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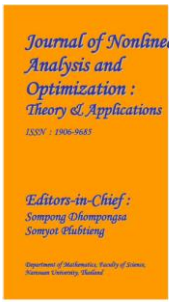

ANALYZING COMPOSITE MATERIALS FOR TURBOCHARGER TURBINE WHEEL DESIGN

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ABSTRACT:
A turbocharger is a turbine that compresses and drives air into a combustion chamber of an internal combustion engine, increasing the volumetric efficiency of a naturally aspirated engine. A compressor is connected to the exhaust turbine and speeds up the exhaust turbine with the help of exhaust gases. This allows a smaller displacement engine to burn more fuel more effectively, resulting in more power being produced. As with a conventional turbocharger, the electric turbocharger spools up and compresses air into the engine when it is activated. 3D modelling software, CREO, is used to create a turbine blade that is then analyzed using ANSYS 14.5 software. The base of the blade is modified to improve cooling efficiency in the design. When designing turbo equipment, material selection is critical since the design is complex and the efficiency is directly linked to the performance of the materials. In this project, two different fluid flow conditions (i.e., laminar and turbulent flow) are considered for present and modified models. Optimization is done by varying the materials Chromium steel, Titanium alloy and Nickel Alloy by performing coupled field analysis (static + thermal) on the turbine blades for both the designs.

I. INTRODUCTION

1.1 Turbo charger:

Turbocharging is a common feature of diesel engines, as it increases overall performance and efficiency. The engine's specific fuel consumption can be drastically decreased by properly utilizing the turbocharger. Compressor impellers and turbine impellers were mounted on either side of the turbocharger. Both impellers must function in succession to compress and expand the air simultaneously. Material selection for impeller design has a considerable impact on overall efficiency. During operation, the impeller material must be able to endure the high pressure of the incoming compressed air. Researchers tested a slew of materials in an effort to boost the diesel engine impeller's efficiency. Turbocharger performance is greatly influenced by the angle of the impeller. Material features of Inconel alloy were used to choose and simulate a new turbocharger design that had a 15% improvement over the current design. Many researchers have also tested the use of nickel alloy and titanium in the impellers of turbochargers. Researchers have also created and experimented with a variety of composite materials in order to fit the unique qualities required by the impellers. The difficulty in converting a composite material for use in impeller production lies in the time- and money-consuming process of near net form machining.

Engineer Alfred Buchi of Switzerland completed the first exhaust gas turbocharger in 1925, introducing a prototype that increased a diesel engine's power by 40 percent, according to one report. However, turbocharging was not commonly acknowledged at the time. With the exception of relatively small diesel engines, it has become important in the last several decades in practically all diesel engines. It is now mandatory. Its limited application in gasoline motors has also resulted in a significant increase in power output and effectiveness. In the same way as other turbo machines, their whole design includes mechanical, aerodynamic, thermal, and acoustic assessments as part of the overall process. Engineers and scientists are still looking for ways to improve their ideas despite being constrained by rules about cost and manufacturing capacity.. Initially, scientists just attempted to translate conceptual designs into usable consumer goods. Turbochargers of this size were intended for naval use, where they were primarily found. Since the turbochargers' performance was a primary priority, their research was focused on thermodynamics. An in-depth study of the dynamics of rotating blades is today an important element of the design process. However, at the time, it was extremely difficult to conduct such an examination. The first turbocharged vehicle machine was designed in 1938.

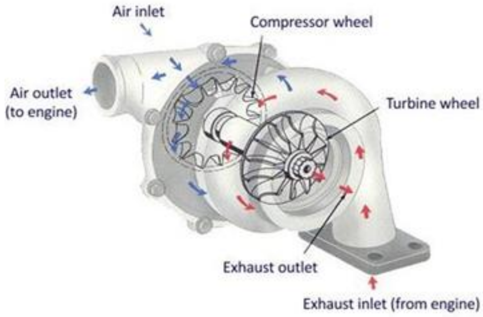

Figure 1.1 Turbo Charger

1.3 Application of Turbo charger

Internal combustion engines use turbochargers (sometimes referred to as "turbos") as air compressors for forced induction. Increasing the mass of air entering the engine is the goal of a turbocharger, just as it is with a supercharger. It is different, though, because a turbocharger is powered by the engine's own exhaust gas turbine. They use the same variety of analyses as other turbo machines, such as mechanical, thermal, and acoustical, in their overall design. Engineers and researchers are still looking for ways to improve their designs while maintaining a balance between the needs and the prices of their work.

However, in the last few decades, it has become needed in all but the smallest diesel engines. Because of this, the power and efficiency of gasoline engines that utilise them have increased significantly. The turbocharger is a one-of-a-kind product. With turbochargers, one of the key issues is the difficulty in producing the angle of curvature at the entrance of the curve inducing blades. Strength and sharpness are vital to its success.

Advantages and Disadvantages of composite materials

The turbocharger comes up with this answer, which is referred to as supercharging. A simple increase in the amount of fuel pumped into each cycle is not enough to achieve this goal, though. In order for the engine to work properly, the air/fuel mixture must be precisely maintained. The engine's efficiency suffers as a result of increased unburned components and decreased combustion efficiency if this step is skipped. This is absolutely at odds with the desired outcome. That's why you need a turbo to "simply" compress additional air into your engine so that you can keep the correct proportions of your combination. A "virtual" cubic capacity is given to the engine, which is more than the actual cubic capacity. Simply explained, turbocharging is a way to boost an engine's power without expanding its overall size. Big diesel engines were already using the basic approach. For example; one may buy chips that can improve power by 100 bhp for select Japanese Cars, such as the Nissan Skyline. In addition, all around the world, on-road speeds were being regulated. Even in the autobahn-blessing country of Germany, most sports vehicles today are electronically limited to a maximum speed of 250 kilometres per hour (155 miles per hour). Big diesel engines were already using the same basic approach. Small turbines powered by the exhaust fumes of the same engine were installed by European carmakers. Air entering the combustion chamber was compressed by this turbine in order to ensure greater explosion and a gain in power. For its part, the fuel injection system ensured that only a predetermined amount of gasoline entered the combustion chamber.

II. LITERAURE REVIEW

D. Ramesh Kumar, B. Shanmugasundaram, 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. The turbine and compressor impeller of a turbocharger will be recommend based on the better material results.

Shujie Liu, Chi Liu, Yawei Hu, SIbo Gao, 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 loads and a dynamic load caused by the centrifugal loads, aerodynamic loads, exciting loads, etc. All these loads are combined with impact loads from collision with particles in the medium, the impeller blade suffers multiple failure modes and this failure modes include abrasion, erosion, stress fatigue, and others.

CH. Satyasai Manikanta, 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 modeling is used when designing this impeller of turbocharger.

M.F. Moreira et, al., [2016] studied about the aluminum 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. This particular wheel presents 14 blades, 7 full blades and 7 small blades. The goal of this study is to check whether the material of the faiure wheels was in accordance with standards, and to identify the fracture mechanisms involved in the premature failure of the wheels. The nine different impeller or compressor wheels were submitted to chemical analysis, microstructural characterization, X-ray diffraction, hardness testing and fractographic examinations.

III. MODELING OF TURBINE WHEEL

his project we are designed the 3D model of the turbocharger turbine wheel by using pro-e software. Eleven and twelve blades of turbine impellers are created by using this software.

3.1 Steps for developing turbo wheel in CREO parametric

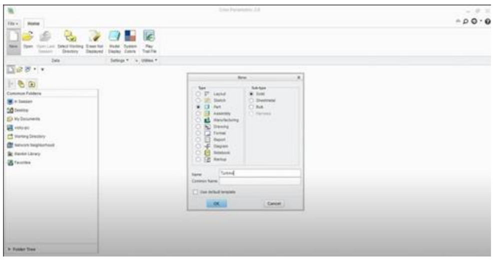

Figure 3.1 Create a file in CREO

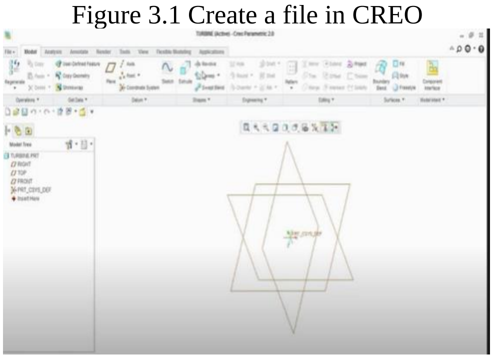

Figure 3.2 CREO workbench

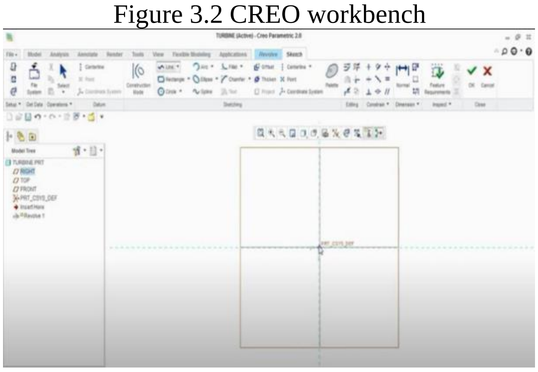

Figure 3.3 Selecting right plane surface

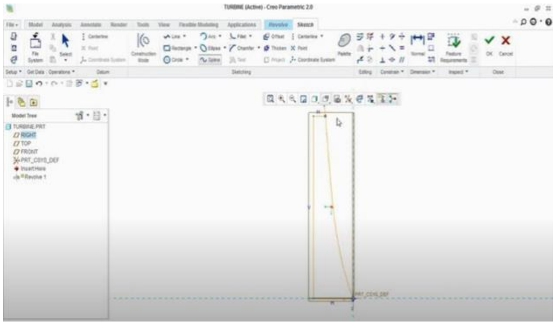

Figure 3.4 Creating base of the turbine

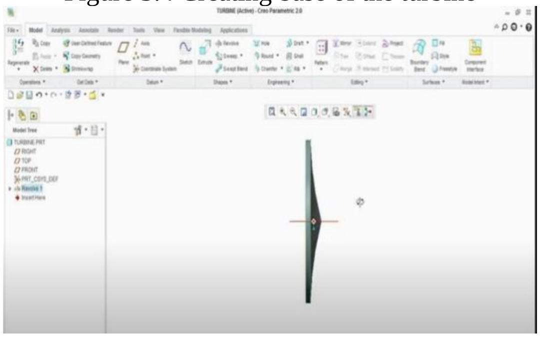

Figure 3.5 applying revolve command

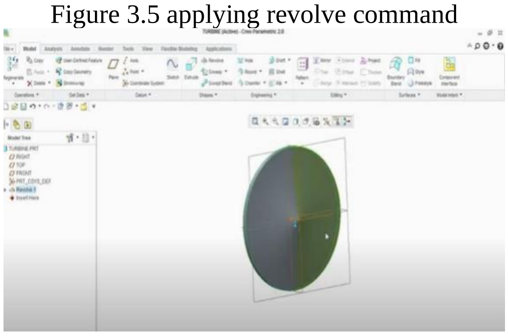

Figure 3.6: Selecting points for turbine blades

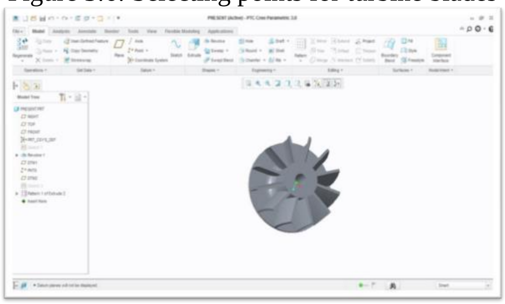

Figure 3.7 Present Model

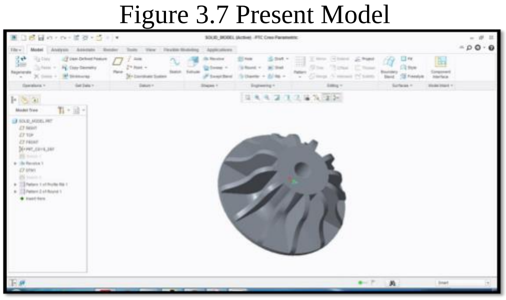

Figure 3.8 Modified model

IV. ANALYSIS OF TURBINE WHEEL

Static, Computational fluid dynamics, and Thermal analysis are performed on turbine wheel by varying materials are Chromium steel, Titanium alloy and Nickel alloy. The results analyzed are deformation, stress, strain, heat transfer coefficient, mass flow rate, heat flow rate, and heat flux

Table 4.1 Material properties

Materials	Density (kg/m^3)	Young's Modulus (GPa)	Poisson's Ratio	Thermal Conductivity(w/m-k)
Chromium steel	7150	245	0.2	60.5
Titanium alloy	4420	110	0.31	21.9
Nickel alloy	8908	150	0.26	70.1

4.1 METHODOLOGY

In all of these approaches the same basic procedure is followed.

During preprocessing

- The geometry (physical bounds) of the problem is defined.
- The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform.
- The physical modeling is defined – for example, the equations of motion + enthalpy + radiation + species conservation
- Boundary conditions are defined. This involves specifying the fluid behaviour and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined.
- The simulation is started and the equations are solved iteratively as a steady-state or transient.
- Finally a postprocessor is used for the analysis and visualization of the resulting solution.

4.2 STATIC ANALYSIS OF TURBINE WHEEL (PRESENT MODEL)

Static analysis is used to determine the strength of turbo charger by using the values of stress strain and deformation. Static analysis has 4 steps to solve the problem

- **Engineering data:** In engineering data we can select the material according to the problem
- Geometry: In geometry we can import the model from design soft ware
- **Model:** In model we can simulate the problem by using meshing and giving boundary conditions
- **Results:** Getting out put results according to the boundary conditions

MATERIAL – NICKEL ALLOY

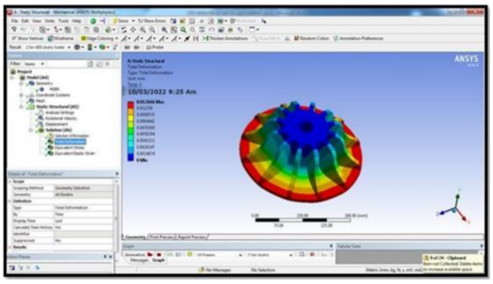

Figure: Deformation of turbine wheel using nickel alloy (modified model)

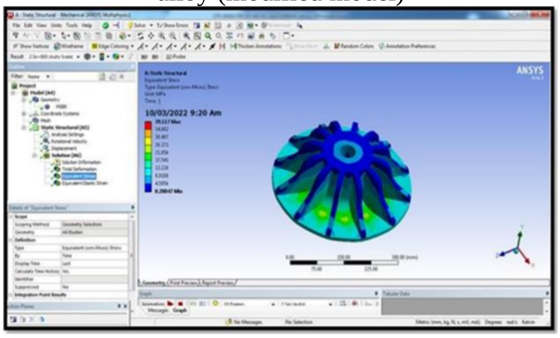

Figure: Stress of turbine wheel using nickel alloy (modified model)

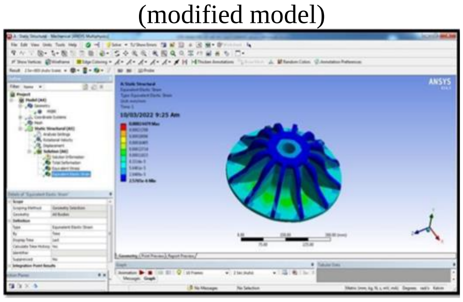

Figure: Strain of turbine wheel using Nickel alloy (modified model)

CFD ANALYSIS OF TURBO CHARGER (PRESENT MODEL)

Now the issues that arises here is building of excessive pressure in an engine block because of turbo charger. This analysis will help to increase the overall volumetric efficiency of the turbo charger. CFD analysis will help us in enhancing the life of the engine. We have also proposed an efficient design of the compressor wheel of the turbocharger to enhance the overall efficiency of the system. This analysis will help to increase the overall volumetric efficiency of the turbo charger. It will help to reduce the overall back pressure. Selection of the turbocharger would be more accurate.

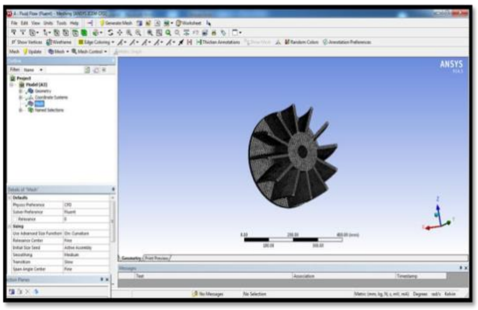

Figure: Meshing model of Turbine wheel

SPECIFYING BOUNDARIES FOR INLET AND OUTLET

Select edge → right click → create named section → enter name → inlet Select edge → right click → create named section → enter name → outlet

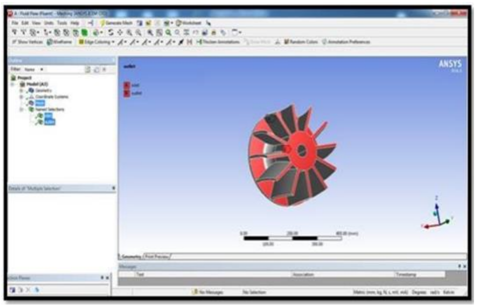

Figure: Specifying boundaries for inlet and outlet

V. RESULTS & DISCUSSIONS

5.1 Static analysis results

The results analyzed from analysis are deformation, stress and strain in Structural analysis.

Table 5.1 Static analysis results

Geometry	**Material**	**Deformation(mm)**	**Stress(N/mm^2)**	**Strain**
Present	Chromium steel	0.054949	43.467	0.00023628
	Titanium alloy	0.066426	25.629	0.0002849
	Nickel alloy	0.065704	49.326	0.00028375
Modified	Chromium steel	0.010477	34.118	0.0002035
	Titanium alloy	0.011804	18.684	0.000238
	Nickel alloy	0.012666	39.117	0.00024479

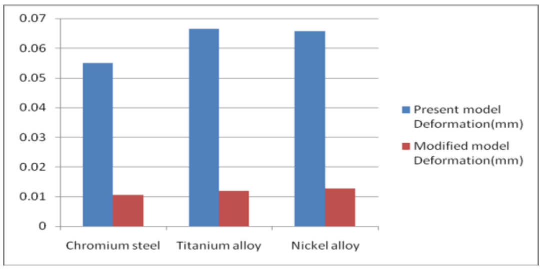

Figure: Comparisons between present and modified models of deformation

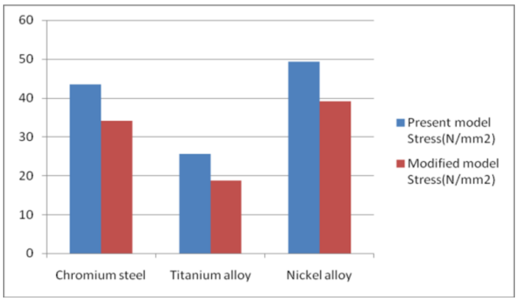

Figure: Comparison between present and modified models of stresses

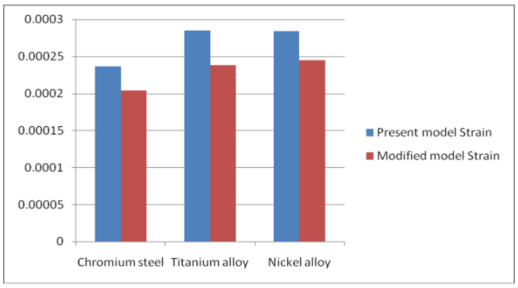

Figure: Comparison between present and modified models of strain

The above shown graphs clearly show the comparison among the structural properties between the three materials on present model and modified model of turbine wheels, the titanium alloy seems to undergo the moderate deformation and minimum stress compared to nickel alloy and chromium steel in modified model compared to present model. Thus, the modified turbine wheel could withstand more stress if titanium alloy is used

CFD results

Table 5.2 Computational Fluid Dynamics Results

Geometry	Inlet velocity(m/s)	Pressure (Pa)	Velocity (m/s)	Temperature(k)	Heat transfer coefficient (w/m^{2}k)	Mass flow rate (kg/s)	Heat transfer rate (watt)
Present	320(laminar)	1.74e+05	8.32e+02	1.20e+03	2.42e+03	0.0040	93142
	4200(Turbulent)	1.76e+05	1.25e+03	1.20e+03	3.21e+03	0.0055	127789
	5400(Turbulent)	3.07e+05	1.67e+03	1.20e+03	3.93e+03	0.00714	160419
Modified	320(laminar)	2.09e+05	1.10e+03	1.20e+03	2.66e+03	0.0020	123244
	4200(Turbulent)	4.10e+05	1.54e+03	1.20e+03	3.46e+03	0.0034	160926
	5400(Turbulent)	6.76e+05	1.98e+03	1.20e+03	4.17e+03	0.0038	175867

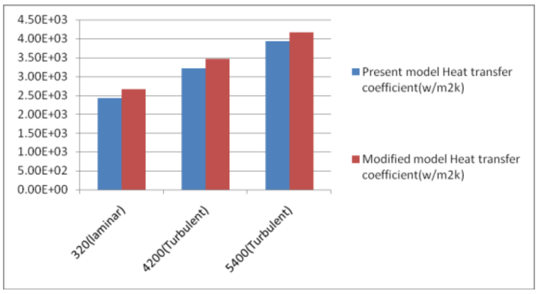

Figure: Comparison between present and modified models of heat transfer coefficient

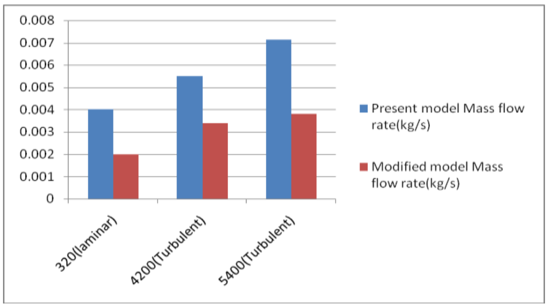

Figure: Comparison between present and modified models of mass flow rate

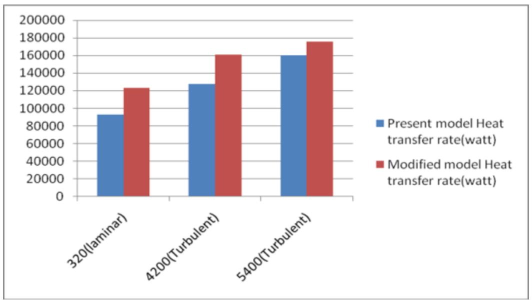

Figure: Comparison between present and modified models of heat transfer rate

By observing CFD analysis results, the heat transfer rate and heat transfer coefficient are more for modified model compared to present model, mass flow rate is less for modified model compared to present model. So, the modified model is better than present model.

Thermal analysis results

Table: Thermal analysis results

Geometry	Material	Temperature(K)		Heat flux W/mm^2
		MIN	MAX	
Present	Chromium Steel	302.22	1203.4	18.50
	Titanium alloy	301.22	1203.6	8.966
	Nickel alloy	305.23	1203.4	20.012
Modified	Chromium Steel	306.63	1203.5	19.324
	Titanium alloy	173.54	1203.1	9.1194
	Nickel alloy	308.12	1203.5	21.218

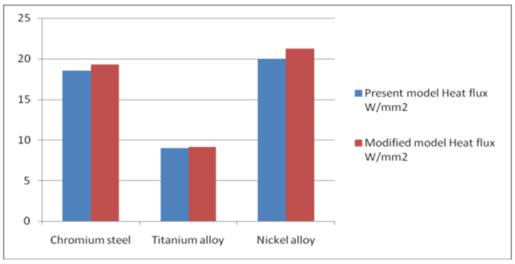

Figure: Comparison between present and modified model of heat flux

The above graphs clearly show the comparison among the thermal properties of the three materials in the present and modified models. The heat flux is maximum for titanium alloy when compared to nickel alloy and chromium steel in modified model compared to present model. So, the modified model is best.

VI. CONCLUSION

In this project, turbo charger turbine wheel is designed and modeled in 3D modeling software CREO and analysis is done by using ANSYS software. The design is modified by changing the base of the blade to increase the cooling efficiency.

By observing the static analysis results, the deformation, stress and strain values are less for modified model compared to present model.

By observing Thermal analysis results, the heat flux value more for modified model compared to present model.

By observing CFD analysis results, the heat transfer rate and heat transfer coefficient are more for modified model compared to present model, mass flow rate is less for modified model compared to present model.

From the above data observed that minimum stress and moderate deformation is obtained for titanium alloy for modified model. Thus, the modified turbine wheel could withstand more stress if titanium alloy is used. The thermal properties of the three materials in the present and modified models. The heat flux is maximum for titanium alloy when compared to nickel alloy and chromium steel in modified model. So the modified model is best. By observing CFD results the heat transfer coefficient and heat transfer rate is more for modified model at all velocities. So from the above results summary concluded that titanium alloy was found better than chromium steel and nickel alloy for modified model.

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