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Design And Analysis Of Gas Turbine Blade

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Abstract:

This research work will design and stress evaluate a jet engine turbine blade. A study on the use of novel materials is needed. The current study used Inconel 718 and Titanium T-6 as turbine blade materials. The influence of temperature and induced stresses on the turbine blade has been studied. A thermal analysis was performed to determine the direction of temperature flow caused by thermal loading. The turbine blade's tensions, shear stresses, and displacements developed due to the coupling effect of heat, and centrifugal loads were investigated structurally. The findings of two materials are compared to indicate the optimal material for a turbine blade (Inconel 718 and titanium T6). Based on the plots and results, Inconel718 is the best material since it is cheaper and has better qualities at higher temperatures than TitaniumT6.

1. INTRODUCTION:

Gas turbines get its power by expanding high-temperature, high-pressure air through rings of stationary and moving blades. The turbine shaft powers the compressor. Raising the volume of working fluid at constant pressure or increasing the pressure at constant volume may enhance the turbine's output, providing there are no losses in either component. Heating the working fluid after compression may do either. A combustion chamber is needed to heat the working fluid by burning air and fuel. Exhaust gas powers the turbine. This work discusses centrifugal stresses caused by high angular speeds and thermal stresses caused by temperature gradients in the blade material. Turbine blade analysis includes structural and thermal analysis. ANSYS software does steady-state analysis. Inconel 718 and Titanium T6 were studied.

II. LITERATURE SURVEY:

V.Veeraragavan studied 10 C4/60 C50 turbine blade types. He analysed titanium, zirconium, molybdenum, and super alloys. He investigated the temperature's influence on various materials throughout time. Molybdenum alloys have superior heat resistance.

R D V Prasad, G Narasa Raju, M S S Srinivasa Rao, N Vasudeva Rao [7] researched cooling techniques that keep blade temperature below allowed ranges. Finite element analysis is utilised to analyse steady state thermal & structural performance for N155 & Inconel 718 nickel-chromium alloys. Four models with solid blades and blades with 5, 9, and 13 cooling holes were evaluated to determine the optimal number. Inconel 718 has greater thermal characteristics than Inconel 155, since the blade temperature and stress are lower.

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 1

Table 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

The 3D CAD model is created using the software CATIA V5; it is shown in fig 1

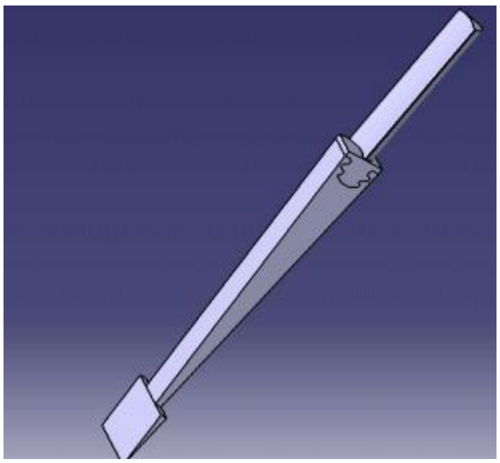

Fig 1: - Sector Model of Turbine Blade

V. DETAILS OF TURBINE BLADE MATERIAL:

The turbine blade is subjected to rotational speed of 10800 rpm and firing temperature of 6190C. Factor of safety is 1.6.

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:

Blade temperature distribution relies on gas heat transfer coefficient and material thermal conductivity. The heat transfer coefficients were determined iteratively. The investigation included steady-state heat transmission. Due to stagnation, the blade's leading edge has the highest temperatures. The blade's radial temperature is consistent. As predicted, blade temperature drops from leading to trailing edge. In fig 2 (Titanium T6) and fig 3 (Inconel 718), Inconel 718 has somewhat lower blade temperatures. Inconel 718's reduced heat conductivity causes this.

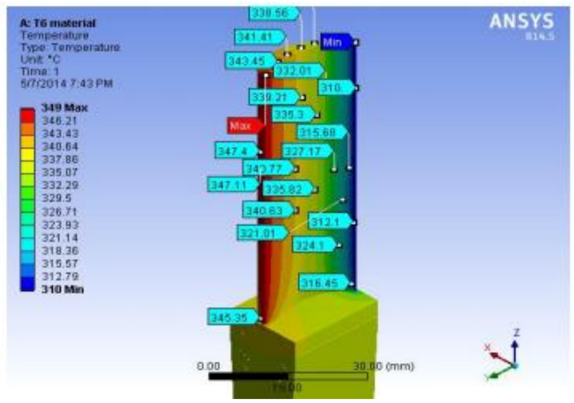

Fig 2:- Temperature distribution on Titanium T6.

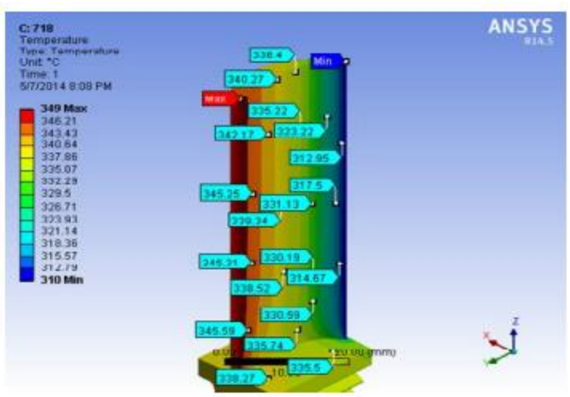

Fig 3: -Temperature distribution on Inconel 718.

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.

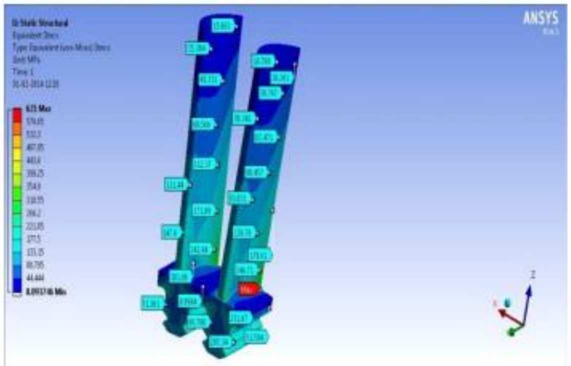

Fig 4:- Von-miss stress on Inconel

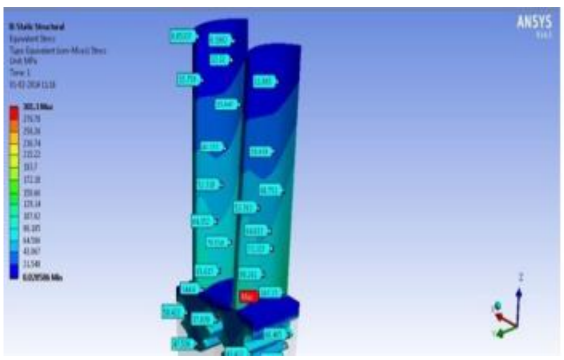

Fig 5:- Von-miss stress on Titanium T6

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.

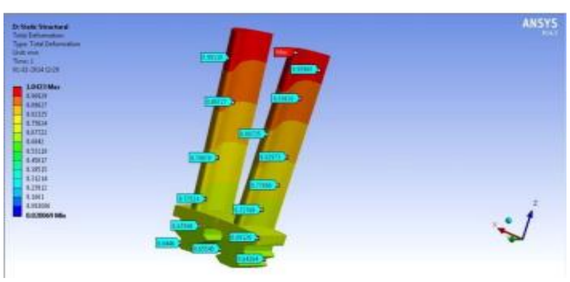

Fig 6:- Total deformation of Inconel 718

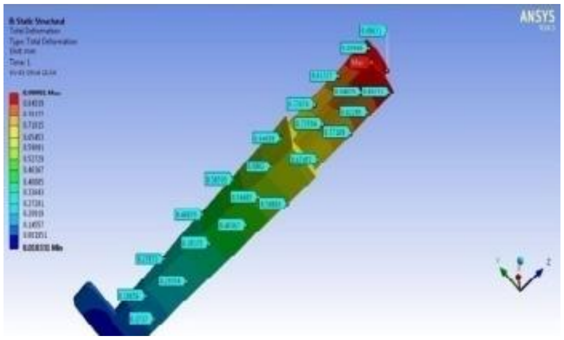

Fig 7:- :- Total deformation of Titanium T6

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 2.

Table 2: 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.
- 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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