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Design and Analysis of Gas Turbine Blade

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ABSTRACT- 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.

I. INTRODUCTION

The gas turbine obtains its power by utilizing the energy of burnt gases and the air which is at high temperature and pressure by expanding through the several rings of fixed and moving blades. The turbine drives the compressor so it is coupled to the turbine shaft. After compression, the working fluid were to be expanded in a turbine, then assuming that there were no losses in either component, the power developed by the turbine can be increased by increasing the volume of working fluid at constant pressure or alternatively increasing the pressure at constant volume. Either of there may be done by adding heat so that the temperature of the working fluid is increased after compression. To get a higher temperature of the working fluid, a combustion chamber is required where combustion of air and fuel takes place giving temperature rise to the working fluid. The turbine escapes energy from the exhaust gas. The present paper deals with the first type is centrifugal stresses that act on the blade due to high angular speeds and second is thermal stresses that arise due to temperature gradient within the blade material. The analysis of turbine blade mainly consists of the following two parts: Structural and thermal analysis. The analysis is carried out under steady state conditions using ANSYS software. The study has been conducted with two different materials Inconel 718 and Titanium T6.

II. LITERATURE SURVEY

V.Veeraragavan [5] had mainly done the research on the aircraft turbine blades; his main focus was on 10 C4/ 60 C50 turbine blades models. He had used the conventional alloys such as titanium, zirconium, molybdenum, and super alloys were chosen for the analysis. He had analyzed the effect of the temperature on the different material for the certain interval of times. And conclude the molybdenum alloys had better temperature resistance capability.

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R D V Prasad, G Narasa Raju, M S S Srinivasa Rao, N Vasudeva Rao [7] had done research on different types of the cooling technique which maintain temperature of the blade to allowable limits, Finite element analysis is used to examine steady state thermal & structural performance for N155 & Inconel 718 nickel-chromium alloys. Four different models consisting of solid blade and blades with varying number of holes (5, 9 & 13 holes) were analyzed to find out the optimum number of cooling holes. They had used two material Inconel 718 and Inconel 155 for their research work and found out Inconel 718 has the better thermal properties as the blade temperature and the stress induce is lesser.

III. METHODOLOGY

1. Problem definition.
2. Calculate the dimensions of blade profile
3. Generate the 3-dimentional computer models
4. Prepare finite element model of the 3D computer model
5. Preprocess the 3D model for the defined geometry
6. Mesh the geometry model and refine the mesh considering sensitive zones for results accuracy
7. Post process the model for the required evaluation to be carried out
8. Determine maximum stress induced in blades.
9. Determine the temperature distribution along the blade profile.
10. Conclude the results.

IV. DESIGN AND CAD MODELLING

By using standard assumptions, theoretical calculations are made to obtain the dimensions of the blade geometry. . The design parameters are given in table 4.1

Table 4.1: Design parameters.

PARAMETER	VALUE	UNIT
Blade height, **h**	0.081833	m
Chord width, **c**	0.02727	m
Pitch, **s**	0.02264	m
Number of blade	69	
Blade inlet angle, β_2	18.3^0	deg
Blade outlet angle, β_3	54.56^0	deg
Mean radius, r_m	0.2475	m

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The 3D CAD model is created using the software CATIA V5; it is shown in fig 4.1.

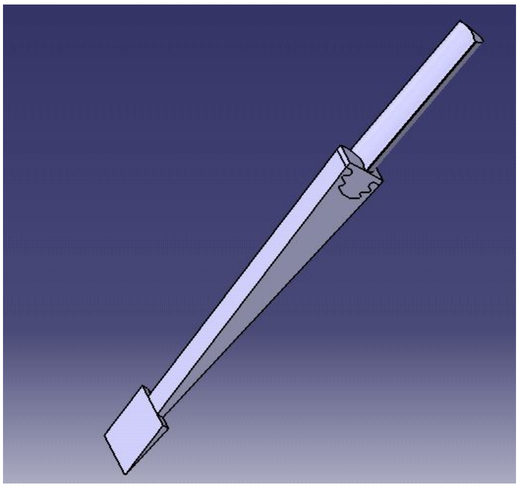

Fig 4.1: - Sector Model of Turbine Blade

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V. DETAILS OF TURBINE BLADE MATERIAL

The turbine blade is subjected to rotational speed of 10800 rpm and firing temperature of 619^{0}C. Factor of safety is 1.6.

Table 5.1:-Material properties.

Properties	**Unit**	**Inconel 718**	**Titanium T6**
Young's modulus	MPa	2E5	1.06E5
Density	kg/m^3	8193.3	4420
Poisson's ratio		0.31	0.3
Tensile yield strength	MPa	1069	530
Allowable stress	MPa	641.8	318
Allowable Shear stress	MPa	385.08	190.8
Specific heat	J/kg-K	556.85	527.5

VI. RESULTS AND DISCUSSION

The temperature distribution of the blade depends on the heat transfer coefficient for gases and the thermal conductivity of the material. The heat transfer coefficients are calculated by iterative process and the same were adopted. The analysis was carried out for steady state heat transfer conditions. It is observed that the maximum temperatures are prevailing at the

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leading edge of the blade due to the stagnation effects. The body temperature of the blade doesn't vary much in the radial direction. However, there is a temperature fall from the leading edge to the trailing edge of the blade as expected. It is observed for solid blade model from fig6.1 (Titanium T6) and fig6.2 (Inconel 718), that the blade temperatures attained for Inconel 718 are marginally lower. This can be attributed to the lower thermal conductivity of Inconel 718.

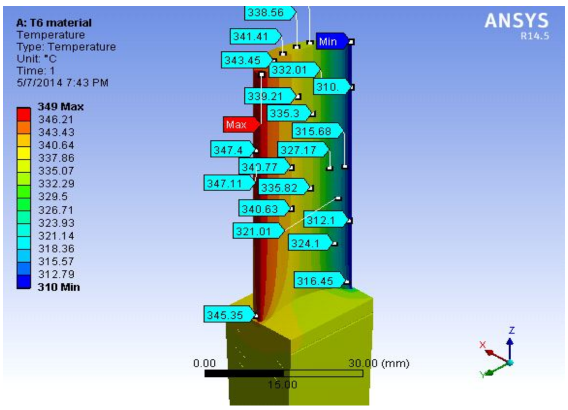

Fig 6.1:- Temperature distribution on Titanium T6.

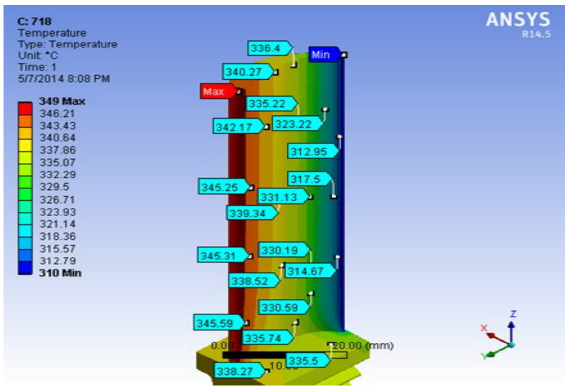

Fig 6.2: -Temperature distribution on Inconel 718.

The temperatures obtained from the thermal analysis are imported to structural analysis. The Centrifugal forces acting on the blade are considered as loads in structural analysis.

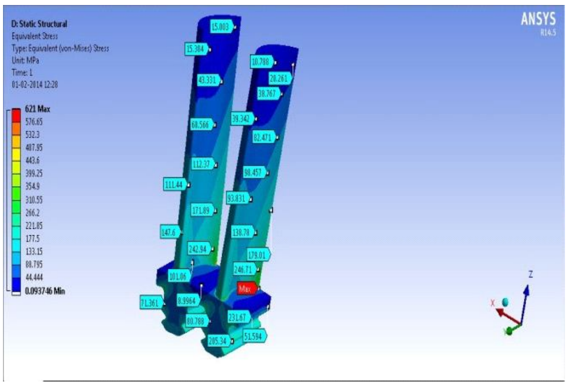

Fig 6.3:- Von-miss stress on Inconel

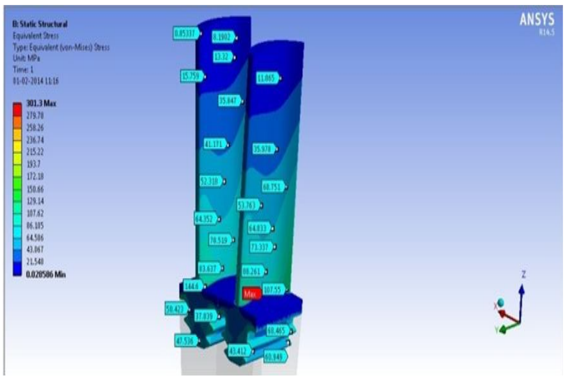

Fig 6.4:- Von-miss stress on Titanium T6

Below fig 6.3, fig 6.4, shows the variation of the von misses stress on the blade and the drum portion, Inconel 718 and titanium T-6 was use in blade whereas steel 286 was use for the drum. As the blades are not shrouded so the stress on the tip of the blade are lesser and higher values of stress is coming on the root of the blades.

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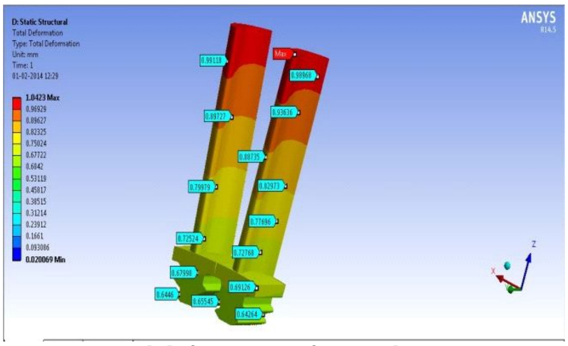

Fig 6.5:- Total deformation of Inconel 718

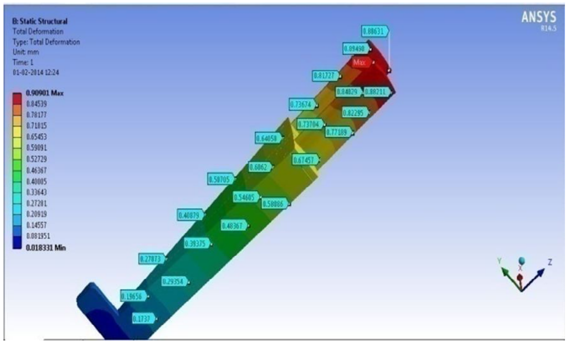

Fig 6.6:- :- Total deformation of Titanium T6

Thermal expansion of Titanium-T6 is lesser as compare to that of Inconel 718; due to this property of the materials the expansion of the Titanium T6 is lesser as compare to that of Inconel 718. The results are shown in table 6.1.

Table 6.1: Comparison of results.

PARAMETERS	INCONEL 718		TITANIUM T6	
Total Deformation(mm)	1.0448		0.90901	
	Analytical Results	Computational Results	Analytical Results	Computational Results
Von Misses Stress(MPa)	641.8	621	318	301.3

VII. CONCLUSION

It is seen from above results both the materials are giving the considerable results; finally the conclusion can be done on the basis of the cost and the availability of the materials.

- If cost of the materials is not a primary issue we can select the titanium T6 which have lesser density, lesser value of deformation at a same time it will have lower value of yield strength and young modulus at higher temperature, which will have a lower strength.
- On the other hand if cost of the material is a primary issue then we can select Inconel 718, it will have little higher deformation at high temperature as compare to titanium T6. But at the same time it will have higher value of elastic strength, higher values of yield strength which will induce lesser value of the stress on the blade.
- It is also seen Inconel 718 have good material properties at higher temperature has compare to that of the titanium T6.

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- Proper way of cooling should be adopted such that hot corrosion and creep strain distribution on the trailing edge will get minimized on turbine blade (Inconel 718)

So we can conclude from above plots and observation that structure is safe for given loading condition and also, Inconel 718 is better material as compare to that of titanium T6 in economically as well as strength at higher temperatures.

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BIOGRAPHY

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