Static Stress Analysis on Centrifugal Compressor Impeller

Meha Setiya et al. [3] carried out structural and thermal analysis on impeller blade of the load compressor aircraft APU 131-9A for four different materials to check the safe limit of stresses. V.R.S.M. Kishore et al. [4] designed the impeller of a turbocharger for a diesel engine to increase its power and efficiency. Structural, modal and thermal analysis of impeller for three different materials was investigated using ANSYS. Syam Prasad et al. [5] analyzed the centrifugal pump impeller which is made of three different alloy materials by conducting static and dynamic tests to estimate its performance. J B Chaudhari et al. [6] studied the stress acting on centrifugal compressor radial impeller blade which was designed for small gas turbine application using solver I-DEAS 10NX and was analyzed to identify the location of maximum stresses. C.H. Satyasai et al. [7] had designed the turbocharger impeller and also carried out structural analysis of the impeller for different materials to achieve better life.

From the literature survey, it is noticed that at higher loads the impeller had more stress at the hub and blade fixation nodes. In this paper, best material is suggested to withstand the high loads. The von-mises stress, total deformation and von-mises strain is investigated using thermal- static stress analysis of the centrifugal compressor impeller for three different materials. By comparing the results obtained for three different alloys from the FEM analysis the best material is identified.

2 MATERIAL SELECTION FOR OPTIMIZATION

The Impeller has to withstand high centrifugal loads, high pressures and temperatures when working. So materials for the study of centrifugal compressor impeller is chosen on the basis of Young’s Modulus, Density, Poisson’s ratio and Ultimate Strength.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>MATERIAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy</td>
<td>Young’s Modulus (Pa)</td>
</tr>
<tr>
<td>Ti 6-2-4-6</td>
<td>1.14E+11</td>
</tr>
<tr>
<td>Inconel alloy 740</td>
<td>2.21E+11</td>
</tr>
<tr>
<td>Aluminun 2618 alloy</td>
<td>0.80E+11</td>
</tr>
</tbody>
</table>
3 MODELING

SolidWorks 2010 software is used to model the impeller. The impeller model is then saved in IGS format which is imported to ANSYS geometry.

4 F E M ANALYSIS

Thermal- static structural analysis is executed using ANSYS R17.2 for different materials to investigate the von-mises stress, total deformation, and von-mises strain for the considered geometry.

4.1 Meshing

The imported geometry is meshed by tetrahedrons method. To achieve fine mesh, element size is adjusted to $3.5 \times 10^{-3}$ m using body sizing. A total of 1, 60,449 elements and 2, 38,696 nodes are obtained.

4.2 Boundary Conditions

The boundary conditions given for static structural analysis are
1. Hub portion is fixed.
2. Rotational velocity of 50,000 rpm.

The imported and meshed geometry is treated with boundary conditions for both thermal and static structural analysis to calculate the von-mises stress, total deformation, and von-mises strain. Firstly, Thermal analysis is carried out and the solution is imported to static structural analysis. Each material is provided with inlet and exit temperatures and solution is evaluated. The obtained temperature load is then imported for static structural analysis.

5 ANALYSIS RESULTS

- Fig. 4 From thermal analysis minimum temperature of 40 deg C is at the inlet and maximum temperature of 200 deg C at the exit.
Fig. 5 Maximum von-Mises stress for TI 6-2-4-6 is found at the hub i.e. $6.75 \times 10^8$ Pa.

Fig. 6 Maximum deformation for TI 6-2-4-6 is found at inlet blade tip i.e. $0.00139$ m.

Fig. 7 Maximum von-Mises strain for TI 6-2-4-6 is found at the hub i.e. $0.00609$.

Fig. 8 Maximum von-Mises stress for Inconel 740 alloy is found at the hub i.e. $1.18 \times 10^9$ Pa.

Fig. 9 Maximum deformation for Inconel 740 alloy is found at inlet blade tip i.e. $0.00122$ m.
Fig. 10 Maximum von-mises strain for Inconel 740 alloy is found at the hub i.e. 0.00554.

Fig. 11 Maximum von-mises stress for Aluminum 2618 alloy is found at the hub i.e. 3.92E+8 Pa.

Fig. 12 Maximum deformation for Aluminum 2618 alloy is found at inlet blade tip i.e. 0.00122 m.

Fig. 13 Maximum von-mises strain for aluminum 2618 alloy is found at the hub i.e. 0.00538.

Results from the analysis for von-mises stress, total deformation and von-mises strain is tabulated below

<table>
<thead>
<tr>
<th>Alloy</th>
<th>von-mises stress (Pa)</th>
<th>Total Deformation (m)</th>
<th>von-mises strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti 6-2-4-6</td>
<td>6.75E+8</td>
<td>1.39E-3</td>
<td>6.09E-3</td>
</tr>
<tr>
<td>Inconel alloy 740</td>
<td>1.18E+9</td>
<td>1.229E-3</td>
<td>5.54E-3</td>
</tr>
<tr>
<td>Aluminum 2618</td>
<td>3.92E+8</td>
<td>1.227E-3</td>
<td>5.38E-3</td>
</tr>
</tbody>
</table>

6 CONCLUSION

This paper mainly concentrates on analyzing the structural integrity of the considered geometry. Static structural analysis is carried out to analyze the strength of the impeller for three different materials i.e. Ti 6-2-4-6, inconel 740 alloy and aluminum 2618 alloy using ANSYS.

From table 2 it is clear that Ti 6-2-4-6 has higher strength compared to inconel 740 and aluminum 2618 alloy. However,
Aluminum 2618 alloy has lower total deformation and von-mises strain than Ti 6-2-4-6 and inconel 740 alloys. Furthermore, Aluminum 2618 alloy is cost effective and has low density which reduces engine weight. From the structural analysis, it can be concluded that Aluminum 2618 alloy is the best material for the considered centrifugal compressor impeller for 50,000rpm.

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REFERENCES


