{11} Pa
3	Poisson's ratio(i)	0.294
4	Thermal conductivity(K)	11.4 $Wm^{-1}K^{-1}$

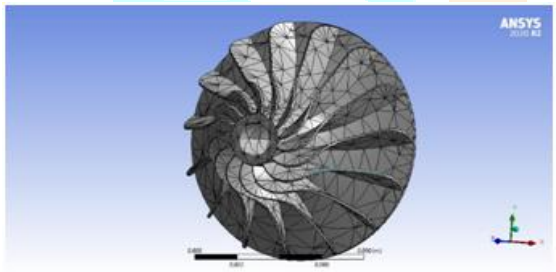
Table.4 Properties of the Cobalt super Alloy

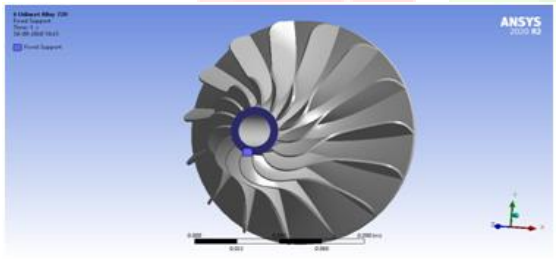
Sl. no	Parameters	Values
1	Density (ρ)	8862 kg/m^3
2	Young's modulus (E)	2.09* 10^{11} Pa
3	Poisson's ratio(i)	0.31
4	Thermal conductivity(K)	100 Wm-^{1}K-^{1}

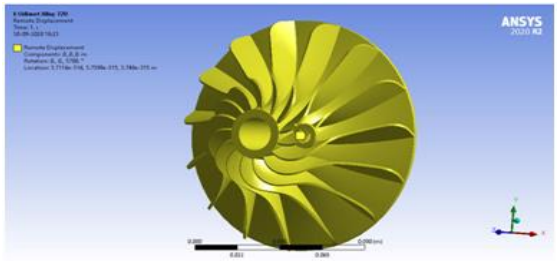
Table.5 Properties of the Aluminium Super alloy

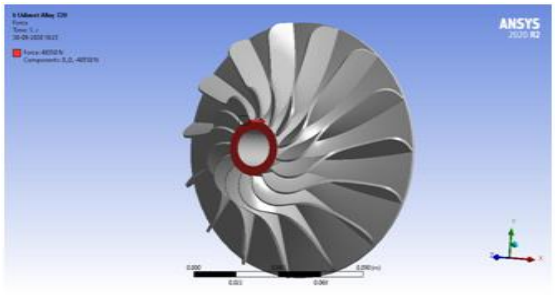
Sl. no	Parameters	Values
1	Density (ρ)	2770 kg/m^3
2	Young's modulus (E)	7.1* 10^{10} Pa
3	Poisson's ratio(i)	0.33
4	Thermal conductivity(K)	205 Wm-^{1}K-^{1}

4. Simulation of the Impeller:









The modelled Impeller was simulated by importing the CAD model into the simulation software (ANSYS).

Select the required material of the model in the "engineering data", then meshing the model in small element, which is element size of 9.623e^-002 m.

For analysis system, choose the "Static Structural, Thermal Module", the boundary conditions

For Trial and error method, for 4 -Stroke Diesel Engine, Indicate Mean Effective Pressure (IMEP) is taken 0.67Mpa. From the Geometry, the Surface Area is 72164.5410 mm^2

Force=Pressure *Area

F=0.67*72164.5410=48.350KN.

Angular Velocity=2π*N/60

Assume, N=Speed of the Impeller (950 RPM)

ω=2π*950/60=99.4837 rad/sec=5700.00187°/sec

Initial Temperature taken as 24 °C, Approximately, Temperature of Impeller =450°C (723 °K)

Heat Flux (q) is taken for steady state thermal conduction.

q=-K*A*(dt/dr)

For Structural Steel:

q=-(60.5) *(0.0721645410) *((450-24)/0.035)) =53139.89726 W/m^2

q=87834.55562 W/m^2 (Cobalt Alloy)

q=180060.8390 W/m^2 (Aluminium Alloy)

q=21958.6389 W/m^2 (Udimet Alloy 720)

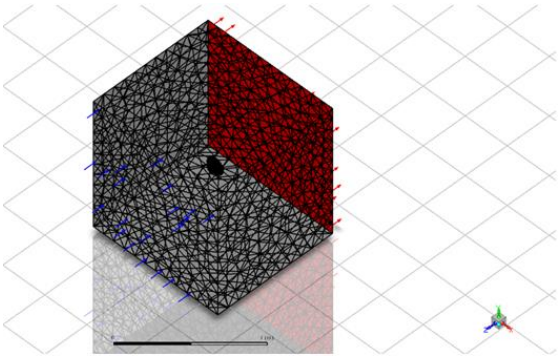
q=10013.1393 W/m^2 (Nickel Alloy 718)

In Fluent Module, k-epsilon (2 eqn) Model taken. Further, boundary conditions value taken run with 50 iterations.

For Diesel Car run at 50Kmph.

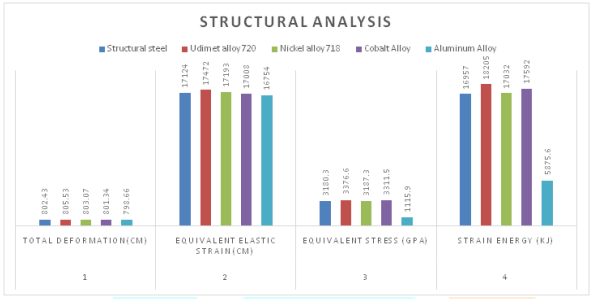
V= (100*1000)/ (60*60) =27.8 m/sec.

Temperature =450°C (723 °K)

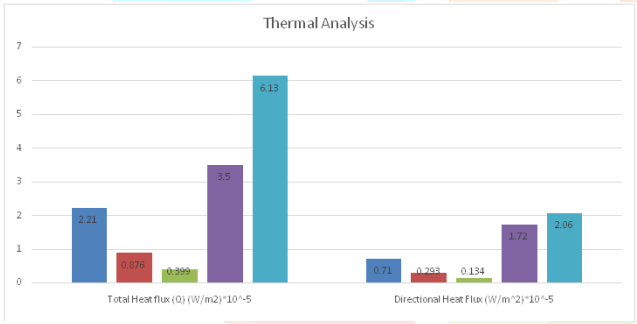


5. Results

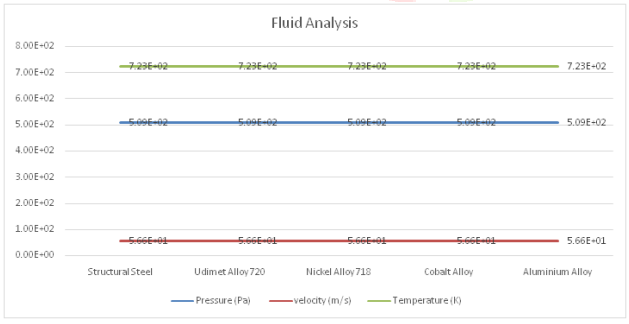
For Static Structural analysis



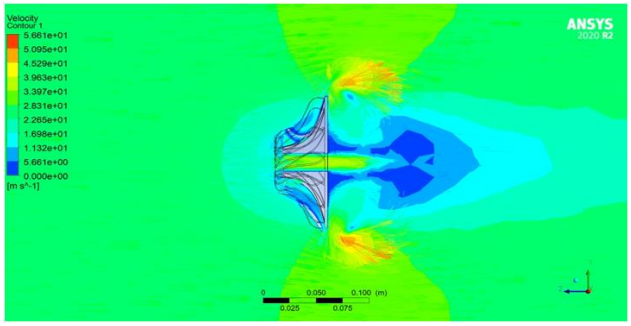
For Thermal Analysis,



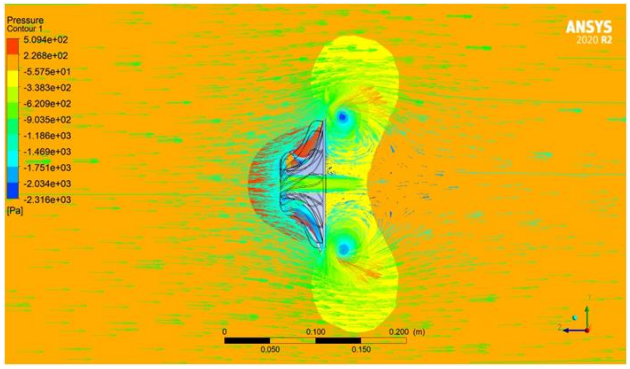
For Fluid Analysis,



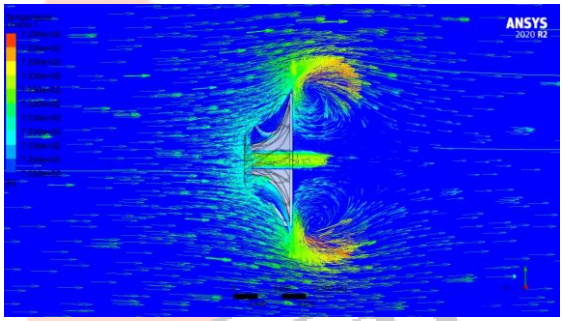
Velocity of all Materials



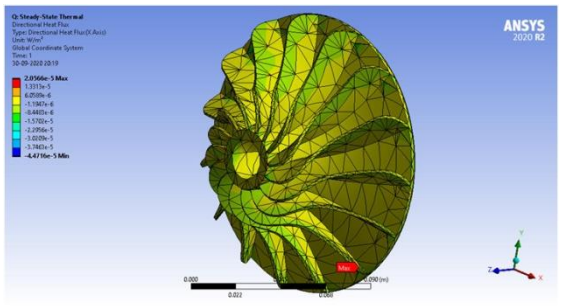
Pressure of all Materials



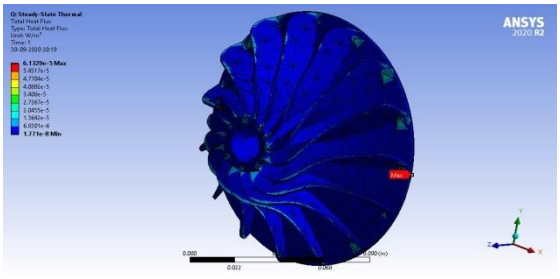
Temperature of all Materials



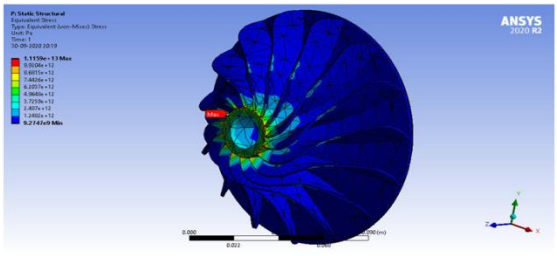
Directional Heat Flux of Aluminium Alloy



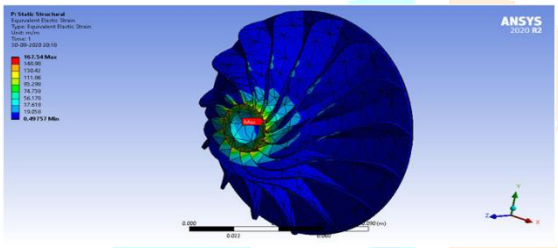
Total Heat Flux of Aluminium Alloy



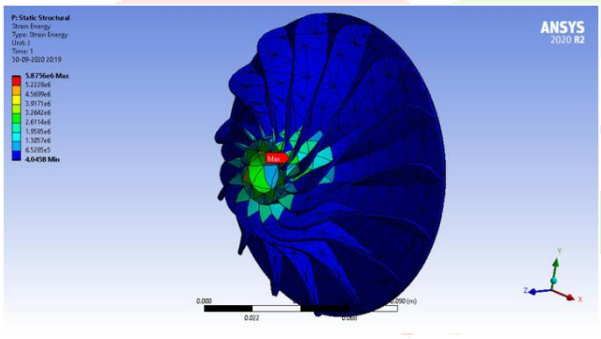
Stress of Aluminium super Alloy



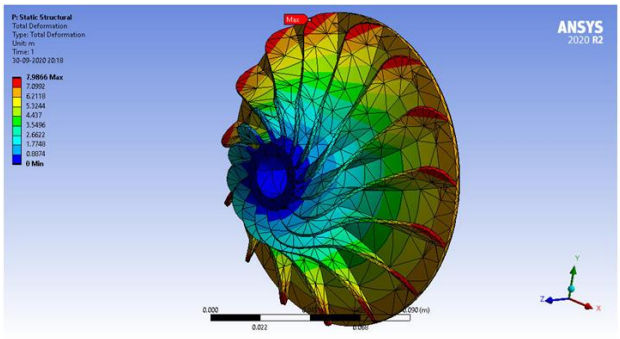
Strain of Aluminium super Alloy



Strain Energy of Aluminium super Alloy



Total Deformation of Aluminium Alloy



6. Conclusion

The analysis was carried out for the impeller of the turbocharger using ANSYS. In the analysis part the model of the impeller was created using and the files were saved in. IGES format and imported to ANSYS. The analysis is carried out on the redesigned model with different materials (Structural Steel, Nickel alloy 718, Cobalt alloy, Aluminium alloy and Udimet alloy 720) and the results were compared. From the above result summarizes charts, we conclude that aluminium alloy was found better than Cobalt, Nickel Alloy 718, Structural Steel and Udimet Alloy 720. From the above Structural Analysis, we observed that minimum stress, strain and total deformation, strain energy stored is obtained Aluminium Alloy. Also, in the thermal Analysis the total thermal flux and Directional Heat flux induced on the impeller was high heat rate transfer for the material Aluminium alloy. In addition, that, In Fluid analysis, Pressure, Velocity, Temperature throughout Constant. Thus, the impeller could withstand less stress and high heat transfer is Aluminium Alloy. So, we conclude that Aluminium Alloy is the most apt material among the five chosen materials for the impeller of the turbocharger.

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