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DESIGN OF TURBOCHARGER AND ANALYSIS OF IMPELLER

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***Abstract*—** In this project we design the turbocharger and analysis the turbocharger turbine wheel. The main objective of this study is to explore the analysis of a turbocharger turbine wheel with design and material optimization. The study deals with structural and steady thermal analysis. A proper Finite Element Model is developed using Creo 3.0. In this project we have taken 12 blade turbocharger turbine wheels for designing and material optimization

We are designed the 3D model of the turbocharger turbine wheel by using Creo 3.0 software and the analysis taken by different materials. This project we are analyzing the pressure acting on the turbocharger impeller turbine wheel by the four materials namely inconel alloy 740, inconel alloy 783, Inconel 625 and incoloy 909. Then the thermal analysis is done to determine the total heat flux in the 12 blades for the given temperature conditions. The temperature acting on the surface of the turbocharger impeller turbine wheel is applied. The results were also used to determine the total heat flux for a particular material.

Keywords — Turbocharger, compressor, turbine, PTC Parametric

I. INTRODUCTION

A turbocharger, or turbo (colloquialism), from Greek "τύρβη" ("wake"), (also from Latin "turbo" ("spinning top")) is a turbine-driven forced induction device that increases an engine's efficiency and power by forcing extra air into the combustion chamber. This improvement over a naturally aspirated engine's output results because the turbine can force more air, and proportionately more fuel, into the combustion chamber than atmospheric pressure alone. This model popularized the turbocharger in North America and set the stage for later turbocharged models from Porsche on the 1975-up 911/930, Saab on the 1978-1984 Saab 99 Turbo, and the very popular 1978-1987 Buick Regal/T Type/Grand National. Today, turbo charging is common on both Diesel and gasoline-powered cars. Turbo charging can increase power output for a given capacity or increase fuel efficiency by allowing a smaller displacement engine. The 'Engine of the year 2011' is an engine used in a Fiat 500 equipped with an MHI turbocharger. This engine lost 10% weight, saving up to 30% in fuel consumption while delivering the same HP (105) as a 1.4 liter engine.

Turbochargers were originally known as turbo superchargers when all forced induction devices were classified as superchargers. Nowadays the term supercharger is usually applied to only mechanically driven forced induction devices. The key difference between a turbocharger and a conventional supercharger is that the latter is mechanically driven by the engine, often through a belt connected to the crankshaft, whereas a turbocharger is powered by a turbine driven by the engine's exhaust gas.

The idea of turbo charging at that time was not widely accepted. However, in the last few decades, it has become essential in almost all diesel engines with the exception of very small diesel engines.

Their limited use in gasoline engines has also resulted in a substantial boost in power output and efficiency. Their total design, as in other turbo machines, involves several analyses including: mechanical, aerodynamic, thermal, and acoustic. Engineers and researchers still seek ways to improve their designs while governed by rules of cost and manufacturing capabilities. At first, scientists simply attempted to develop the conceptual designs into reliable products for end users. These turbochargers were very large and were mostly destined for marine applications. Because of this, their studies were based on the output performance of the

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turbochargers with focus on the thermodynamics of the process.

II. LITERATURE REVIEW

The objective of this paper is to be design the impeller of a turbocharger for a diesel engine to increase its power and efficiency, and showing the advantage of designing twelve blade turbine of a turbocharger. An investigation in to usage of new materials is required. The investigation can be done by using Creo 3.0 software. The Creo 3.0 is used for modelling the impeller and analysis. Creo 3.0 is dedicated finite element package used for determining the variation of stresses, strains, deformation and thermal across profile of the impeller. An attempt has been made to investigate the effect of temperature, pressure and induced stresses on the impeller. Turbine blade is critical part of turbocharger which has shown increasing growth of failure damaging turbine disk. It deals with Static and thermal analysis of turbine blade which is made up of INCONEL 718 to estimate its performance. The causes of failure for turbine blade have also been found out.mm. A structural analysis has been carried out to investigate the stresses and displacements of the turbine blade. A thermal analysis has been carried out to investigate the thermal gradient and thermal stress. The analysis has been done using Creo 3.0 software. The analysis revels come of the critical areas in different component of turbo machine. Also this this gives the detail steps on how to do analysis of turbo machines arts using Creo 3.0. Current study can be extend further to analytical analysis of high speed rotor using Finite Element Method.

They found that the heat transferred to the compressor increases the compressor outlet temperature increases the compressor outlet temperature, compared if the compressor was adiabatic. Shaaban and Seume identified the main parameters affecting the deterioration of the compressor efficiency in hot conditions through a theoretical and experimental investigation.

Based on the literature review, it is understood that the major components in turbocharger are suffering from huge pressure and load. So that it is essential to study static analysis of various components of turbocharger in order to select proper material. In this study designing of impeller are designed and simulated using CREO PARAMETRIC software.

III. DIFFERENT TYPES OF TURBOCHARGER

TYPES OF TURBOCHARGER:

1. Single-turbo
2. Twin-turbo
3. Twin-scroll Turbo
4. Variable Geometry Turbo
5. Electric turbo

1) Single-turbo:

Single turbochargers alone have limitless variability. Differing the compressor wheel size and turbine will lead to completely different torque characteristics. Large turbo will bring on high top-end power, but smaller turbo will provide better low-end grunt as they spool faster. There are also ball bearing and journal bearing single turbo.

2) Twin-turbo:

Just like single turbochargers, there are plenty of options when using two turbochargers. We could have a single turbocharger for each cylinder bank (V6, V8, etc.). Alternatively, a single turbocharger could be used for low RPM and bypass to a larger turbocharger for high RPM (I4, I6, etc.). We could even have two similarly sized turbo where one is used at low RPM and both are used at higher RPM.

3) Twin-scroll turbo

Twin-scroll turbochargers are better in nearly every way than single-scroll turbo. By using two scrolls, the exhaust pulses are divided. For example, on four cylinder engines (firing order 1-3-4-2), cylinders 1 and 4 might feed to one scroll of the turbo, while cylinders 2 and 3 feed to a separate scroll. In a traditional single-scroll turbo manifold, the exhaust pressure from cylinder 1 will interfere with cylinder 2 pulling in fresh air since both exhaust valves are temporarily open, reducing how much pressure reaches the turbo and interfering with how much air cylinder 2 pulls in. By dividing the scrolls, this problem is eliminated.

4) Variable Geometry Turbocharger

Internal vanes within the turbocharger alter the area-to-radius (A/R) ratio to match the RPM. At low RPM, a low A/R ratio is used to increase exhaust gas velocity and quickly spool up the turbocharger. As the revs

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climb, the A/R ratio increases to allow for increased airflow.

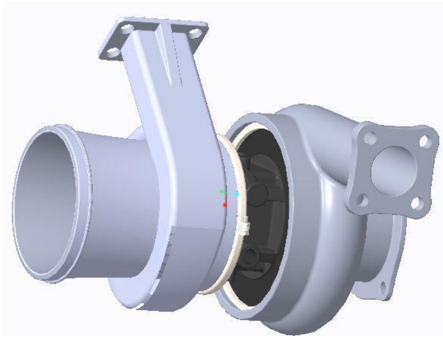


Fig.1: Turbocharger 3D model

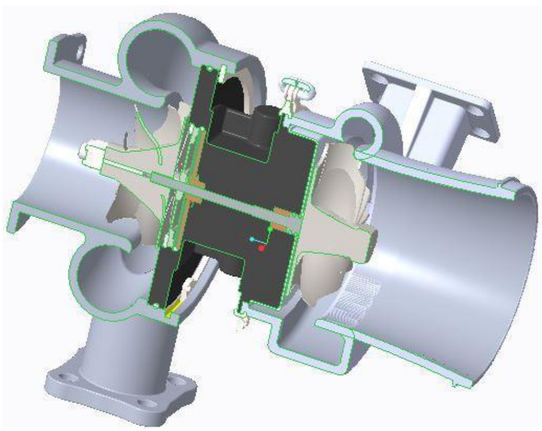


Fig .2: Turbocharger 3D cut section view

IV. MODELLING OF TURBOCHARGER

A reduced order turbocharger model developed consisting of an assembly of bodies of known geometry parameters. Such simplified model was obtained by means of progressive steps: firstly a full 3D-CAD model of the turbocharger was developed and then by analysis of the overall turbocharger configuration, the geometry was simplified to an assembly of three cylindrical bodies representing the turbine, the bearing housing and the compressor.

Finite element analysis overview

Finite element analysis (FEA) involves solution of engineering problems using computers. Engineering structures that have complex geometry and loads, are either very difficult to analyze or have no theoretical solution.

A. Analysis:

Analysis plays main role for studying the impeller in various conditions and after designing the impeller it is necessary to analyse the impeller for study their stresses and strains in different using materials for studying the best suitable material for impeller. Type of analysis is to select and in this project structural analysis is carrying out for impeller. Analysis is carried separately for each using material and analysing their deformation ranges and stresses and strains .This analysis is carried in three stages called preprocessor, solution processor and post processor. Each stage is having its own characteristics for analysing. After analysis of each using material impeller designing, the suitable material is selected for impeller manufacturing according to necessary conditions.

B. Materials

In the Turbo Charger used in four types of materials,

- ✓ **Inconel 740**
- ✓ **Inconel Alloy 783**
- ✓ **Incoloy 909**
- ✓ **Inonel 625**

1) INCONEL 740

It is nickel-base and solid solution strengthened by its content of cobalt. It exhibits excellent resistance to high temperature corrosion due to the effects of chromium. During heat treatment, niobium, aluminum, and titanium form the gamma prime precipitates required for strengthening. INCONEL alloy 740 exhibits high strength at elevated temperatures.

Table.1: Chemical properties for INCONEL 740

C	Ni	Cr	Mo	Co	Al	Ti	Nb	Mn	Fe	Si
0.03	Bal	25	0.5	20	0.9	1.8	2.0	0.3	0.7	0.5

Table.2: Material Properties for INCONEL 740

PARAMETER	VALUES
Density	8050 kg/m^3
Poisson's ratio	0.35
Young's Modulus	221 Gpa
Thermal Conductivity	10.2 w/m°C
Specific Heat	449 J/Kg°C
Yield Strength	313.7 Mpa
Tensile Strength	796.4 Mpa

2) INCONEL ALLOY 783

INCONEL alloy 783 has high mechanical properties at room temperature and retains much of its strength at temperatures to about 1300°F (704°C). All mechanical properties given here are for the standard heat treatment: Solution anneal at 2050°F (1121°C)/1 hr, air cool, plus "beta age" at 1550°F (845°C)/4 hr, air cool to room temperature, plus age harden at 1325°F (718°C)/8 hr, furnace cool at 100°F (55°C)/ hr to 1150°F (621°C)/8 hr, and air cool.

Table.3: Chemical properties for INCONEL ALLOY 783

Cr	Ni	Fe	Nb	Al	Co	B	C	Mg	Si	P	S	Ti	Cu
3.5	30	27	3.5	6	Remainder	0.012	0.03	0.5	0.5	0.015	0.005	0.4	0.5

The alloy's expansion rate is about half the rate of other alloys having comparable strength. At the inflection point, this is in the region of 800°F (425°C), the alloy changes from ferromagnetic to paramagnetic and displays higher expansion coefficients with increasing temperature.

Table.4: Material property for INCONEL ALLOY 783

PARAMETER	VALUES
Density	7810 kg/m^3
Poisson's ratio	0.31
Young's Modulus	177 Gpz
Thermal Conductivity	10.1 w/m°C
Specific Heat	445 J/Kg°C
Yield Strength	779 Mpa
Tensile Strength	1194 Mpa

The alloy changes from ferromagnetic to paramagnetic and displays higher expansion coefficients with increasing temperature. The combination of low expansion and constant elastic modulus, in conjunction with relatively high thermal conductivity, makes INCOLOY alloy 909 highly resistant to thermal fatigue and thermal shock.

3) INONEL 625

Inconel Alloy 625 is a nickel-based super alloy that possesses high strength properties and resistance to elevated temperatures. It also demonstrates remarkable protection against corrosion and oxidation. Its ability to withstand high stress and a wide range of temperatures, both in and out of water, as well as being able to resist corrosion while being exposed to highly acidic environments makes it a fitting choice for nuclear and marine applications. Some modifications were made to its original composition that has enabled it to be even more creep-resistant and weld able. Because of this, the uses of Inconel 625 have expanded into a wide range of industries such as the chemical processing industry, and for marine and nuclear applications to make pumps and valves and other high pressure equipment.

Table.5: Chemical properties for INONEL 625

Cr	Mo	Co	Nb+Ta	Al	Ti	C	Fe	Mn	Si	P	S	Ni
23	10	1	4.15	0.4	0.4	0.1	5	0.5	0.5	.015	.015	Bal

C. Material property

Table.6: Material property for INONEL 625

PARAMETER	VALUES
Density	8440kg/m^3
Poisson's ratio	0.30
Young's Modulus	207Gpa
Thermal Conductivity	10.1w/m°C
Specific Heat	410 J/Kg°C
Yield Strength	528 Mpa
Tensile Strength	992 Mpa

V. ANALYSIS OF TURBINE IMPELLER

For turbine impeller 4 materials investigation is done using structural analysis and thermal analysis.

The variation of von misses stress, Max principal strain, and deformation for four different materials of turbine impellers. Using structural analysis.

The variation of temperature and total heat flux in turbine wheel for four different materials by using steady state thermal analysis.

A. MESHING IN CREO 3.0

Turbine blade model is imported in Creo stimulation, and is meshed properly in Creo parametric 3.0 to divide it into elements and nodes. Tetra mesh is used for turbine blade, and element size length is 1 mm. Quality checks and mesh optimization for elements were also performed taking into consideration of aspect ratio, distortion, stretch.

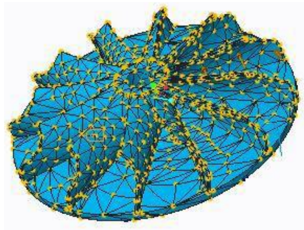


Fig.3 Meshed impeller

B. STRUCTURAL AND THERMAL ANALYSIS OF BLADES

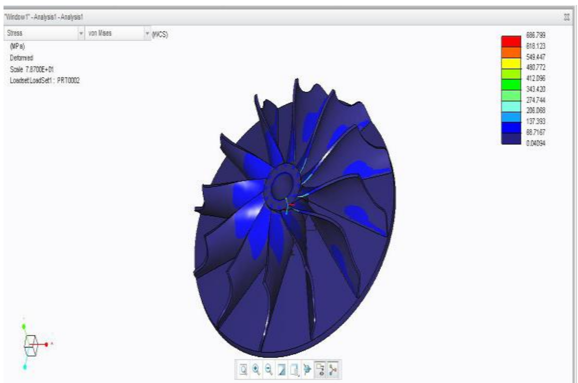


Fig.4 Stress analysis for INCONEL 740

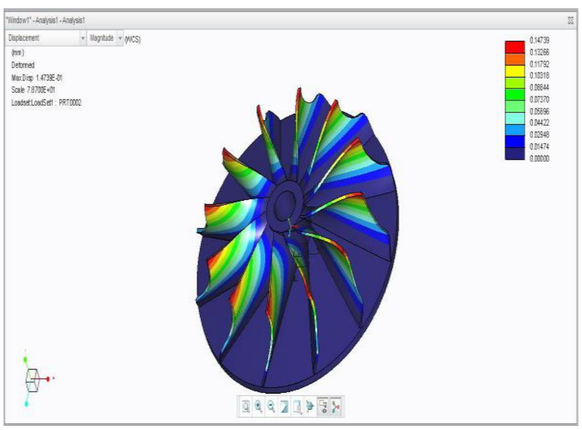


Fig.5 Stress analysis for INCONEL 740

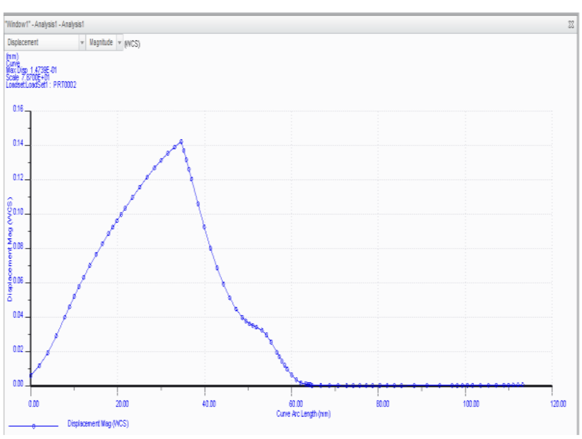


Fig.6 Variation of displacement induced in the blade along the length of the blade

C. Displacement Analysis

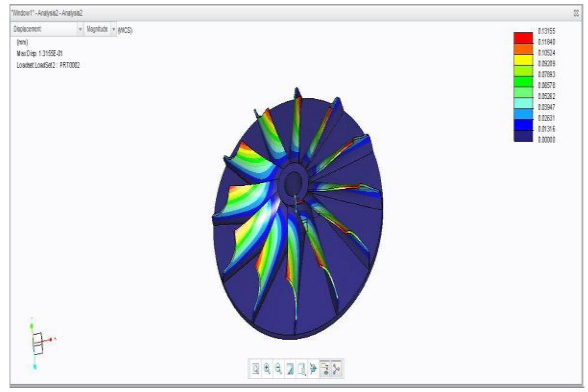


Fig.7 Displacement analysis for INCONEL 783

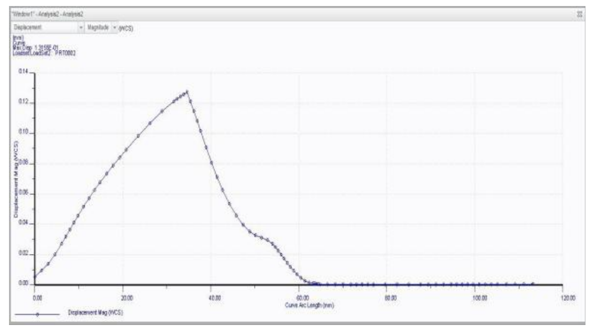


Fig.8 Variation of displacement induced in the blade along the length of the blade

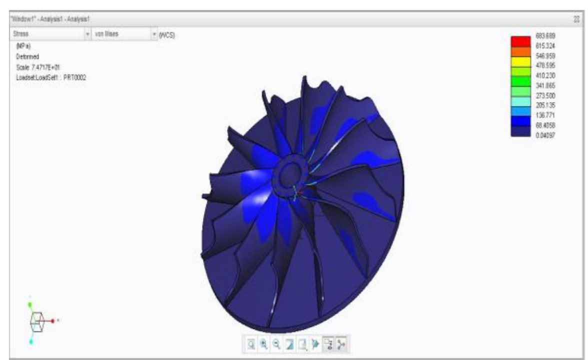


Fig.9 Stress analysis for INCONEL 625

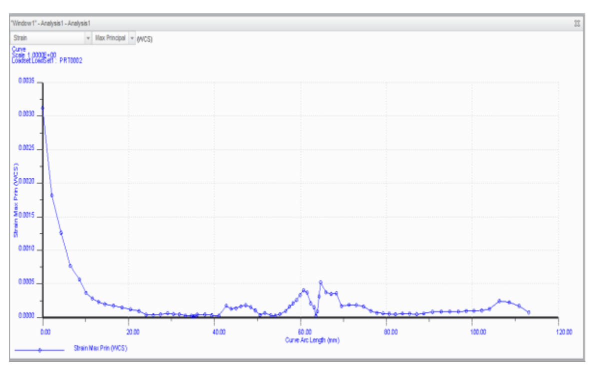


Fig.10 Variation of stress induced in the blade along the length of the blade

D. INCOLOY 909

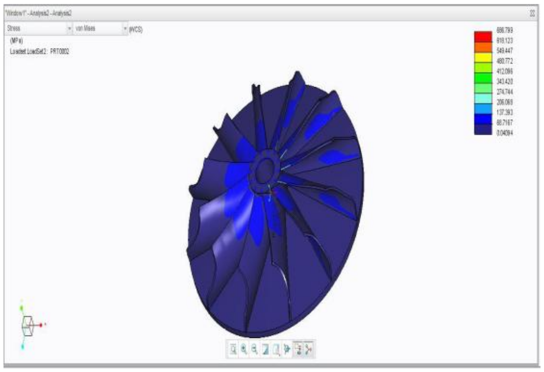


Fig.11 Stress analysis for INCOLOY 909

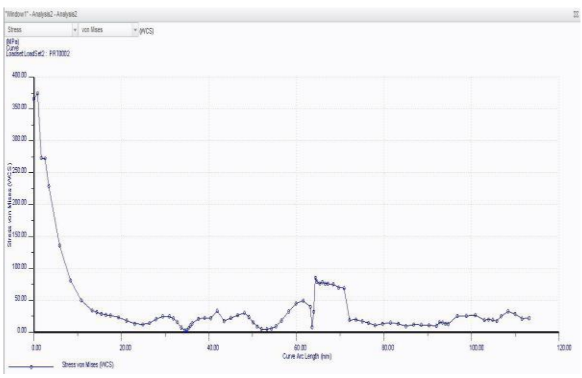


Fig.12 Variation of stress induced in the blade along the length of the blade

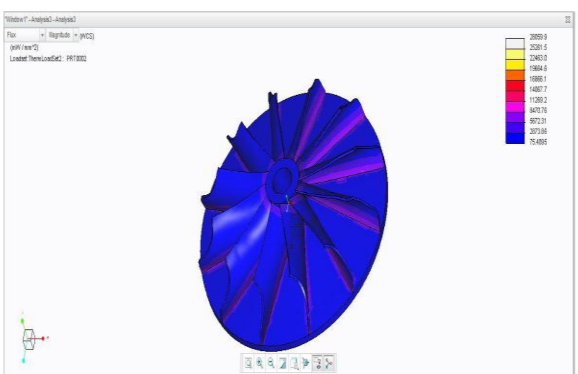


Fig.13 Heat flux for INCOLOY 909

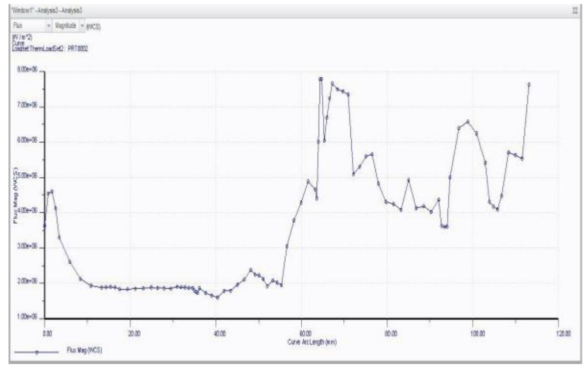


Fig.14 Variation of heat flux induced in the blade along the length of the blade

VI. RESULT AND DISCUSSION

1) COMPARSION WITH DIFFERENT MATERIALS

Static analysis has been carried out to predict stress, strain and displacement shows result for von mises stress, stress in x-direction, stress in y-direction, stress in z-direction, displacement in all directions .Thermal analysis has been carried out to predict results. This shows the result for thermal heat flux in turbine blade and also shows the distribution of temperature on surface of turbine blade.

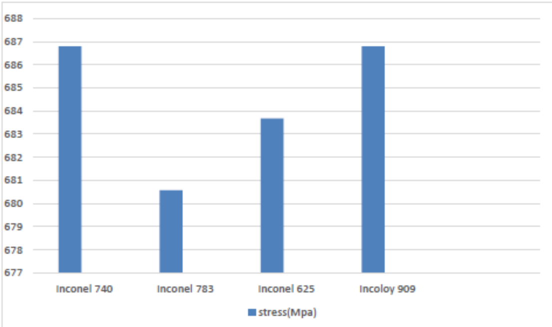
Table.7: Comparison of various parameters with different materials

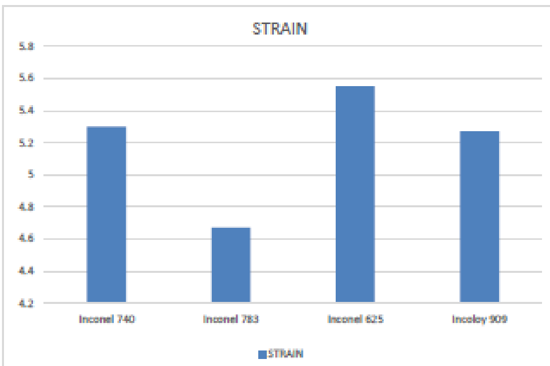
MATERIAL	STRESS (Mpa)	STRAIN (x10^-3)	DISPLACEMENT (mm)	HEAT FLUX (mW/mm^2)
Inconel 740	686.79	5.30	0.14739	23112
Inconel 783	680.57	4.67	0.13155	23682
Inconel 625	683.68	5.55	0.15525	23589
Incoloy 909	686.79	5.27	0.14647	28059

Comparing the four materials inconel alloy783 turbine wheel has the low values of total deformation and also the heat flux values high over incoloy alloy 909 and low compared to Inconel 740.Incoloy 909 has high heat flux values and deformation values. Because of its high deformation values it.

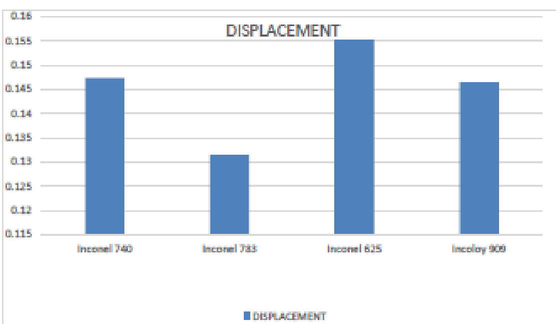
2) GRAPH RESULT

A. Stress comparison





B.Strain comparison



VII. CONCLUSION

Turbine rotor assembly is more vulnerable to failure due to structural and thermal load. Distribution of stress along blade was studied by software and it shows that critical region of turbine blade which is between hub and blade requires careful attention. Maximum deformation occurs at tip section of blade. Periodic maintenance is necessary to satisfy prescribed conditions of turbocharger like clearances, balancing, exhaust gas temperature to avoid vibrations. The rotor misbalancing need to look upon critically while carrying out analysis because change in thickness of blade seriously imbalance rotor causing rpm of rotor to be fluctuating and whirling of shaft. Structural and thermal analysis is carried out and maximum stress induced is within safe limit. Analyzing results for turbocharger turbine wheel under pressure and temperature are listed in the Table 10.9. Analysis has been carried out on turbine wheel and four materials (Inconel 740, Inconel 783 and Inconel 625 and Incoloy 909). The results such as structural analysis of displacement, stress, and strain for each material are determined and thermal analysis of heat flux for each material are determined. From the above analysis, finally we have concluded the Inconel material is suitable and best material for manufacturing of turbocharger turbine wheel compare to other materials.

REFERENCES

[1] V.R.S.M. Kishore Ajjarapu, K. V.P.P.Chandu, D.M.Mohanthy Babu, "Design and analysis of the impeller of a turbocharger for a diesel engine" International Journal of Advanced Engineering Research and studies, Vol. II, Oct.-Dec 2012, pp 46-49.
[2] Static and Thermal Analysis of Turbine Blade of Turbocharger Kamlesh Bachkar, W.S. Rathod M.Tech Student, Assistant Professor Department of Mechanical Engineering, Veermata Jijabai Technological Institute, Mumbai, Maharashtra, India.
[3] Watson, N. and Janota, M. S., 1982, Turbocharging the Internal Combustion Engine,
[4] Wiley,New York. Gunter, E. G. and Chen, W. J., 2005, ―Dynamic Analysis of a Turbocharger in Floating Bushing Bearings,‖ Proc. 3rd International Symposium on Stability Control of Rotating Machinery, Cleveland,OH.
[5] Gunter, E. G. and Chen, W. J., 2000, DyRoBeS© Dynamics of Rotor Bearing Systems User's Manual, RODYN Vibration Analysis, Inc., Charlottesville, VA.
[6] Holmes, R., Brennan, M. J. and Gottrand, B., 2004, ―Vibration of an Automotive Turbocharger – A Case Study,‖ Proc. 8th International Conference on Vibrations in Rotating Machinery, Swansea, UK, pp 445- 450