🌐 *United International Journal of Engineering and Sciences* 🌐
(UIJES – A Peer-Reviewed Journal); ISSN:2582-5887 | Impact Factor:8.075(SJIF)
📘 *Volume 5 | Special Issue 1 | 2025 Edition*
National Level Conference on "Advanced Trends in Engineering Science & Technology" – Organized by RKCE

Modelling and Geometrical Optimization of Turbocharger Compressor using Incoloy 740, Incoloy Alloy 909, Incoloy Alloy A-286 by Catia V5 and Ansys

A Kalyan[1], M Anvesh[2], R Ramjedson[3], S Satish Kumar[4], M Yani Rachel[5]
[1345]UG Students, [2]Assistant Professor
Dept of Mechanical Engineering,
R K College of Engineering,
Vijayawada, India
addepallikalyan88@gmail.com[1], anvesh.malneedi8@gmail.com[2],
adoniramjedson1811@gmal.com[3],samanasasatishkumar@gmail.com[4], reachelbattu@gmail.com[5]

***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. turbocharger to compress more air flowing into the engine's cylinder. When air is compressed the oxygen molecules are packed closer together. This increase in air means that more fuel can be added for the same size naturally aspirated engine. 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".**
The aim of the project is modelling a turbo charger compressor wheel using in Catia v5 and Static and modal analysis using in Ansys software. Finally find out the Von-misses stresses, Total deformations, Shear stress, Strain in static analysis and in dynamic analysis using these materials INCOLOY 740, INCOLOY ALLOY 909, INCOLOY ALLOY A-286. find out the Frequencies at different total deformations I suggest the design modification to the Compressor to improve performance of the compressor.

***Keywords* – Turbocharger, Automobile industry, Internal combustion engine, Naturally aspirated engine, Static analysis, Modal analysis.**

I. INTRODUCTION

Turbochargers are widely used in automotive, aerospace, and marine applications to improve engine efficiency and power output. The compressor wheel, which compresses the intake air, is subjected to extreme mechanical and thermal stresses. The material and design of the compressor wheel play a crucial role in its performance and durability. This study investigates the structural and modal behavior of a turbocharger compressor wheel using different materials and blade configurations.

The primary objectives of this study are: To evaluate the strength of the turbocharger compressor wheel using different materials.To compare the performance of 5-blade and 6-blade designs.To determine the optimal material and design for the compressor wheel. Center-Housing. The turbine-compressor common shaft is supported by a bearing system in the center housing (bearing housing) located between the compressor and turbine . The shaft wheel assembly (SWA) refers to the shaft with the compressor and turbine wheels attached, i.e., the rotating assembly. The center housing rotating assembly (CHRA) refers to SWA installed in the center-housing but without the compressor and turbine housings. The center housing is commonly cast from gray cast iron, but aluminum can also be used in some applications. Seals help keep oil from passing through to the compressor and turbine. Turbochargers for high exhaust gas temperature applications, such as spark ignition engines, can also incorporate cooling passages in the center housing.

II .LITERATURE REVIEW

D. Ramesh Kumar et al. (2017) investigated the use of Inconel N06230 and Incoloy A-286 for turbine and compressor impellers, respectively, using ANSYS and CATIA. They concluded that these materials provided the best performance in terms of minimum von-Mises stress, maximum frequency, and heat flux, making them ideal for turbocharger applications.

Shujie Liu et al. (2016) studied the fatigue life assessment of centrifugal compressor impellers, emphasizing the importance of considering centrifugal and aerodynamic loads in FEA. They highlighted the challenges of simulating real-world conditions and recommended well-designed experiments to reduce errors in fatigue life predictions.

CH. Satyasai Manikanta et al. (2016) conducted a structural analysis of turbocharger impellers using materials like AISI 4063 steel, Inconel 718, Technitium, and Titanium 2646, concluding that Titanium 2646 offered the best performance due to its lower stress and displacement values.

M.F. Moreira et al. (2016) analyzed the premature failure of aluminum compressor wheels in turbocharged diesel engines, attributing the failures to intergranular corrosion and fatigue.

B.P. Terani et al. (2015) emphasized the importance of engine downsizing and the role of turbochargers in improving engine performance, while V.R.S.M. Kishore Ajjarapu et al. (2015) compared different materials for impellers, recommending Incoloy 909 for compressors and Inconel 740 for turbines based on their stress and frequency performance.

Alain Batailly et al. (2015) focused on the vibratory analysis of impellers, highlighting the importance of modal interactions and critical speeds in design.

Neelambika et al. (2014) and Shaikh Mohammad Rafi et al. (2014) explored CFD analysis and structural optimization of impellers, respectively, with the latter concluding that Inconel 706 provided the best performance.

Seiichi Ibaraki et al. (2013) optimized compressor impeller designs for high-pressure turbocharged diesel engines, achieving improved efficiency and operating range.

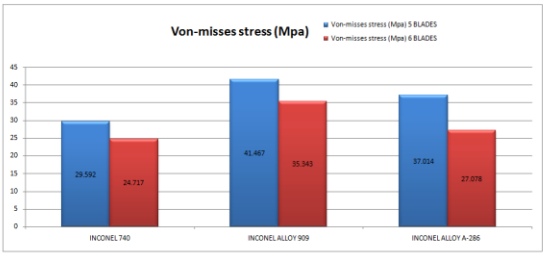
B. Mohan et al. (2011) and Changhee Kim et al. (2016) studied composite impellers and the effects of impeller deformation on performance, respectively, while Isaias Hernandez-Carrillo et al. (2017) explored advanced materials like PEEK-GF30 and ABS for microturbine impellers. S. Mayakannan et al. (2016) and Rachel Schwind et al. (2015) investigated impeller designs for centrifugal pumps and turbochargers, respectively, with the latter concluding that tandem impeller designs improved operating range at the cost of efficiency.

Santosh Shuklaa et al. (2015) recommended Titanium alloy for mixed flow pump impellers due to its minimal deformation and stress. These studies collectively demonstrate the importance of material selection, design optimization, and advanced simulation techniques in improving the performance and durability of turbocharger compressor wheels and impellers.

III. RESULTS AND DISCUSSIONS

Design and analysis is done using with various designs 5 blades and 6 blades with different materials . Here find out the stresses, total deformations, strain, shear stresses obtained by analyzing the turbocharger compressor by using different materials Inconel 909, Inconel 740 , Inconel alloy A 286 material.

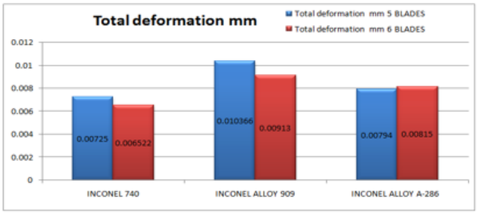
The graph 1 shows that with Variation of stresses two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286 Finally least von-mises stress is Inconel 740 material 6 Blades design have 24.717 Mpa.



Graph 1: Von-Misses Stress

3.1 Total Deformation

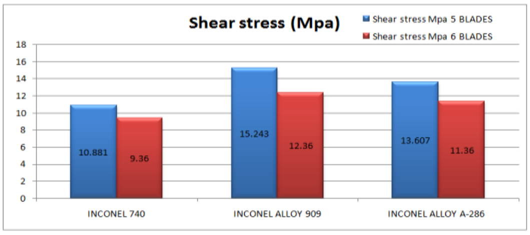
The graph 2 shows that with Variation of Total deformation two different designs with and compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Total deformation is Inconel 740 material 6 Blades design have 0.0065mm.



Graph 2: Total Deformation

3.2 Shear Stress

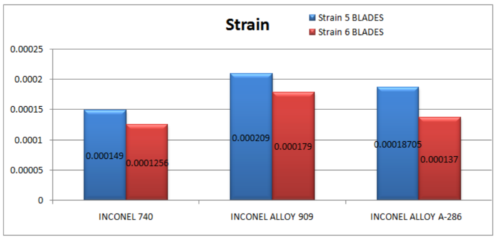
The below graph 3 shows that with Variation of Shear stress two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Shear stress is Inconel 740 material 6 Blades design have 9.36 Mpa



Graph 3: Shear Stress

3.3 Strain

The below graph 4 shows that with Variation of Strain two different designs with and 6 blades compressor and 5 blades compressor using different materials Inconel 740 and Inconel 909, Inconel Alloy A-286. Finally least Strain is Inconel 740 material 6 Blades design have 0.000125.



Graph 4: Strain

3.4 Modal Analysis

INCONEL 740 MATERIAL			
5 BLADES		6 BLADES	
FREQUENCY Hz	TOTAL DEFORMATION MM	FREQUENCY Hz	TOTAL DEFORMATION MM
45.63	1.563	50.63	1.311
70.31	2.957	80.45	2.645
106.44	5.44	113.92	4.631

Table 2 :Deformation Inconel 740 of at different frequencies

IV. CONCLUSION

In this work, a turbocharger compressor wheel was designed using CATIA and analyzed in ANSYS Workbench by varying the blade geometry (five and six blades) and materials (Inconel 740, Inconel 909, and Inconel Alloy A-286). The results showed that the six-blade compressor wheel made of Inconel 740 performed the best among all tested configurations. It exhibited the least total deformation (0.0065 mm), the lowest von-Mises stress (24.717 MPa), the minimum shear stress (9.36 MPa), and the lowest strain (0.000125).

The modal analysis further confirmed that the six-blade design made of Inconel 740 achieved higher natural frequencies with lower deformation when compared to the five-blade design.

Therefore, it can be concluded that the six-blade compressor wheel with Inconel 740 is the most suitable design, offering greater strength, stability, and reliability for turbocharger applications.

REFERENCES

[1] D. Ramesh Kumar, B. Shanmugasundaram, and P. Mohanraj, "Design and Analysis of Turbocharger Impeller in Diesel Engine," International Journal of Advanced Mechanical and Mechanics Engineering, 2017.
[2] S. Liu, C. Liu, Y. Hu, S. Gao, Y. Wang, and H. Zhang, "Fatigue life assessment of centrifugal compressor impeller based on FEA," Elsevier, 2016.
[3] C. H. Satyasai Manikanta, S. D. V. V. S. B. Reddy, and A. Sirishabhadrakali, "Design & Analysis of Turbocharger Impeller," International Journal & Magazine of Engineering, Technology, Management and Research, 2016.
[4] M. F. Moreira, "Failure analysis in aluminum turbocharger wheels," Elsevier, 2016.
[5] B. P. Terani, K. S. Badarinarayan, and P. A., "Stability Analysis of Turbocharger Impeller: A Review," International Research Journal of Engineering and Technology (IRJET), 2015.
[6] V. R. S. M. Kishore Ajjarapu, K. V. P. P. Chandu, and 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, 2015.