Modelling And Geometrical Optimization Of Turbo Charger Compressor

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Abstract - Turbocharger is used throughout the automobile industry as they can intensify the output of an internal combustion engine without the need to increase its cylinder size. In order to increase the implementation of the conventional turbocharger compressor's to boost the pressure in the engine. The application of such a mechanical device enables automotive manufacture ring industries to adopt smaller displacement engines, commonly known as "engine downsizing". Historically, turbochargers were often used to increase the potential of an already powerful internal combustion engine.Here in this project I am modeling turbo charger hosing and its components and designing the compressor wheel by using creo3.0 and doing Structural and dynamic Modal analysis by using Finite element analysis package Ansys15.0. the Main aim of this project to increase the strength and improve the response of the compressor wheel for this I am optimizing the material and also changing the existing design by comparing the results of deformations and natural frequencies the best model from this data I suggest the design modification to the company to improve performance of the compressor.

Keywords - ANSYS, Creo3.0, Horse power, Turbocharger.

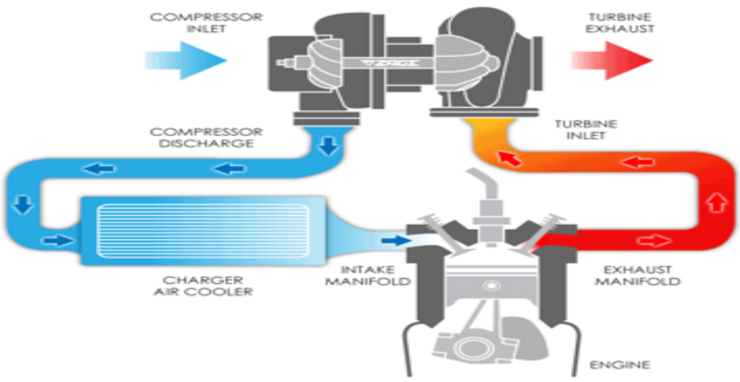
I. INTRODUCTION TO TURBO CHARGER

A naturally-aspirated engine is one common type reciprocating piston IC engine that depends on atmospheric pressure to counter the partial vacuum in the induction tract to draw in combustion air. In a naturally aspirated engine; air for combustion or an air/fuel mixture is drawn into the engines cylinders by atmospheric pressure acting against a partial vacuum that occurs as the piston travels downwards toward bottom dead centre during the induction stroke. Due to restriction at intake track, a small pressure drop occurs as air is drawn in, resulting in a volumetric efficiency of less than 100 percent - and a less than complete air charge in the cylinder.

A supercharge is an air compressor used for forced induction of an internal combustion engine. The greater mass flow-rate provides more oxygen to support combustion than would-be available in a naturally-aspirated engine, which allows more fuel to be provided and more work to be done per cycle, increasing the power output of the engine. A supercharger can be powered mechanically by a belt, gear, shaft, or chain connected to the engine's crankshaft. It can also be powered by an exhaust gas turbine. A turbine-driven supercharger is known as turbocharger.

II.WORKING OF TURBO CHARGER IN DIESEL ENGINES

The diagram below depicts the process of utilizing the engines exhaust gases to force clean air into the motor for combustion. In the diagram above, you may notice a "charge air cooler"or more commonly known as an intercooler.



Working of turbo charger

Although not utilized in all cases, most turbocharged platforms utilize an intercooler to cool the compressed air back down to the ambient air temperature. This is due to the fact that heat is transferred from the turbine of the turbocharger to the compressor by of the exhaust gases flowing through it. This causes an undesired effect of heating the compressed air that is formed by the compressor of the turbocharger. A higher temperature air becomes less dense of oxygen molecules, which intern cause less oxygen to flow into the combustion chambers and produces a smaller, less powerful combustion (less power output). So to counter this effect, an intercooler is implemented to cool the air back down.

III.APPLICATIONS

1)Petrol-powered cars
2)Diesel-powered cars
3)Motorcycles
4)Aircraft

IV.LITERATURE REVIEW

Mohd Muqeem [1], in his study discussed that turbochargers are used throughout the automotive industry as they can enhance the output of an internal combustion (ic) engine without the need to increase its cylinder capacity. The application of such a mechanical device enables automotive manufacturers to adopt smaller displacement engines, commonly known as “engine downsizing”. The aim of this paper is to provide a review on the techniques used in turbo charging to increase the engine output and reduce the Exhaust emission levels.

CH.satya sai Manikanta [2] in his paper presents structural analysis of turbocharger impeller by using different materials under different static and dynamic conditions to obtaining the stress values and strain values and deformation ranges For designing the impeller 30,000 rpm is considered for this project. Impeller was designed by CATIA software and analysis was done by ANSYS software.

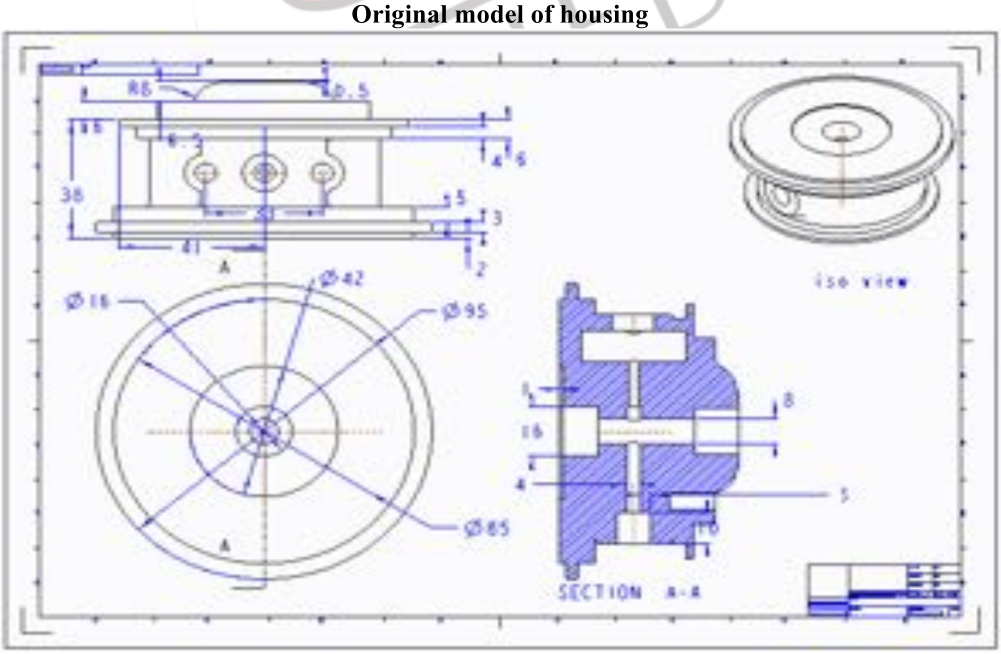
Vigneshwar N [3] in his paper is to discuss on turbocharger compressor wheel at different blade angles to find out the maximum efficiency of a turbo-charged at inlet blade angle $\beta_1 = 65^0, 45^0$ and 35^0 and studied the analysis of fluid flow phenomena over a compressor wheel of the turbocharger with the help of computational fluid dynamics (ANSYS-CFX).

V.MODELLING OF TURBO CHARGER HOUSING IN CREO

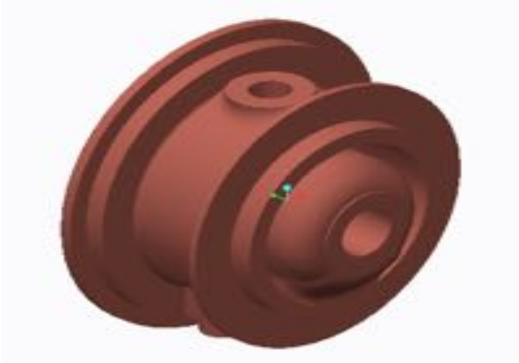
Creo Parametric is a computer graphics system for modeling various mechanical designs and for performing related design and manufacturing operations. The system uses a 3D solid modeling system as the core, and applies the feature-based, parametric modeling method. In short, Creo Parametric is a feature-based, parametric solid modeling system with many extended design and manufacturing application.

PART NAME: **CENTER HOUSING**

Original model of housing

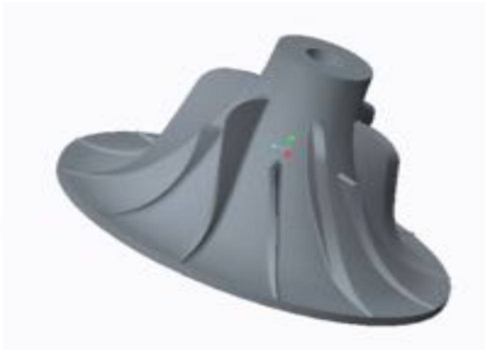


Drawing of housing

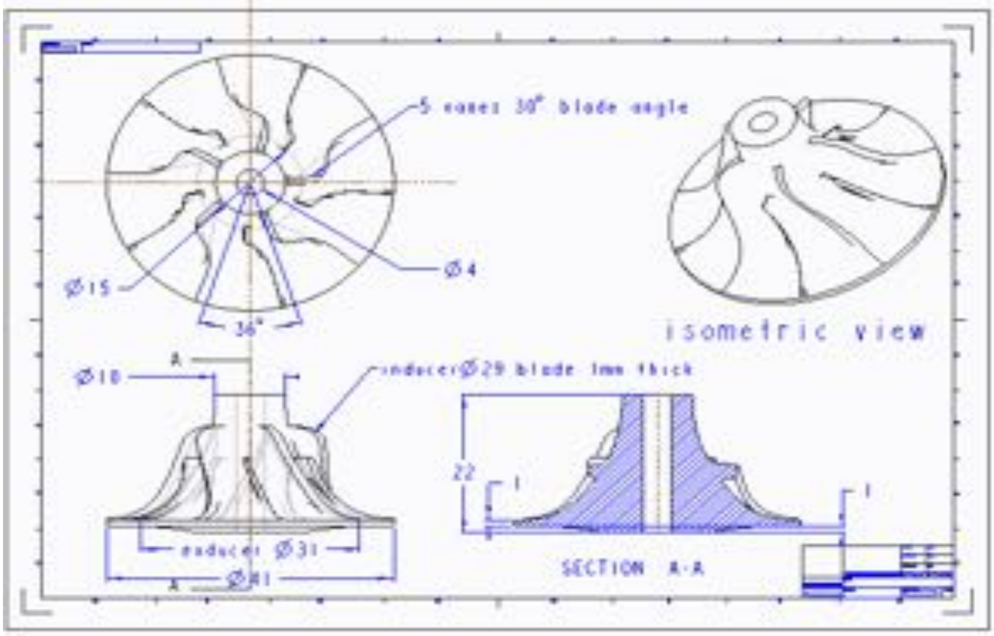


3 -d model of housing

PART NAME: **COMPRESSOR**

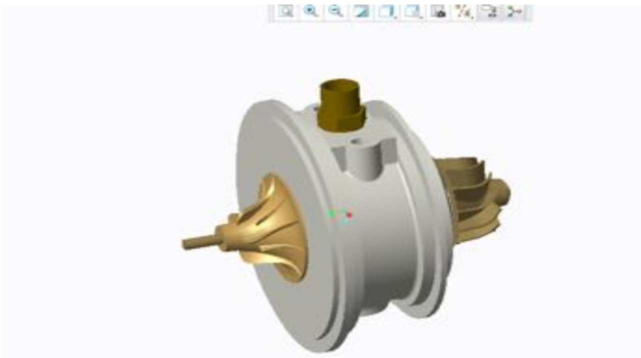


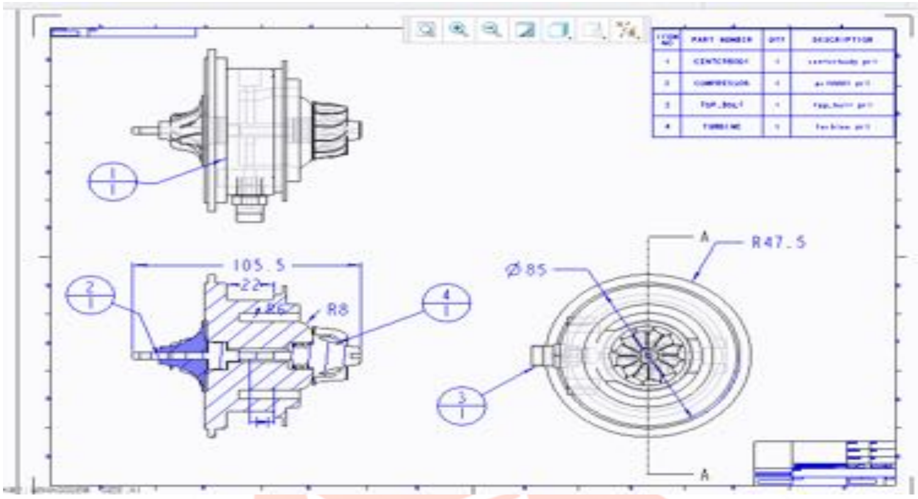
3D MODEL OF COMPRESS



ORTHOGRAPHIC VIEWS OF COMPRESSOR

ASSEMBLY OF TURBO CHARGER HOUSING COMPONENTS:





Assembly drawing of turbocharger housing

VI.TATA INDIGO ENGINE SPECIFICATIONS:

Engine volume =1405cc, Bore diameter =0.075m, Stroke length=0.0795m,
Max power =68HP @4500 rpm, Max torque =127@2500rpm,
Fuel type=diesel
No of gears =5

Here how to calculate the volume and mass of air moving through the engine, and how to size a turbochargers' compressor to move that quantity of air. It should also offer some enlightenment of the effects of temperature, pressure, and intercooling on the engine's performance.

$$\text{Volume of air (CFM)} = \frac{\text{engine rpm} \times \text{engine cid}}{(1728 \times 2)}$$

Engine volume 1405cc =85.738 cubic inches

The efficiency of the engine is assumes as a 85% (for high speed engines)

$$\text{Volume of air flowing into the engine} = \frac{\text{engine rpm} \times \text{engine cid}}{1728 \times 2}$$

$$= \frac{4500 \times 85.738 \text{ CI}}{1728 \times 2}$$

$$\text{Volume of air flowing into the engine} = 111.638 \text{ CFM}$$

From the ideal gas equation

Atmospheric pressure is about 14.7 psia at sea level.

A boost gauge reads 0 psia before it is hooked up. Hook it up, boost the car, and it reads 17 psia. 17 psi is the gauge pressure; the absolute pressure at sea level is 14.7 + 17= 31.7.psia

Intake manifold temperature=80degR

Absolute temperature=80+460=540degR

$$\text{No of molecules of air(n)} = \frac{P \times V \times 29}{10.73 \times T \text{ degR}}$$

$$= \frac{31.7 \times 111.638 \times 29}{10.73 \times 540 \text{degR}}$$

$$= 17.712 \text{ lb/m}$$

$$\text{Actual flow} = \text{Corrected air flow (lb/m)} \times \text{volumetric efficiency}$$

$$= 17.712 \times 0.85$$

$$= 14.552 \text{ lb/m}$$

The discharge temperature is calculated by using the following relation

The inlet pressure is atmospheric (pin) =14.7psia

The outlet boost pressure (pout)=17+14.7psia=31.7psia

$$Tout = Tin + \frac{Tin \times [-1+(Pout/Pin)^{0.263}]}{Efficiency}$$

$$Tout = 540 + \frac{540 \times [-1+(31.7/14.7)^{0.263}]}{0.85}$$

$$=660.948degR-460=200.948degF$$

ENGINE EXHUAST FLOW CALCULATIONS

Exhaust flow rate may be calculated using the following formula. Exhaust temperature

And intake airflow rate must be determined to calculate the exhaust flow rate. Exhaust temperature and manufacturers maximum backpressure may be approximated using the chart below

$$\frac{(\text{exhaust temp} + 460)}{540} \times \text{intake air flow(cfm)} = \text{exhaust flow}$$

4-CYCLE ENGINE AIRFLOW CALCULATION

$$= \frac{(\text{engine size(cid)} \times \text{rpm})}{3456} \times \text{volumetric effficiency} = \text{intake air flow(cfm)}$$

2-CYCLE ENGINE AIRFLOW CALCULATION

$$= \frac{(\text{engine size(cid)} \times \text{rpm})}{1728} \times \text{volumetric effficiency} = \text{intake air flow(cfm)}$$

Exhaust temp=1000°F (for naturally aspirated 4-cycle engine)

$$\text{Exhaust flow} = \frac{1000+460}{540} \times 111.638$$

$$=31.46CFM$$

$$\text{Corrected flow} = \frac{\text{actual flow} \times (Tin/545)^{0.5}}{(Pin/13.949)}$$

Note that I am using 13.949 because we are measuring everything in psia instead of in inches of mercury, which Turbonetics assumes.

13.949 psia = 28.4 inches mercury absolute.

29.92 inches mercury is atmospheric pressure at sea level, so 29.92 - 28.4 = 1.52 inches mercury vacuum.

That is their standard suction pressure

$$\text{Corrected flow} = \frac{14.553 \times (540/545)^{0.5}}{(14.7/13.949)}$$

$$=13.746lb/min$$

Then the compression ratio= Pout/Pin

$$Pout/Pin = \frac{(20 + 14.7)}{14.7} = 2.36$$

VII ANALYSIS OF TURBO CHARGER COMPRESSOR WHEEL

FINITE ELEMENT METHOD;

The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering schools and industries. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problems rather than exact closed form solution

BASIC COMPONENTS OF SOFTWARE

Pre-processor

- Handles discretization and pre-processing.
- Element properties, assemblage of elements and solution of equations of equilibrium.

Processor

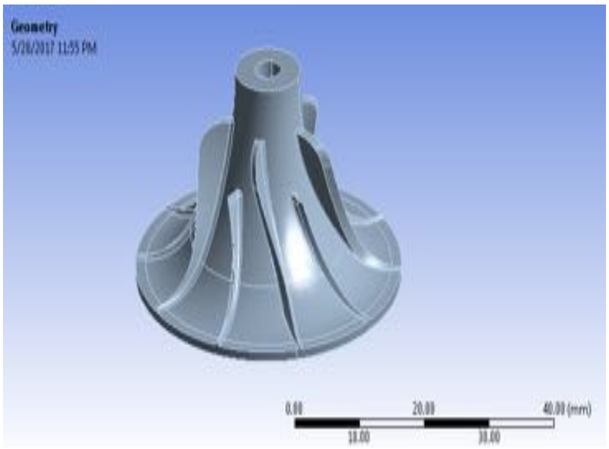
- Handles analysis and processing, which involves computation of element properties, assemblage of elements and solution of equations of equilibrium.

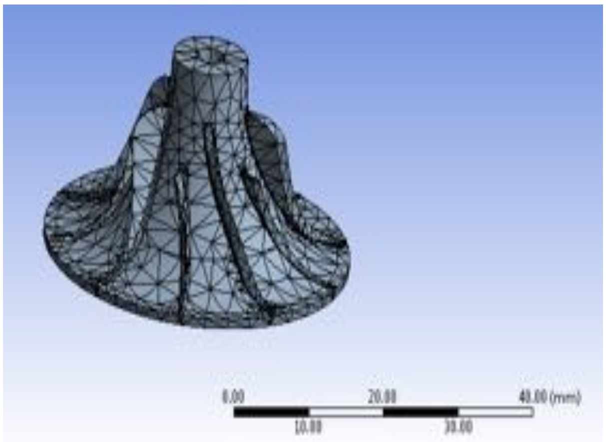
Post- processor

- Accepts analysis results, computes stress and handles post-processing of results through generation of tables/pictures

ANALYSIS OF 5-BLADE COMPRESSOR WHEEL AND DIFFERENT MATERIALS

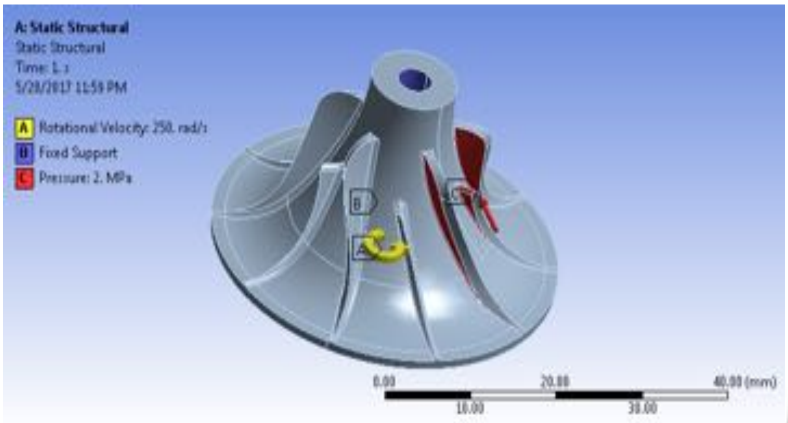
The geomety and the meshed model of the cylinder block is shown in fig



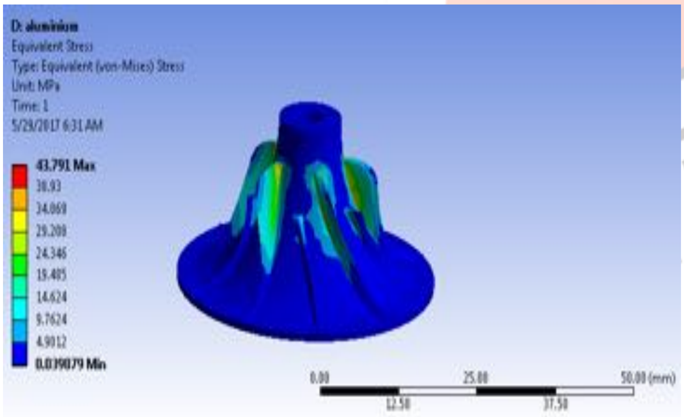


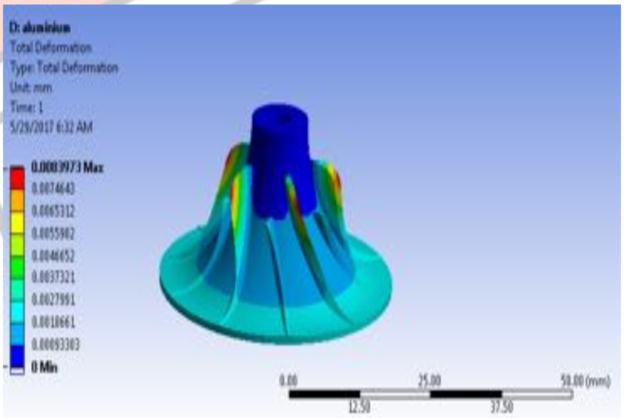
Boundary Conditions

The structural and modal analysis boundary conditions for the 5-blade compressor wheel as shown in the fig



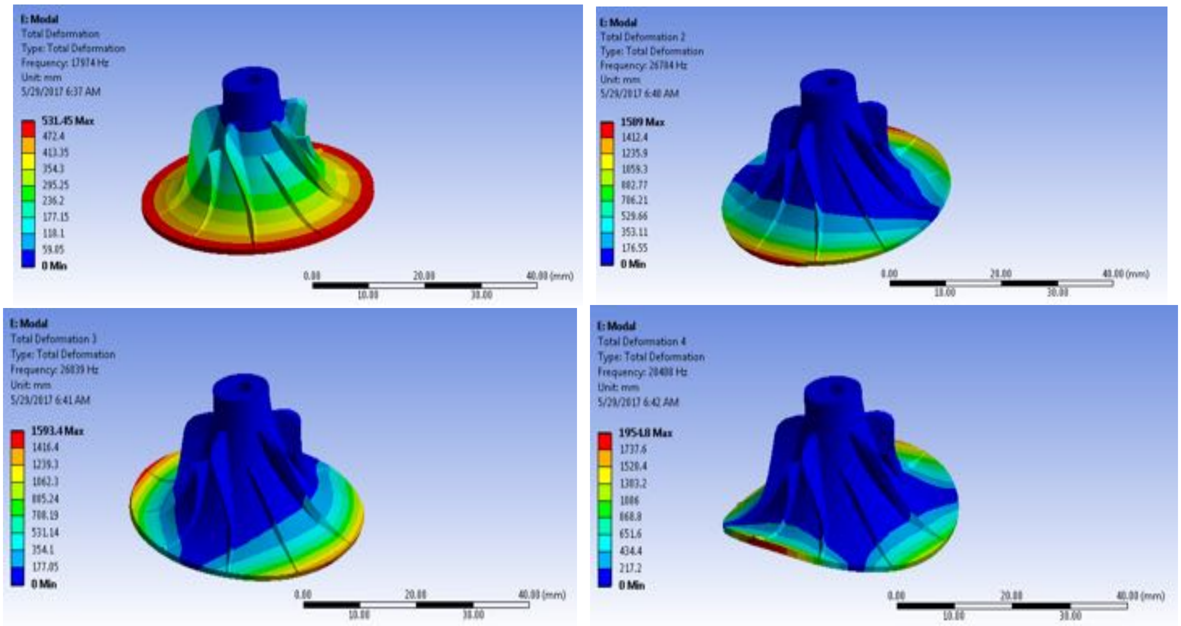
The equivalent stress and the total deformation of the compressor wheel are shown in Fig





MODAL ANALYSIS OF ALUMINUM ALLOY COMPRESSOR WHEEL

The total deformation and the mode shapes of compressor wheel are shown in figure



MODE SHAPES

VIII RESULTS AND DISCUSSION

The turbo charger compressor wheel is analyzed in ANSYS 15.0 by importing the system in to the work bench. Both structural and modal analysis is done on the compressor wheel.

Structural and modal analysis:

Defining the boundary conditions and loading conditions are the important parameters. First of all we have to define the material properties like mass density, young`s modules, thermal conductivity and Poisson's ratio.

Five blade compressor wheel analysis:

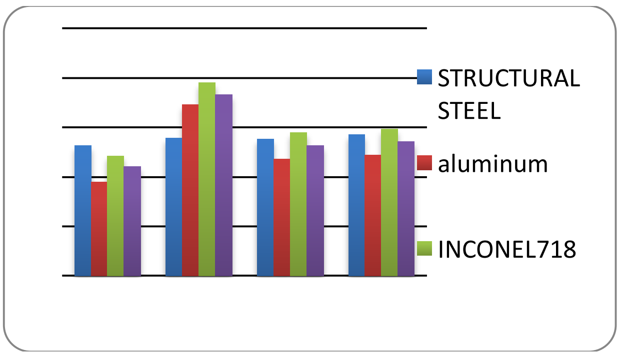
The structural and modal analysis of the compressor wheel are shown in table

		5-BLADE COMPRESSOR WHEEL		NATURAL FREQUENCIES (HZ)				WEIGHT ((gms)
S.NO	**MATERIAL**	**STRESSES (MPA)**	**DEFOR-MATION (MM)**	**MODE -1**	**MODE -2**	**MODE -3**	**MODE -4**	
1	STRUCTURAL STEEL	45.26	0.003015	18098	26447	26483	28222	50.222
2	ALUMINUM ALLOY	43.791	0.008397	17974	26784	26839	28408	18.5
3	INCONEL 718 ALLOY	44.857	0.58676	1278.4	1858	1861.7	1983.5	52.41
4	STAINLESS STEEL	44.409	0.003104	17833	26236	26291	27943	49.583

GRAPHS:

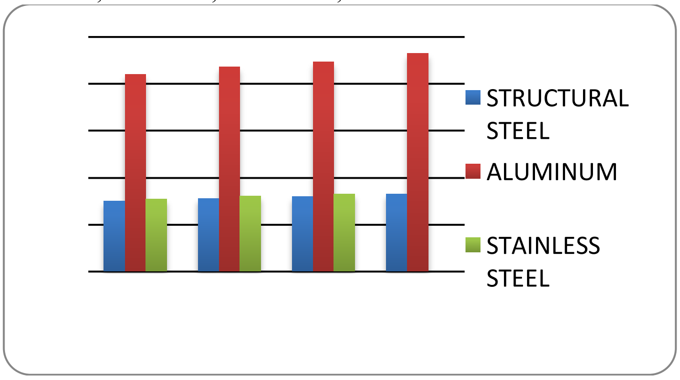
STRESS VS NO OF BLADES

The below graph shows that Variation of stresses on five , six , seven & eight blades compressor wheel of turbo charger of different materials like structural steel,aluminum,inconel718, stainless steel. Least stress is aluminum material



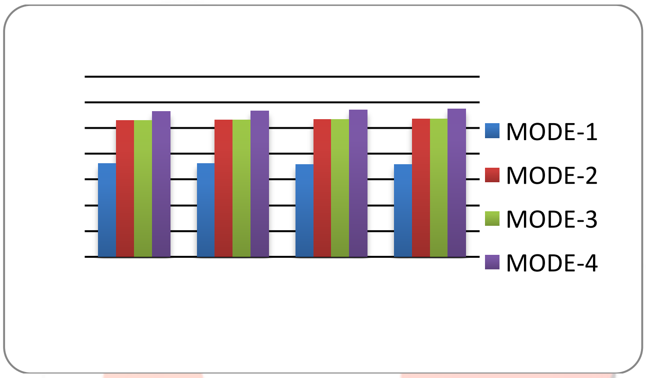
DEFORMATION VS NO OF BLADES

The below graph shows that Variation of deformation on five , six , seven & eight blades compressor **w**heel of turbo charger of different materials like structural steel,aluminum,inconel718, stainless steel. Least deformation is structural steel material



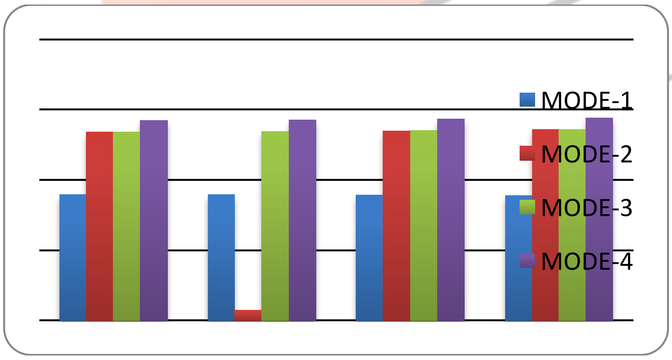
STRUCTURAL STEEL NATURAL FREQUENCIES

The above graph shows that ,frequencies with Variation of modes for 4 different blade designs ie.,5 blades, 6 blades , 7 blades,8blades with material structural steel. While observing all the results 5 blade gives the best.



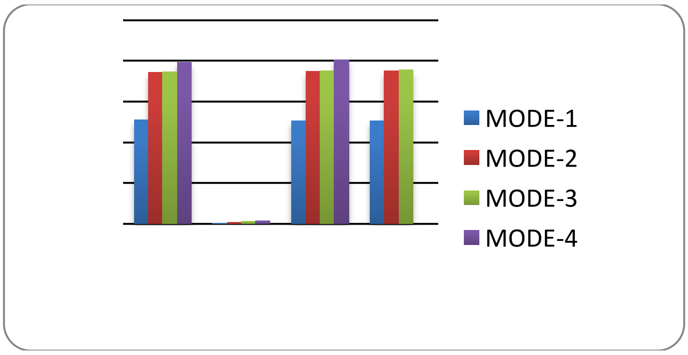
ALUMINUM NATURAL FREQUENCIES

The below graph shows that, frequencies with Variation of modes for 4 different blade designs ie.,5 blades, 6 blades , 7 blades,8 blades with material Aluminium. While observing all the results 6 blade gives the best.



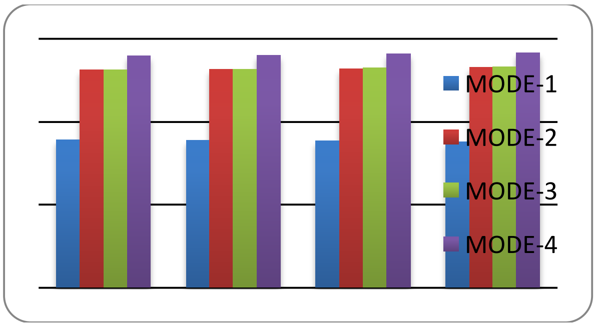
INCONEL 718 ALLOYS

The below graph shows that, frequencies with Variation of modes for 4 different blade designs ie.,5 blades, 6 blades , 7 blades,8blades with material Inconel 718 Alloys. While observing all the results 6 blade gives the best.



STAIN LESS STEEL

The below graph shows that, frequencies with Variation of modes for 4 different blade designs ie.,5 blades, 6 blades , 7 blades,8blades with material stainless steel. While observing all the results 6 blade gives the best.



CONCLUSION

In this project the turbo charger compressor wheel is designed in CREO 3.0 software. The analysis is done on ANSYS workbench. In this analysis was done by changing the geometry of the compressor blades and changing the materials of the compressor wheel. The present used material for the compressor wheel is aluminum. In this project other materials are considered which have more strength and stability.

From the above observations I conclude that out of all four designs five blade stainless steel gives best stresses and deformation results compare with six, seven and eight blade compressor wheel.

From the above observations weight taken in to the considerations five blade aluminum materials gives the best results.

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