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Structural Analysis of Centrifugal Compressor Impeller using ANSYS

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Abstract: **In this present work, compressor impeller has been analyzed with different materials to increase the efficiency of turbocharger. The research work has been done by using CREO and ANSYS software. The modelling of compressor impeller has been done by using CREO software. The variation of deformations, strains and stresses of the compressor impeller using different materials has been determined by ANSYS software. A structural analysis is used to carry out the displacements, strains, and stresses of compressor impeller. The compressor impeller of turbocharger of diesel engine will be recommended based on the results.**

Index Terms: **centrifugal compressor impeller, Creo, Ansys, structural analysis, different materials, stresses, deformations, strains.**

I. Introduction

Turbocharger is the device which is used to increase the efficiency of the diesel engine. Centrifugal compressors are used in turbochargers to increase the mass flow rate of fluid through the runner. Inlet, impeller/rotor, and diffuser are the main components of the centrifugal compressor. In this study, different materials are selected for the analysis those are copper alloy, incoloy alloy-286, titanium alloy and stainless-steel alloy. In this work, the modeled is created in CREO and this modeled is used for analyzing in ANSYS software by selecting different materials. The deformations, strains and stresses are evaluated for different materials at different conditions.

Farah Elida selama et. al. [1] has conducted simulation work using ANSYS-CFX on centrifugal pump impeller for determine the performance. By increasing the speed of the impeller, the efficiency of the centrifugal pump is shown in the results.

Dr. S. Shankar et. al. [2] has conducted analysis work on compressor impeller using ANSYS - CFX to determine the inner flow characteristics of radial flow pump by changing the number of blades. In the results, the performance and efficiency of the compressor by changing blades is discussed.

S. Rajendran et. al [3] has carried out simulation work on impeller of centrifugal pump using ANSYS-CFX to understand the complex interflows in centrifugal pumps and numerical solution of the three-dimensional flow is shown in results.

Bhanumik B. Patel et. al [4] has conducted design and flow analysis of impeller by using ANSYS-CFX. The model is created using SOLIDWORKS software and it is used in ANSYS by changing the blade angles. CFD software also used to determine the heads, which are shown in results.

Ajith M S et al [5] has carried out analysis work of centrifugal pump impeller using ANSYS FLUENT. In this work, impeller is designed by head, speed, and discharge. The impeller analysed by forward and backward vanes in CFD and velocity and variation of pressure distribution are shown in results.

Alpesh Kumar R et al [6] has conducted experimental study and simulation work using CFD of centrifugal pump impeller. In this work, internal flow of centrifugal pump is observed by ANSYS-CFX and characteristics curves like head, rate of flow, efficiency are calculated and compared these results with experimental work.

P. Gurupranesh et. al [7] has carried out analysis of centrifugal pump impeller in CFD to increase the performance. In this project, model is created by SOLIDWORKS, this model is used for CFD by changing the vane profiles to increase the performance. The values of increased efficiency and head are shown in results.

Satish M et al [8] has conducted stress analysis using ANSYS on the impeller of centrifugal pump by changing speed. In this project, stresses developed in impeller and deformation developed in impeller is calculated using ANSYS by changing speed. The safe speed levels are shown in results.

D. Ramesh Kumar et al [9] has carried out design and analysis of impeller of turbocharger. In this project, a model is created in CATIA and analysis is carried out in ANSYS and structural analysis is carried out by selecting the different materials for the impeller. By observing the structural results, best material is selected which is shown in results.

B James Prasad Rao et al [10] has conducted design and analysis work on turbocharger impeller by changing the materials by applying different loads on impeller. In this project, the structural analysis (stress, strain, and deformation) are calculated and those are shown in results.

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II. Materials selection

For structural analysis of compressor impeller Copper alloy, Incoloy alloy-286, Titanium alloy and Stainless steel are selected. The properties of materials like young's modules, the ratio of poison and density are in Table.1

A. Modeling

Compressor impeller model is created in CREO software and is saved in IGS format. This model is imported in ANSYS for structural analysis.

Fig.1 shows the 3D impeller model which is used for analysis.

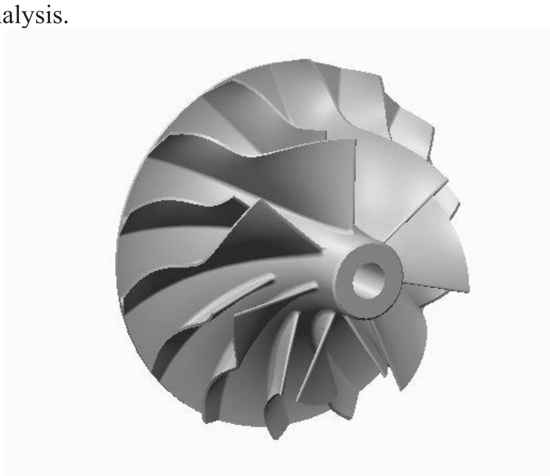

Figure 1. 3D Model of Compressor impeller

III. FEM Analysis

Static structural analysis is selected in ANSYS for different materials to identify the deformations, Von-Mises strain, and Von-Mises stresses at different loading conditions.

A. Meshing

The geometry which is created in SOLIDWORKS is imported in ANSYS is meshing by tetrahedron method which is shown in Fig.2.

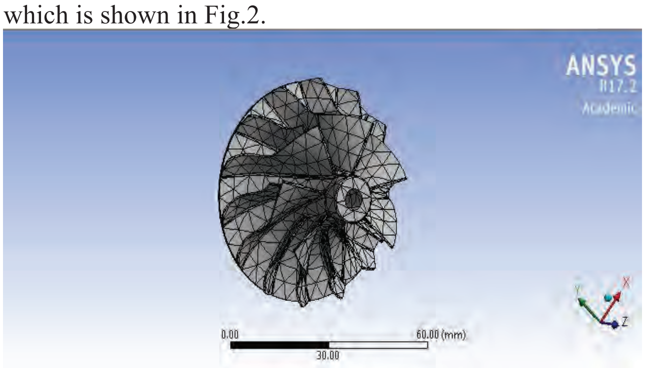

Figure 2. Meshed impeller.

B. Boundary Conditions:

Centrifugal compressor impeller domain is considered. Rotating frame of reference with a rotational speed of 735 rpm. The working fluid through the impeller is water at 27 C. The hub is fixed in the compressor impeller.

IV. Results and Discussions

For compressor impeller four materials are used to carry out the investigation in static structural analysis by changing the loads.

A. Structural analysis of copper alloy material

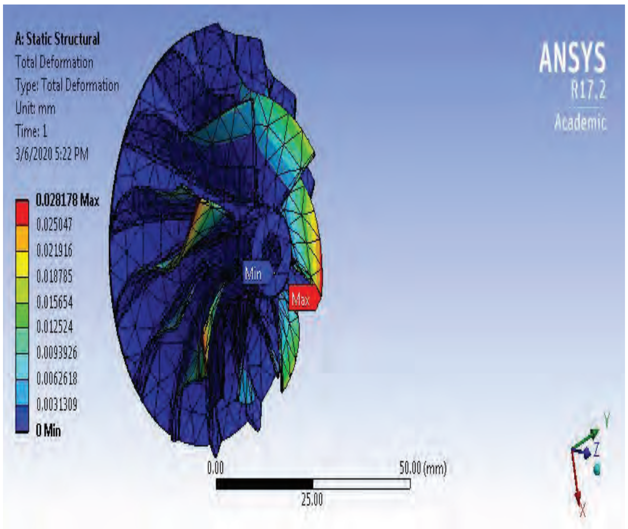

Figure 3. Total deformation of copper alloy.

Fig.3 shows the variations in total deformation on compressor impeller. From the above figure, minimum total deformation is zero and maximum total deformation is 0.028178 mm.

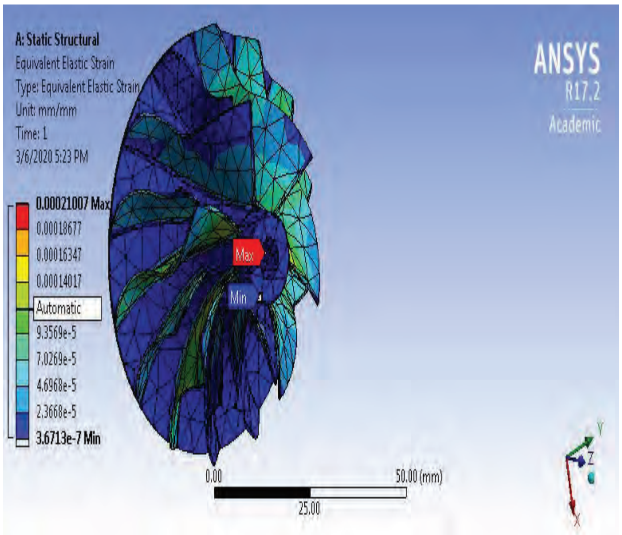

Figure 4. Equivalent elastic strain of copper alloy.

Fig.4 shows the elastic strain distribution in copper alloy material. It is observed that the maximum value of elastic strain is 0.0002107.

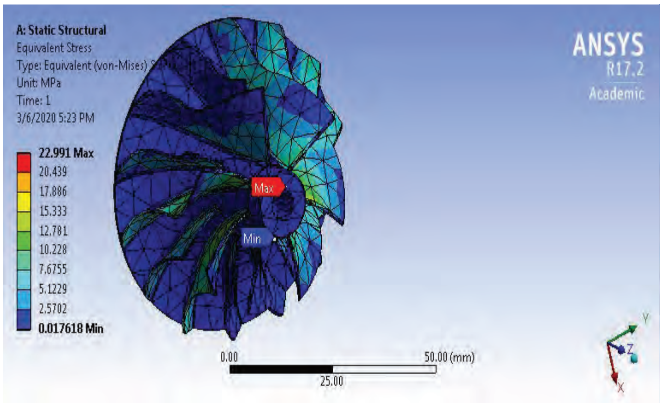

Figure 5. Von-mises stresses for copper alloy.

Fig.5 shows that von-mises stresses for copper alloy and it is observed that the maximum value is 22.991Mpa.

B. Structural analysis of Incoloy alloy-286 material

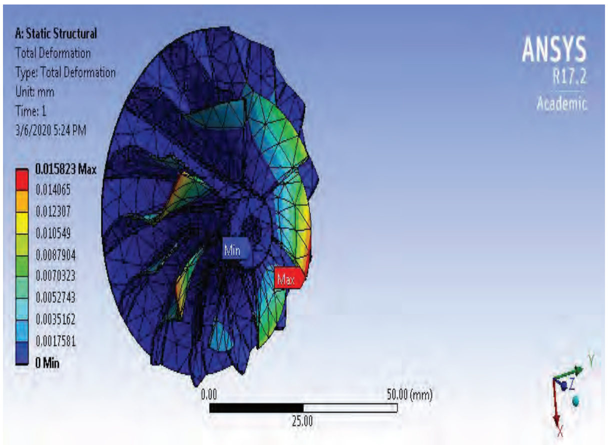

Figure 6. Total deformation of Incoloy alloy-286 impeller.

Fig.6 shows the variation of total deformation on compressor impeller. It is observed that the maximum deformation value is 0.0158 mm.

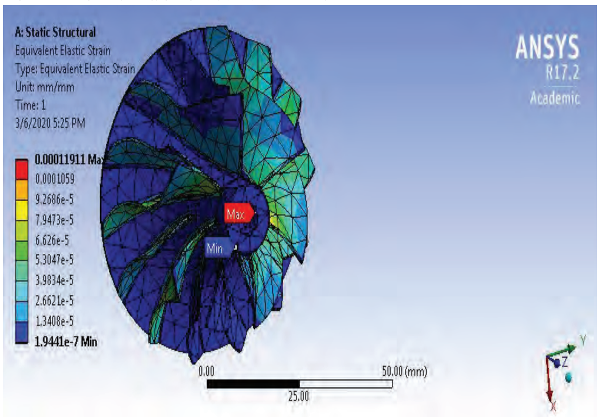

Figure 7. Equivalent elastic strain of Incoloy alloy-286.

Fig.7 shows the variation of equivalent elastic strain of impeller. It is observed that the maximum value is 0.0001191.

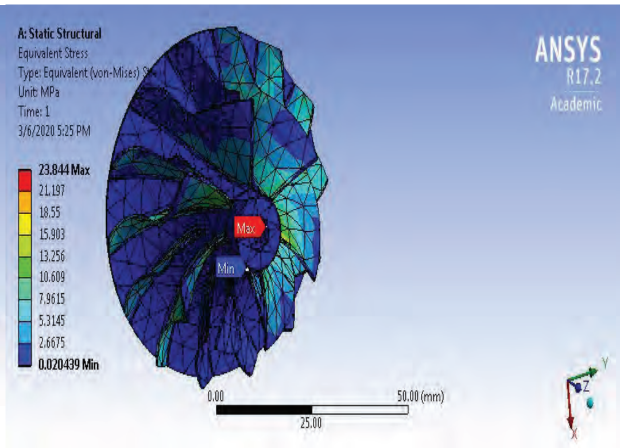

Figure 8. Von-mises stresses for Incoloy alloy-286.

Fig.8 shows that von-mises stresses for Incoloy alloy-286 and it is observed that the maximum value is 23.884Mpa.

C. Structural analysis of Titanium alloy material

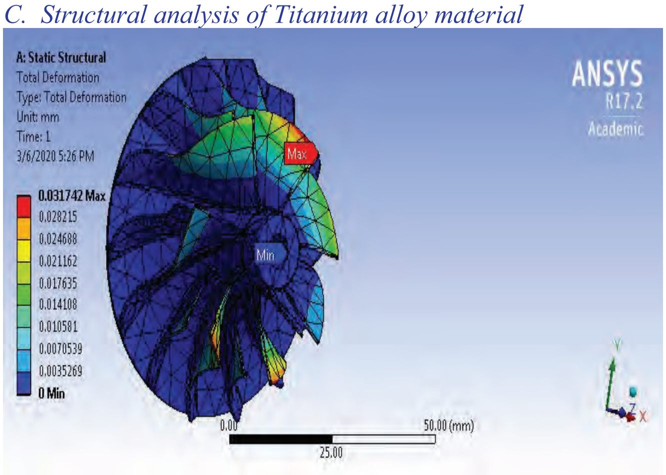

Figure 9. Total deformation of Titanium alloy.

Fig.9 shows the variations in total deformation on compressor impeller. From the above figure, minimum total deformation is zero and maximum total deformation is 0.03174 mm.

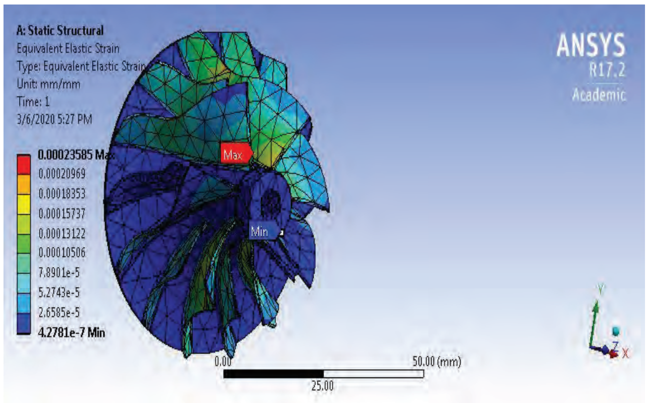

Figure 10. Equivalent elastic strain of titanium alloy.

Fig.10 shows the elastic strain distribution in Titanium alloy material. It is observed that the maximum value of elastic strain is 0.000235

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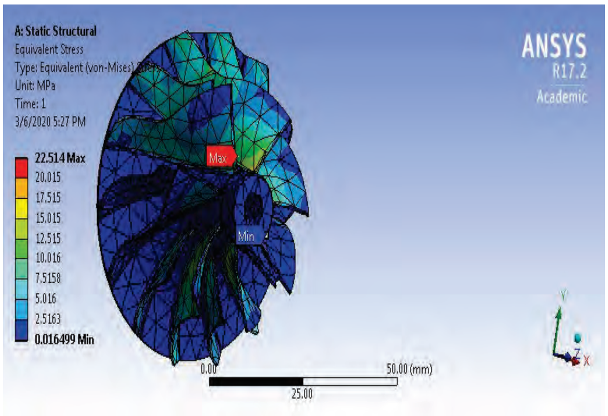

Figure 11. Von-mises stresses for titanium alloy.

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Fig.11 shows that von-mises stresses for Titanium alloy and it is observed that the maximum value is 22.514Mpa.

C. Structural analysis of Stainless-Steel alloy material

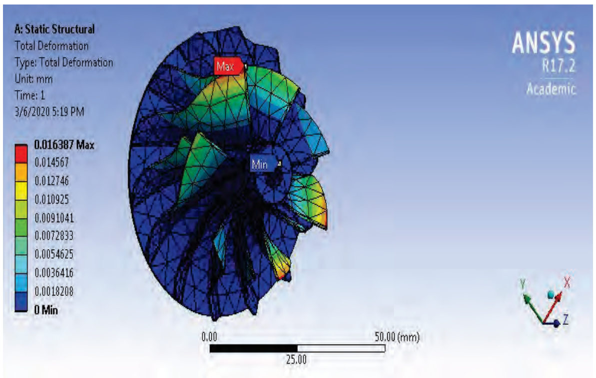

Figure 12. Total deformation of Stainless-steel alloy.

Fig.12 shows the variations in total deformation on compressor impeller. From the above figure, minimum total deformation is zero and maximum total deformation is 0.01638mm.

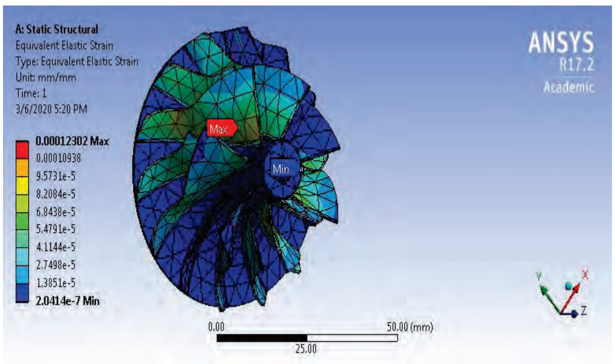

Figure 13. Equivalent elastic strain of Stainless-Steel alloy.

Fig.13 shows the elastic strain distribution in Stainless-steel alloy material. It is observed that the maximum value of elastic strain is 0.000123.

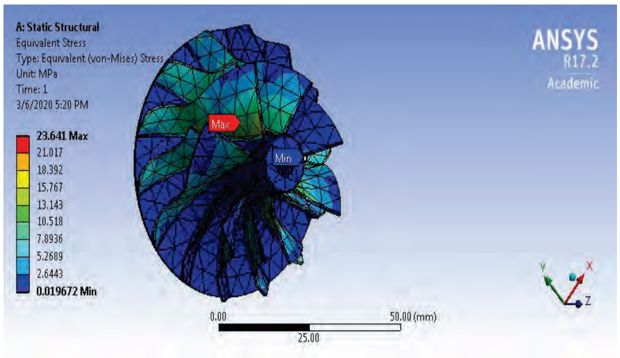

Figure 14. Von-mises stresses for Stainless-Steel alloy.

Fig.14 shows that von-mises stresses for Stainless-Steel alloy and it is observed that the maximum value is 23.641Mpa.

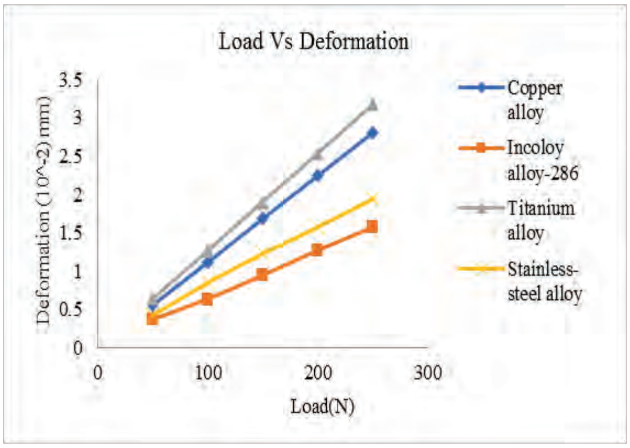

Figure 15. Load Vs Deformation for different materials

Fig.15. shows the variation of total deformation for different materials at different loads. From the above figure, the maximum deformation is for copper alloy material and minimum deformation is for Incoloy alloy-286.

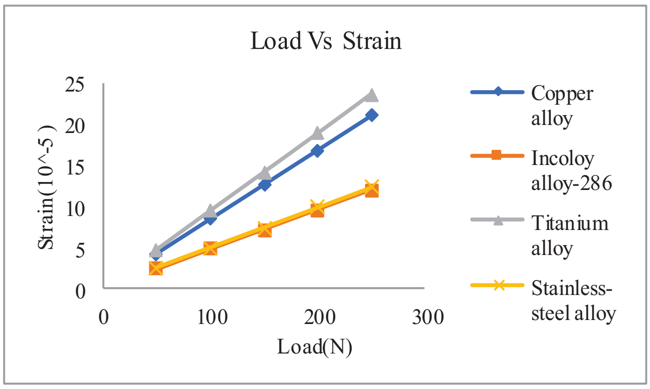

Figure 16. Load Vs Strain for different materials

Fig .16 shows the variation of strain with respect to different loads for different materials. From the above figure, copper alloy has more value of strain than other material and Incoloy alloy-286 has less strain than other materials.

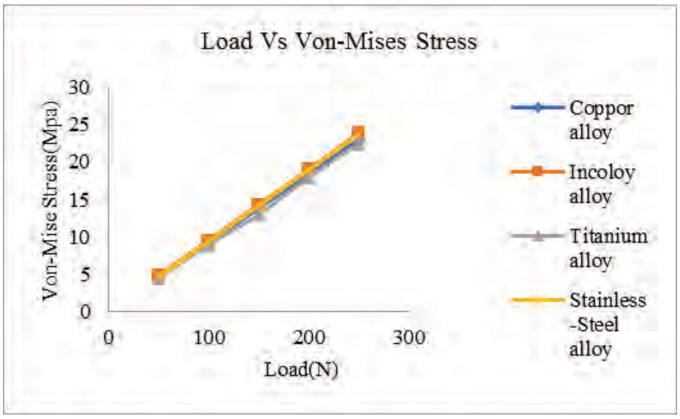

Figure 17. Load Vs Von-Mises Stress for different materials

Fig.17 shows the variation of Von-Mises stress for different materials at different load conditions. From the above figure, it is observed that Incoloy alloy-286 and Copper alloy have more von-mises stresses and Titanium alloy has less stresses than that of other materials.

Table II shows the total deformation, Strain and Von-mises stress for different materials.

V. Conclusions

- From the results and discussions, it is clearly shown that Incoloy alloy-286 has minimum total deformation, i.e. 44.4% less than that of copper alloy,50.7% less than titanium alloy and 4.2 % less than stainless steel alloy.
- Strain values for Incoloy alloy-286 are 46.6% less than that of copper alloy, 52.5% less than titanium alloy and 0.08% less than stainless steel alloy.

But while comparing the Von-mises stresses, Incoloy alloy has less difference than Titanium alloy.

So, finally, Incoloy alloy -286 will give good results than others.

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