Design and Finite Element Analysis of a Gas Turbine Blade

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Abstract: A turbine blade is the individual component which makes up the turbine section of a gas turbine. In this project, a turbine blade is designed and modeled in 3D modeling software Pro/Engineer. The design is modified by changing the base of the blade to increase the cooling efficiency. Since the design of turbo machinery is complex, and efficiency is directly related to material performance, material selection is of prime importance. In this project, two materials are considered for turbine blade titanium alloy and nickel alloy. Optimization is done by varying the materials Titanium alloy and Super Alloy by performing coupled field analysis (thermal+structural) on the turbine blade for both the designs. In this project, CFD technique is employed to investigate the flow the fluid over the turbine blade. Analysis is done in Ansys.

Keywords: CFD, Thermal and Structural.

I. INTRODUCTION

A gas turbine, also called a combustion turbine, is a type of internal combustion engine. It has an upstream rotating compressor coupled to a downstream turbine, and a combustion chamber or area, called a combustor, in between. The basic operation of the gas turbine is similar to that of the steam power plant except that air is used instead of water. Fresh atmospheric air flows through a compressor that brings it to higher pressure. Energy is then added by spraying fuel into the air and igniting it so the combustion generates a high-temperature flow. This high-temperature high-pressure gas enters a turbine, where it expands down to the exhaust pressure, producing a shaft work output in the process. The turbine shaft work is used to drive the compressor and other devices such as an electric generator that may be coupled to the shaft. The energy that is not used for shaft work comes out in the exhaust gases, so these have either a high temperature or a high velocity. The purpose of the gas turbine determines the design so that the most desirable energy form is maximized. Gas turbines are used to power aircraft, trains, ships, electrical generators, and tanks.

A. Theory of operation

In an ideal gas turbine, gases undergo four thermodynamic processes: an isentropic compression, isobaric (constant pressure) combustion, an isentropic expansion and heat rejection. Together, these make up the Brayton cycle.

II. LITERATURE REVIEW

The objective of this project is to design and stresses analyze a turbine blade of a jet engine. An investigation for the usage of new materials is required. In the present work turbine blade was designed with two different materials named as Inconel 718 and Titanium T-6. An attempt has been made to investigate the effect of temperature and induced stresses on the turbine blade. A thermal analysis has been carried out to investigate the direction of the temperature flow which is been develops due to the thermal loading. A structural analysis has been carried out to investigate the stresses, shear stress and displacements of the turbine blade which is been develop due to the coupling effect of thermal and centrifugal loads. An attempt is also made to suggest the best material for a turbine blade by comparing the results obtained for two different materials (Inconel 718 and titanium T6). Based on the plots and results Inconel718 can be consider as the best material which is economical, as well as it has good material properties at higher temperature as compare to that of TitaniumT6.

III. INTRODUCTION TO CAD/CAE:

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation.

A. INTRODUCTION TO PRO-ENGINEER

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.
Different modules in pro/engineer
Part design, Assembly, Drawing& Sheet metal.

B. Introduction to Finite Element Method
Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions. Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

IV. RESULTS AND DISCUSSIONS:
A. Models of pro-e wildfire 5.0:

B. Static Analysis of Gas Turbine Blade
VI. RESULTS AND DISCUSSIONS

Table 1. Static Analysis Result

<table>
<thead>
<tr>
<th>Deformation(mm)</th>
<th>strain</th>
<th>Stress(N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium alloy</td>
<td>Nickel alloy</td>
<td></td>
</tr>
<tr>
<td>0.08965</td>
<td>0.047478</td>
<td>0.00044889</td>
</tr>
<tr>
<td>4 holes</td>
<td>9.772e-8</td>
<td>4.7799e-10</td>
</tr>
<tr>
<td>6 holes</td>
<td>1.0372e-7</td>
<td>5.4999e-8</td>
</tr>
</tbody>
</table>

Table 2. Thermal Analysis Result

<table>
<thead>
<tr>
<th>Temperature(k)</th>
<th>Heat flux(W/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium alloy</td>
<td>Nickel alloy</td>
</tr>
<tr>
<td>650</td>
<td>650</td>
</tr>
<tr>
<td>4 holes</td>
<td>650</td>
</tr>
<tr>
<td>6 holes</td>
<td>650</td>
</tr>
</tbody>
</table>

VII. CONCLUSION

In our project we have designed a turbine blade used in gas turbines and modeled in 3D modeling software Pro/Engineer. Two other models with 4 holes and 6 holes are also modeled. We have done structural and thermal analysis on all the models of turbine blades using Titanium alloy and Nickel alloy. By observing the analysis results, the analyzed stress values are less than their permissible stress values. So using both the materials is safe. The stress and deformation values are more for Nickel alloy. By observing the thermal results, thermal flux is more for Nickel alloy than Titanium alloy. So using Nickel alloy is better than Titanium alloy. But the main disadvantage is its weight. By comparing the results for all the models, thermal flux is increasing by increasing number of holes, so heat transfer rate is increased. So we can conclude that by using Nickel alloy with 6 holes is better.
VIII. REFERENCES

[7] An advanced impingement/film cooling scheme for gas turbines – numerical study by A. Immarigeon, (Department of Mechanical and Industrial Engineering, Concordia University, Montréal, Canada), I. Hassan, (Department of Mechanical and Industrial Engineering, Concordia University, Montréal, Canada).
[9] CFD Simulation on Gas turbine blade and Effect of Hole Shape on leading edge Film Cooling Effectiveness by Shridhar Paregouda, Prof. Dr. T. Nageswara Rao.

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