Analysis of an Impeller in A Turbocharger

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ABSTRACT

In this study, an impeller is taken from a turbocharger, and it is subjected to rotational velocity. The induced stresses and strains are taken and tabulated. In this paper, an effort is made to see the best material among the 4 materials used for the impeller. The materials used are Structural Steel, Gray Cast Iron, Titanium alloy, Aluminium Alloy, and Inconel 718 superalloy. The model of the impeller is created in the Design Modeler software of the ANSYS 2021 R1. The add-in of Bladegen is also used in Design Modeler to create the impeller.

KEYWORDS: ANSYS, ANALYSIS, BLADEGEN, IMPELLER, STATIC STRUCTURAL

INTRODUCTION

Turbochargers are forced induction devices used to pump air into the internal combustion engines. They were invented back in the 1920s but made an entry into the commercial automobile market in the 1970s during the Oil Crisis of 1973 and the 1977 Clean Air Amendments. These are generally used in diesel engines for increasing the power output. It has two impellers, one in the turbine part of the turbocharger and another in the compressor part of the turbocharger. It relies on the exhaust gas pressure of the engine to run the turbocharger. They have to run simultaneously to expand and compress air continuously. The impellers must be made of suitable materials to withstand the pressurized air at the working operations.

Usage of suitable material increases the overall efficiency of the whole component by a margin. Many materials were researched by scientists to improve the performance of the impeller to improve the overall efficiency of the component when used in a diesel engine. A Superalloy known as Inconel is simulated and tested upon by researchers and it is found a 15% increase in efficiency over conventional turbochargers. Many alloys are tried and tested for the same purpose. Among them, Titanium alloy and Aluminium Alloy are also found to be efficient enough to show a difference in performance from conventional materials like Structural steel and Gray Cast Iron. But the creation of these alloys and superalloys is a time-consuming process and machining these impellers are not easy as well. So, existing alloys and materials are taken for this study. The properties are taken for these materials and analysis is considered. The model is created in Design Modeler in ANSYS, using Bladegen add-in. The model created is taken and static structural analysis is done by approximating the substance properties. The structural stresses and strains are noted down and analyzed.

PURPOSE OF THE STUDY

- to create the model in Design modeler using Bladegen
- to execute static structural analysis on the said impeller
- to tabulate and analyze the results to determine the best material to be used for making an Impeller.

EXPERIMENTATION

The dimensions of the impeller are assumed considering the dimensions of an impeller used in the real-life turbocharger. The dimensions are used to create a 3D model of the impeller in Design Modeler as shown in fig. 1.

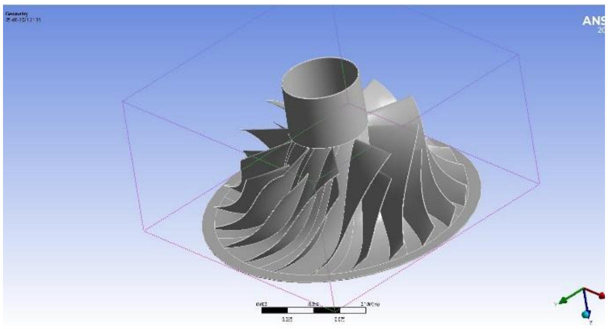

Fig. 1 Impeller model design.

The properties of the materials used in the study are tabulated in table. 1.

The finite element analysis was conducted for each material separately. Static Structural Analysis was conducted in ANSYS version 2021 R1. The analysis for each material is discussed in detail in further parts of this study. The impeller is loaded into the ANSYS Static structural software. The model is then finely divided into tetrahedral units to derive a fine and accurate result. The image for the mesh of the impeller is shown below in fig. 2.

MATERIAL	DENSITY (Kg/m^3)	YOUNG'S MODULUS (Pa)	POISSON'S RATIO
STRUCTURAL STEEL	7850	$2*10^{11}$	0.3
GRAY CAST IRON	7060	$6.6*10^{11}$	0.211
TITANIUM	4430	$1.138*10^{11}$	0.342
ALUMINIUM ALLOY	2710	$7*10^{11}$	0.33
INCONEL 718	8220	$2*10^{11}$	0.294

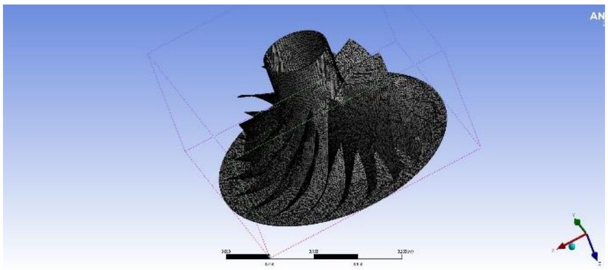

Fig 2. Meshed model of Impeller

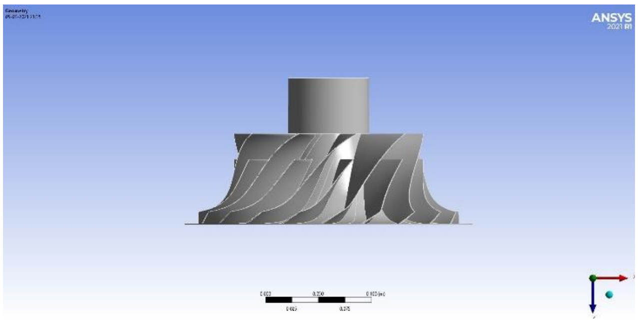

Fig 3. Side view of the Impeller.

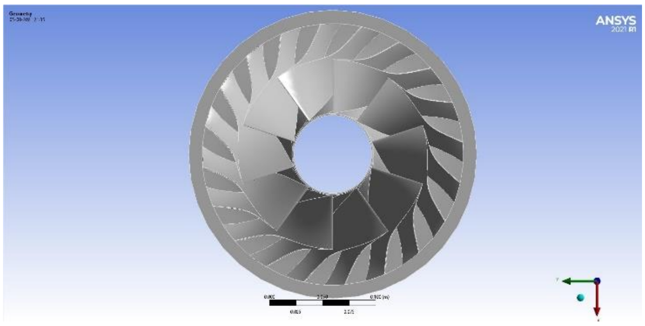

Fig 4. Top view of the Impeller.

The conditions applied on the impeller are pressure applied on the blades by the incoming stream of air. Rotational velocity is applied to it and fixed support or a constraint on the top.

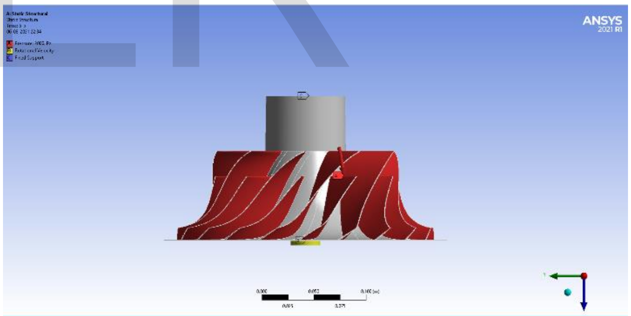

Fig 5. Application of forces on the Impeller.

RESULTS

The results are taken for each material separately and their maximum and minimum values are tabulated in the final table.

STRUCTURAL STEEL

The results for the FEA analysis of impeller having structural steel as its components are shown below.

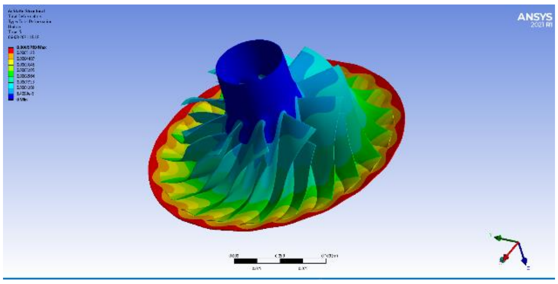

Fig 6. Total deformation of the impeller.

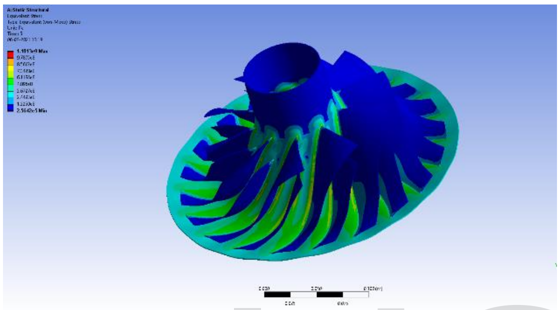

Fig 7.Equivalent strain on the Impeller

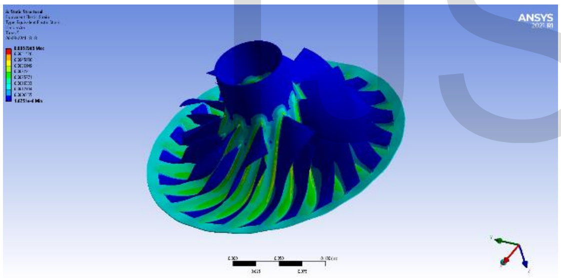

Fig 8. Equivalent strain (von mises) on the Impeller.

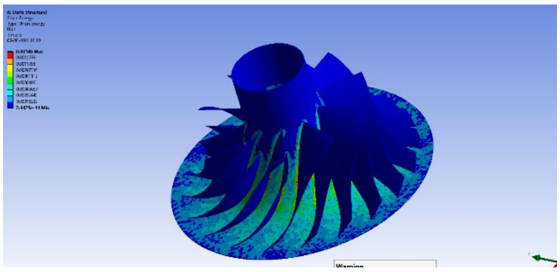

Fig 9. Strain energy generated on the Impeller.

GRAY CAST IRON

The results for the FEA analysis of impeller having Gray Cast Iron as its components are shown below.

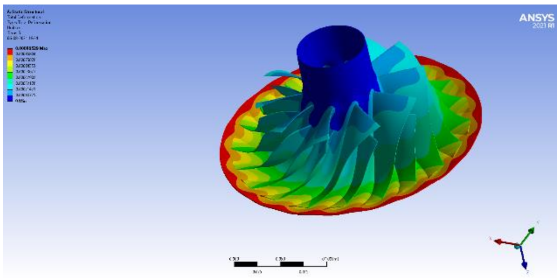

Fig 10. Total deformation of Impeller

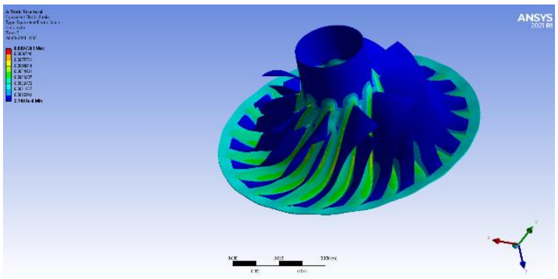

Fig 11. Equivalent strain on the Impeller

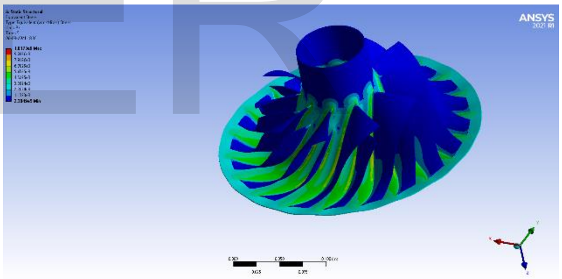

Fig 11.Equivalent strain (von mises) on the Impeller. .

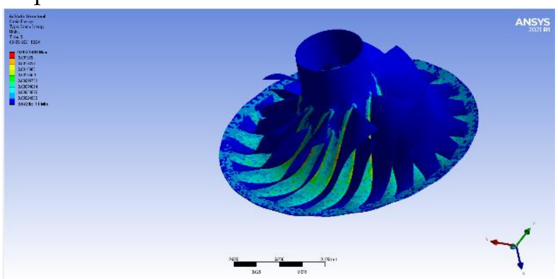

Fig 12.Strain energy generated on the Impeller.

TITANIUM ALLOY

The results for the FEA analysis of impeller having Titanium alloy as its components are shown below.

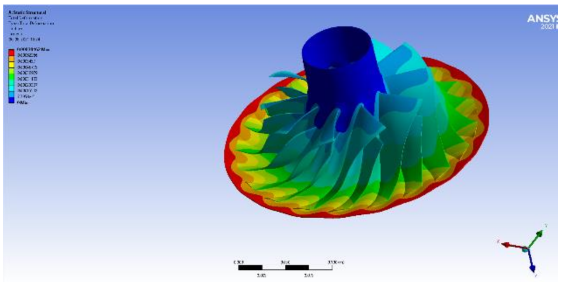

Fig 13. Total deformation of Impeller

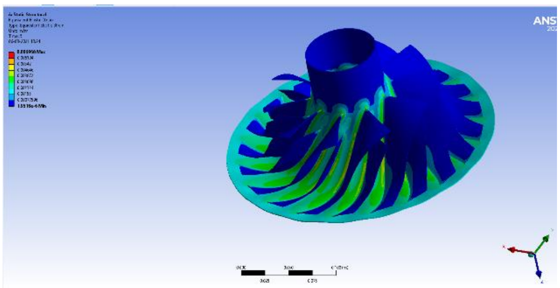

Fig 14.Equivalent strain on the Impeller

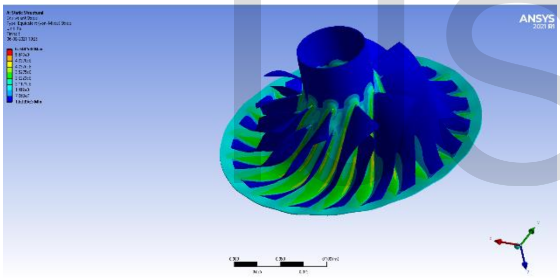

Fig 15.Equivalent strain (von mises) on the Impeller.

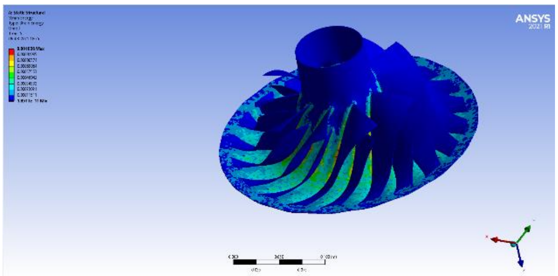

Fig 16. Strain energy generated on the Impeller.

ALUMINIUM ALLOY

The results for the FEA analysis of impeller having Aluminium alloy as its components are shown below.

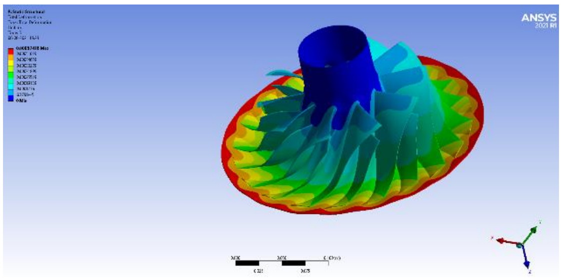

Fig 17. Total deformation of Impeller

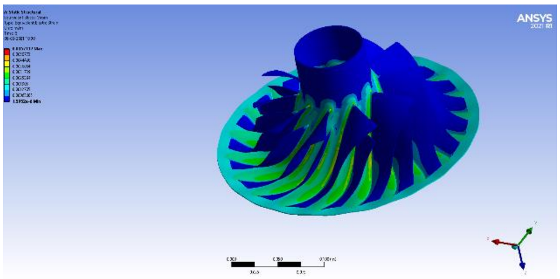

Fig 18.Equivalent strain on the Impeller

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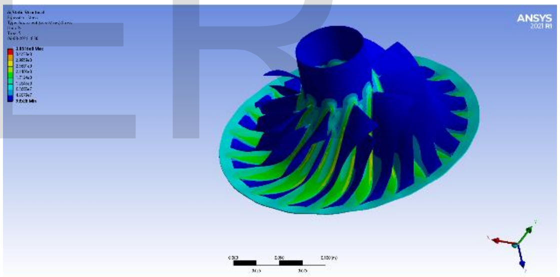

Fig 19. Equivalent strain (von mises) on the Impeller.

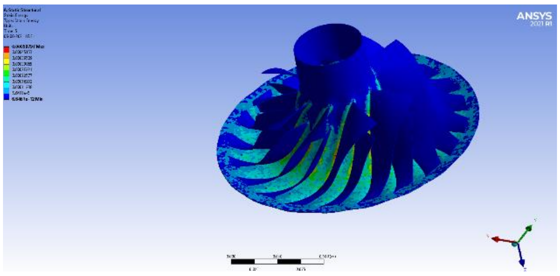

Fig 20. Strain energy generated on the Impeller.

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INCONEL 718

This is a superalloy made up of a Nickel-Chromium mixture. The results for the FEA analysis of impeller having Inconel 718 as its components are shown below.

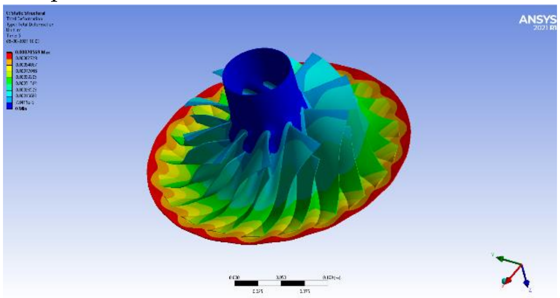

Fig 21. Total deformation of Impeller

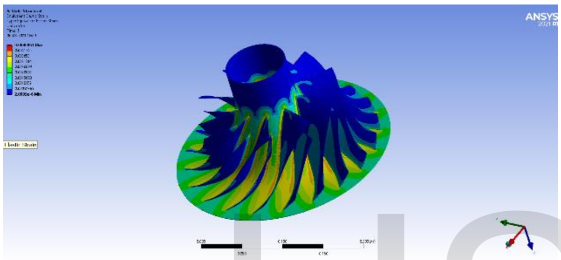

Fig 22. Equivalent strain on the Impeller

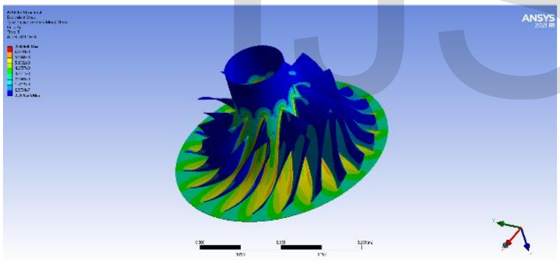

Fig 23. Equivalent strain (von mises) on the Impeller.

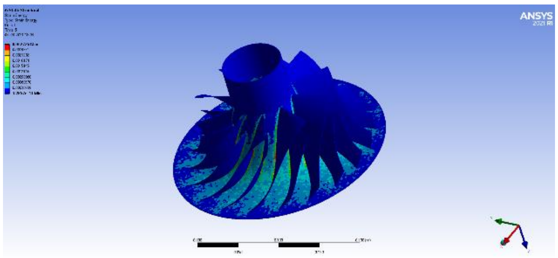

Fig 24. Strain energy generated on the Impeller

TABLES

CONSOLIDATED RESULTS TABLE

TOTAL DEFORMATION (meters)

MATERIAL	MINIMUM	MAXIMUM
STRUCTURAL STEEL	0	0.5769
GRAY CAST IRON	0	0.96529
TITANIUM	0	0.70162
ALUMINIUM ALLOY	0	0.57418
INCONEL 718	0	0.70569

EQUIVALENT STRAIN

MATERIAL	MINIMUM	MAXIMUM
STRUCTURAL STEEL	1.6251e-6	0.0057965
GRAY CAST IRON	2.7407e-6	0.0097361
TITANIUM	1.951e-6	0.006968
ALUMINIUM ALLOY	1.5952e-6	0.0057117
INCONEL 718	2.099e-6	0.0046961

EQUIVALENT STRESS (VON MISES) (Pa)

MATERIAL	MINIMUM	MAXIMUM
STRUCTURAL STEEL	2.5642e+5	1.1013e+9
GRAY CAST IRON	2.30493+5	1.0179e+9
TITANIUM	1.6339e+5	6.3481e+9
ALUMINIUM ALLOY	93928	3.8516e+9
INCONEL 718	2.7617e+5	7.694e+9

STRAIN ENERGY (Joules)

MATERIAL	MINIMUM	MAXIMUM
STRUCTURAL STEEL	2.4425e-11	0.00146
GRAY CAST IRON	3.6728e-11	0.002244
TITANIUM	1.8911e-11	0.001036
ALUMINIUM ALLOY	8.8467e-11	0.00050797
INCONEL 718	3.2857e-11	0.002725

The above tables show the 4 types of results obtained in the detailed analysis of the Impeller.

CONCLUSIONS

The model was created in Design Modeler in ANSYS using Bladegen add-in. The model impeller is undergone static structural analysis taking materials like Structural Steel, Gray Cast Iron, Titanium Alloy, Aluminum Alloy, and Inconel 718. Among all the materials used, Aluminum seems to be undergoing a lower amount of deformation, stress, and strain amidst other materials. So, without the consideration of Thermal stresses and strains, Aluminum seems to be the suitable component for the creation of the Impeller blade.

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