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Design and Structural Analysis of Gas-Turbine Blade

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ABSTRACT

The objective of this project is to design and structural analyze a turbine blade of a gas- turbine engine. In a gas turbine engine, a single turbine section is made up of a disk or hub that holds many turbine blades. That turbine section is connected to a compressor section via a shaft and that compressor section can either be axial or centrifugal. Air is compressed, raising the pressure and temperature, through the compressor stages of the engine. The temperature is then greatly increased by combustion of fuel inside the combustor, which sits between the compressor stages and the turbine stages. The high-temperature and high-pressure exhaust gases then pass through the turbine stages. The turbine stages extract energy from this flow. To survive in this difficult environment, turbine blades often use exotic materials like super-alloys and many different methods of cooling. Withstanding of gas turbine blades for the elongation is a major consideration in there design, because they are subjected to high tangential, axial, centrifugal forces during their working condition. A structural analysis has been carried out to investigate the stresses, shear stress and displacements of the turbine blade which is been developed. CATIA V5 is used for design of solid model of turbine blade. MSC NASTRAN 2012.1software is used for analysis of FE model generated by meshing of blade using HYPERMESH V12 software.

INTRODUCTION

Gas Turbine Engine

The gas turbine engine is an internal combustion engine. And is a rotary heat engine operating by means of series ofprocesses consisting of compression of air taken from the atmosphere, heat addition by constant pressure combustion of fuel in air, expansion of high energy gas by turbine and finally discharge of the gas to the atmosphere.These all processes are continuous, because of that gas turbine engine known as continuous engine. The gas turbine engine working cycle is Brayton Cycle.

Figure 1 Gas Turbine Engine

GAS-TURBINE ENGINE CYCLE

The basic principle of the airplane turbine engine is identical to any internal combustion engine and all engines that extract energy from chemical fuel. The basic 4 steps for any internal combustion engine are:

1. Intake of air by inlet.
2. Compression of the air by compressor.
3. Combustion in combustion chamber, where fuel is injected and burned to convert the stored energy.
4. Expansion by turbine and exhaust, where the converted energy is put to use.

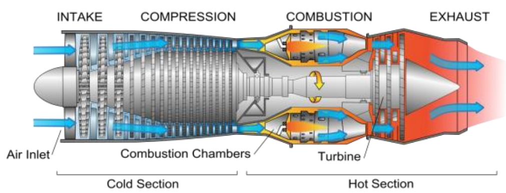

Figure 2 Diagram of Gas Turbine Engine.

The cycle followed by Gas Turbine Engine is Brayton cycle, in which air is compressed isentropically, combustion occurs at constant pressure, and expansion over the turbine occurs isentropically back to the starting pressure.

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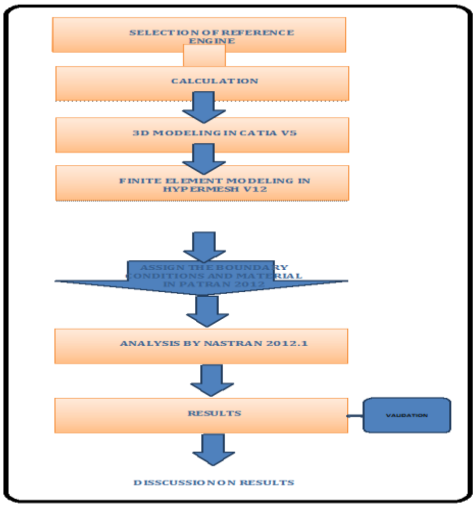
METHODOLOGY

3D turbine blade rotor geometry is developed in CATIA V5 by using coordinate of airfoil and calculated vales of other dimensions of blade. This model is exported to HYPERMESH V12 for meshing, by using this 3D model converted into Finite Element Model. This Finite Element Model is taken in to PATRAN 2012, in this all boundary conditions and material properties are given for finding out the Vonmisses stress, principle stress and deformation. The analysis is done by NASTRAN 2012.1

Flow chart diagram shown below shows the different steps that carried throughout the project from the beginning to the end results.

Methodology



LITERATURE SURVEY

design of axial flow and radial flow gas turbines marcel dekker

This report describes about the design of axial flow and radial flow gas turbines. This describe how to design a turbine blade, what all data's we need for the design of turbine blades, etc..

From this report we will get the knowledge about the calculation of blade height and width. In this so many solved problems regarding the calculation of blade parameters also given, that is very helpful for this project work.

AN EXPERIMENT IN TURBINE BLADE PROFILE DESIGN(Ministry of Technology Aeronautical Research Council)

I .H .Johnston and Dianne Smart

This report describes a method for designing the blades of a highly loaded two stage turbine on the basis of certain design parameters derived from an efficient turbine of lower loading. Also presents the test performance measured with the original and new blades when tested in both single stage and two stage configurations. A full and detailed presentation of the experimental work is given to illustrate the problems in instrumentation and in interpretation of test measurements which were encountered.

The new blades give an improvement in the efficiency of the first stage, but the performance of the second stage remains unchanged and an analysis of blade section velocity distributions give additional proof of the shortcomings of an essentially empirical design approach.

DESIGN

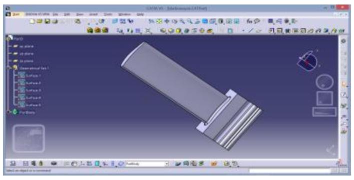


figure 3 catia v5 model of turbine blade -pressure side

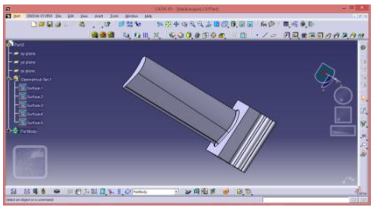


figure4catia v5 model of turbine blade- suction side

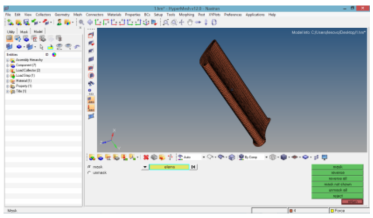


figure 5 meshed airfoil(pressure side) and fillet section

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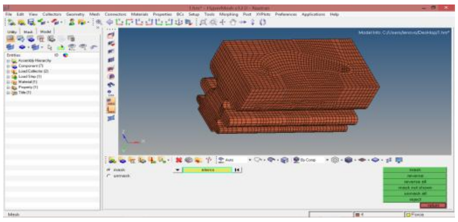

Figure 6 meshed root section

ANALYSIS

NASTRAN-PATRAN is used for structural analysis of the turbine rotor blade .In this project I considered the material INCONEL 718, and applied the loads and boundary conditions and generate the stress and radial deformation. I selected INCONAL 718 because of its high temperature withstanding ability, high ultimate and yield strength. The steps involved in analysis are:-

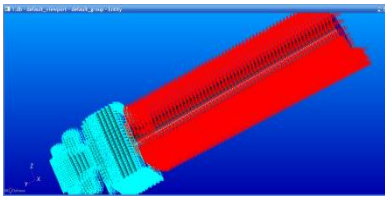

figure 7 pressure appliyed on the turbine blade

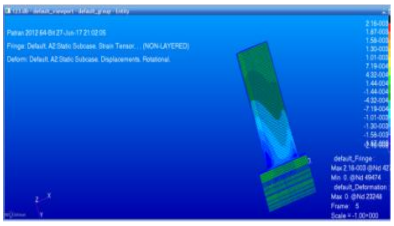

figure 8displacement, rotational.

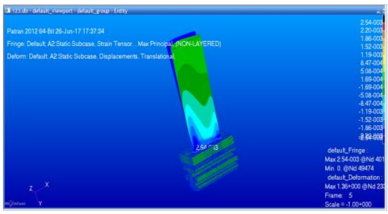

figure 9 displacement, translational

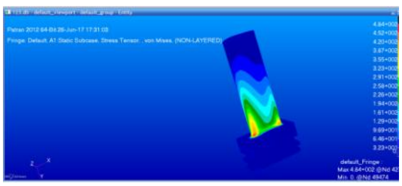

figure 10 vonmises stress

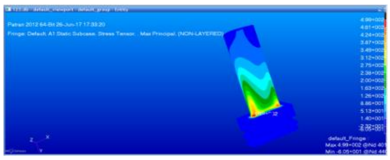

figure 11 maximum principle stress

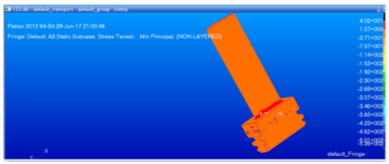

figure 12 minimum principle stress

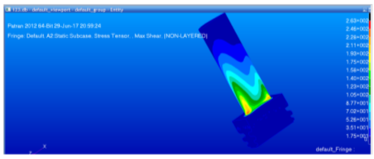

figure 13 maximum shear stress

The above figures are the end result of the structural analysis of gas turbine blade. Here all the stress output data's are in 'MPa' and the displacements are in 'mm'.

Results from Analysis

Table 1 result

RESULT	
Von Mises Stress	484MPa
Principle Stress	MAX-499MPa MIN-40.2MPa
Shear Stress	265MPa
Displacement	Rotational- 0.00216mm Translational- 0.00254mm

RESULT AND VALIDATION OF STRUCTURAL ANALYSIS

For any project validation is very important. In this project I validate structural analysis in terms of factor of safety,margin of safety and by considering a material that have almost similar properties. The material name is Inconel X750.

Table 2 MECHANICAL PROPERTIES OF INCONEL X750, 718

	INCONEL X750	INCONEL 718
Density	8.28e-6kg/mm^3	8.82e-6kg/mm^3
Poisons ratio	0.3	0.27
Young's modulus	210GPa	190gpA
Ultimate tensile strength	1137.6MPa	1275.6Mpa

Table 3 COMPARISON TABLE INCONEL 718&X750

RESULT	INCONEL 718	INCONEL X750
Von Mises Stress	484MPa	485MPa
Max.Principle Stress	499MPa	494MPa
Min. Principle stress	40.2MPa	39.6MPa
Max.Shear stress	263MPa	265MPa
Displacement translational	.00254mm	.002mm
Displacement rotational	.00216mm	.002mm

Table 4 validation table2

MATERIAL	INCONEL718	INCONEL-X750
VON MISES STRESS	484MPa	485MPa
DISPLACEMENT ROTATIONAL%	.0021	.00194
DISPLACEMENT TRANSLATIONAL%	.00247	.00194
FoS	2.137	1.5
MARGIN OF SAFETY	1.137	.5

CONCLUSION

1. The structural analysis of turbine rotor blade geometry developed for this project has a safe life at high load condition.
2. Finite element analysis for structural and thermal analysis of gas turbine rotor blade is carried out using solid185 element.
3. Maximum deflection and is observed at the blade tip section and minimumdeflection at the root of the rotor blade.
4. Maximum stresses are observed at the root of the turbine blades.
5. Inconel718 is the best material for turbine rotor blade because of FoS 2.137
6. For reducing the effect of temperature on blade we can choose thermal barrier coating. Other cooling methods reduce the strength of the material, because of removal of material from inside the blade.
7. This project summarizes how to design turbine rotor blade geometry, and predict that geometry is safe on the basis of static structural analysis (based on elongation and factor of safety).

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