DESIGN AND ANALYSIS OF CERAMIC(SIC) GAS TURBINE VANE

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Abstract - *The objective of this Project was to develop design concepts for a cooled ceramic vane to be used in the first stage of the High Pressure Turbine (HPT). To insure that the design concepts were relevant to the gas turbine industry needs. The first was an analysis of the cycle benefits arising from the higher temperature capability of Composite materials (SIC) compared with conventional metallic vane materials. The size, shape and internal configuration of the turbo shaft engine vanes were selected to investigate a cooling concept appropriate to small vanes. Shape Optimization made on geometry using CATIA V5 software. Using blade geometry and materials like SIC (silicon carbide) analysis done using ANSYS 15.0.*

Gas turbine play a vital role in the today's industrialized society, and as the demand for power increase, the power output and thermal efficiency of the gas turbine must also increase. One method of increasing both the power output and thermal efficiency of the engine is to increase the temperature of the gas entering the turbine. In the advanced gas turbine, the inlet temperature of around 1500^0c is used; however this temperature exceeds the melting temperature of the metal airfoils. Therefore, along with high temperature material development, a refined cooling system must be developed for continuous safe operation of the gas turbines with high performance.

Key Words: **Gas Turbine, Titanium T6, Silicon carbide, Brayton cycle, Stress, Total Heat flux, Deformation.**

1. INTRODUCTION

Gas turbine is the main component in industries like power generation; processing plant and aircraft propulsion. In 1960s, by material property limited the turbine blade and gas turbine firing temperature around the 800C.But now a day's gas turbine engines operate at high temperatures (1200-1500°C) to improving thermal efficiency and power output. Due to increasing the gas temperature, the heat transfer to the blades will also increase significantly resulting in their thermal failure. With the existing materials, it is not possible to go to higher temperatures. Therefore a suitable cooling method must be developed for continuous safe operation of gas turbines with high performance. In order to employ high gas temperature in gas turbine stages, it is necessary to cool the casing, nozzles, rotor blades and discs. Cooling of these components can be achieved either by air or liquid cooling. By using the liquid cooling method to face the some disadvantages of these processes i.e. the problems of leakage, corrosion. Besides other side, air cooling method, it's allows to be discharged into the main flow without any problem. The blade metal temperatures can be reduced by around 200-300°C. By using suitable blade materials (nickel-based alloys) now available, an average blade temperature of 800°C can be used. This gives the permit maximum gas temperatures around 1200-1500°C. Air cooling method is briefly described in two main parts i.e. internal cooling & external cooling.

Internal cooling of the blade can be achieved by passing cooling air through internal cooling passage from hub towards the blade tips. The internal passages may be circular or elliptical and are distributed near the entire surface of a blade. The cooling of the blade is achieved by conduction and convection. Relatively hot air after traversing the entire blade length in the cooling passages escapes to the main flow from the blade tips. A part of this air can be usefully utilized to blow out thick boundary layers from the suction surface of the blades. Hollow blades can also be manufactured with a core and internal cooling passage. Cooling air enters the leading edge region in the form of jet and then turns towards the trailing edge. Cooling of the blade takes place due to both jet impingement (near the leading edge) and convection heat transfer.

External cooling of the turbine blades is achieved in two ways. The cooling air enters the internal passage from hub towards the tips. On its way upward it's allow to flow over the blade surface through a number of small orifices inclined to the surface. A series of such holes is provide at various sections of the blade along their lengths. The cooling air flowing out of these small holes forms a film over the blade surface. Besides cooling the blade surface it decreases the heat transfer from the hot gases to the blade metal. Cooling air is force through this porous wall which forms an envelope of a comparatively cooler boundary layer or film. This film around the blade prevents it from reaching very high temperatures. Besides the effusion of the coolant over the entire blade surface causes uniform cooling of the blade.

1.1 Theory of operation:-

The basic operation of the gas turbine is a Brayton cycle with air as the working fluid. Fresh atmospheric air flows through the 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; the energy that is not used for shaft work comes out in the exhaust gases that produce thrust. The purpose of the gas turbine determines the design so that the most desirable split of energy between the thrust and the shaft work is achieved. The fourth step of the brayton cycle (cooling of the working fluid) is omitted, as gas turbines are open systems that do not use the same air again.

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

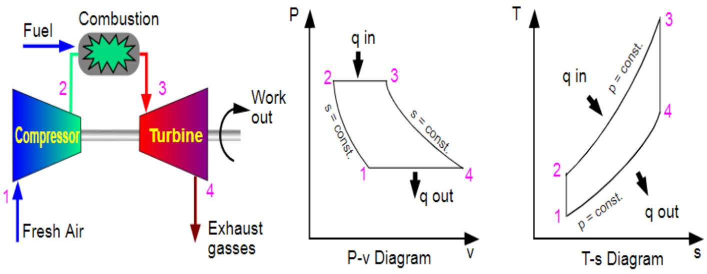

Fig-1 : working of Brayton cycle

2. LITERATURE SURVEY

Theju V et.al had mainly done the research work on jet engines turbine blade; the study was done on two different materials Inconel -718 and Titanium T6; to investigate the effect of temperature and induced stresses on turbine blade. The study concluded that the Titanium T-6 would have lesser value of deformation and lower strength; however if cost of material is the primary issue then inconal-718 could be selected it would have little higher deformation and higher strength. Also Inconel have good material properties at higher temperature than titanium.

V. Veeragavanet.al had done their research on aircraft turbine blades, his main focus was on 10C4/60C50 turbine blade models. Conventional alloys Such as titanium, zirconium, and molybdenum were chosen for analysis .he studied the effect of temperature on different material for the certain interval of times and concluded that molybdenum had better temperature resistance capability.

G. Narendranath et.al. examine the first stage rotor blade off the gas turbine analyzed using ANSYS 9.0. The material of the blade was specified as N155. Thermal and structural analysis is done using ANSYS 9.0 Finite element analysis software. The temperature variations from leading edge the trailing edge on the blade profile is varying from 839.531C to 735.162C at the tip of the blade. It is observed that the maximum thermal stress is 1217 and the minimum thermal stress is the less than the yield strength value i.e., 1450.

3. MATHODOLOGY

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.

4. DESIGN AND CAD MODELLING

From blade drawing profile sheet modeling is done by using the design software CATIA V5 R19. Blade profile is obtained by the help of CATIA tools 3d modeling.

4.1 EXPERIMENTAL PROCEDURE

Aim: To design a 3 D model of a turbine blade by using CATIA V5 R20.

Equipment: Intel core 2 duo computer installed with CATIA V5 R19

Software: CATIA V5 R19

Step 1: Select XY sketch plane

Step 2: Take the geometric coordinates

Step 3: select the coordinate system and enter the coordinates

Step 4: Select the bottom surface of the rod and enter sketcher

Step 5: Draw the sketch of a profile with the key points shown in the reference

Step 6: go to work bench and pad to a thickness of 27mm.

Step 7: select the top surface of the flange and go to sketcher

Step 8: draw a rectangle at bottom of the profile.

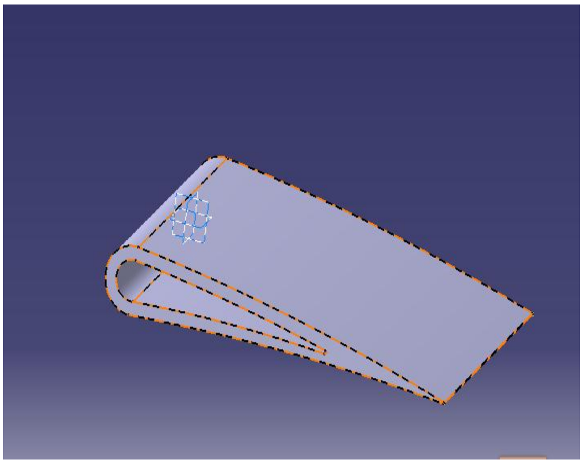

Fig -2: Basic design of turbine blade

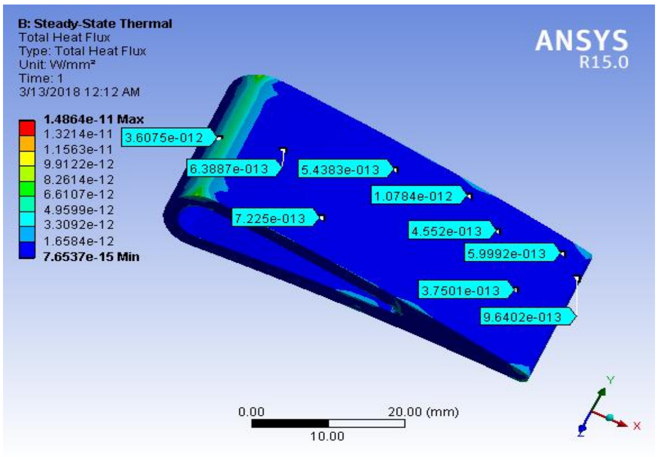

Fig -3: Total heat flux for titanium t6

5. DETAILS OF TURBINE BLADE MATERIAL

Properties	Units	Sic	Titanium T6
Young's modulus	MPa	1.2e+005	1.1e+005
Density	Kg/m³	3200	4430
Poisson's ratio	-	0.37	0.34
Tensile yield strength	MPa	1500	880
Bulk Modulus	MPa	1.5385e+005	1.1603e+005
Thermal conductivity	W/m°K	20.7	7.1
Specific heat	J/Kg-k	650	527.5

6. 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 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 fig.3 (Titanium T6) and fig.4 (Sic), that the blade heat flux generated in Sic more than Titanium T6 alloy.

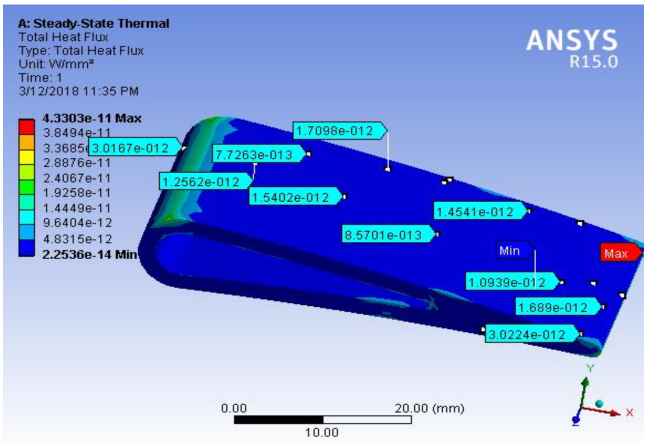

Fig -4: Total heat flux for sic

Below fig.5, fig. 6, shows the variation of the von misses stress on the blade, Sic and titanium T-6. 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.

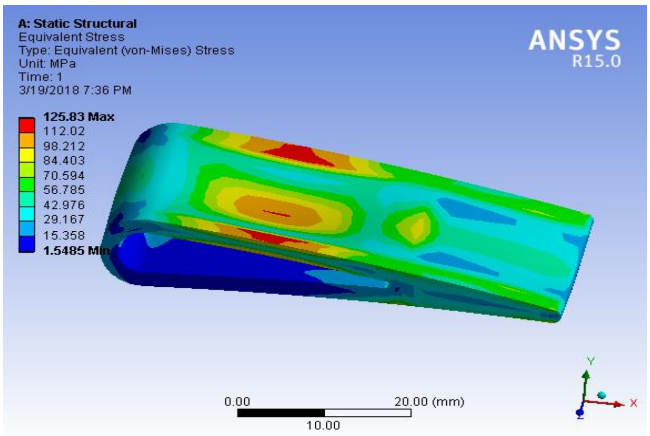

Fig -5: Total Von Misses Stress for material of SIC

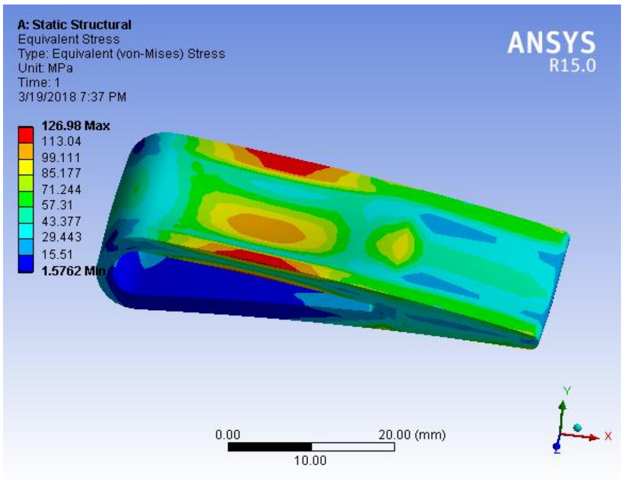

Fig-6: Total Von Misses Stress for material of Titanium T6

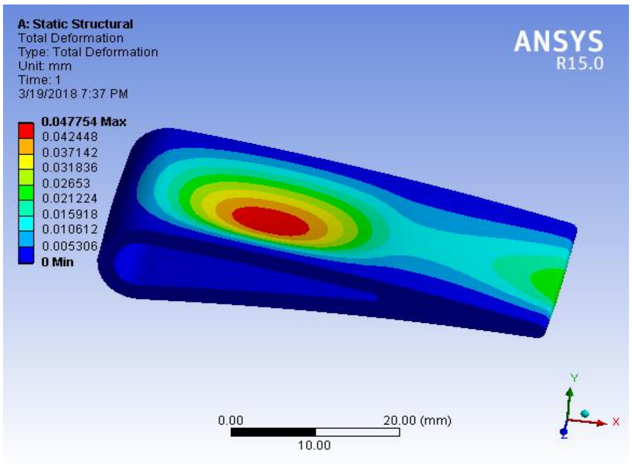

Fig-7: Total Deformation for material of Titanium T6

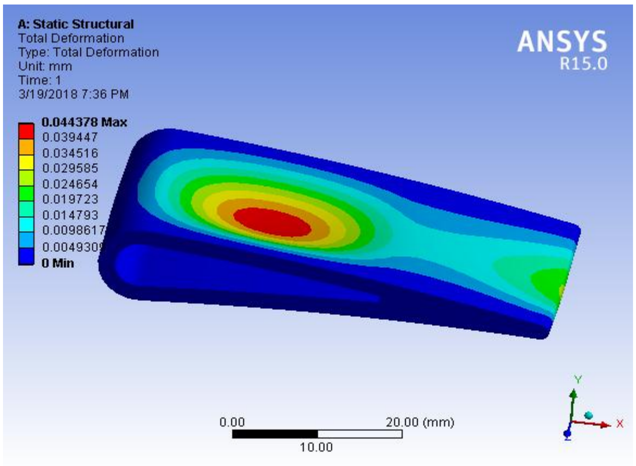

Fig -8: Total Deformation for material of SIC

Total heat flux developed in Sic more as compare to that of Titanium T6 alloy; due to this property of the materials the heat flux of the Titanium T6 is lesser as compare to that of Sic. The results are shown in table 6.1.

Table -1: Comparison of results.

PARAMETERS	SIC		TITANIUM T6	
	Min	Max	Min	Max
Total deformation (mm)	0.01598	0.04437	0.01479	0.04775
Total heat flux(W/mm^2)	1.87 $*10^{-6}$	7.23 $*10^{-5}$	1.02 $*10^{-5}$	2.48 $*10^{-5}$
Von Misses Stress(MPa)	56.78	125.83	57.31	126.98

7. CONCLUSIONS

This Project was to develop design concepts for a cooled ceramic vane to be used in the first stage of the High Pressure Turbine (HPT). The optimization shapes are model and varies material are consider. Models shapes are used to Analysis with various materials (Titanium T6 alloy, Sic). Gas turbine is studied for its structural performance and Thermal analysis considering SIC as the blade material. The analysis was conducted on ANSYS 15.0 sotwere.

From result table, materials and geometry modification. Fig shows that best material and Geometry are with case material (SIC) is best to suit working load conditions. Reduction Stress Comparing with Titanium T6 with total heat flux is more in SIC. And the stress developed in Titanium T6 is 126.98(MPa).

Material 2 to Material 1 Compared and Reduction Stress

- % of Stress Reduction is SIC – 13%

Deformation in Titanium T6& SIC:

- Deformation of SIC :-0.04437 mm
- Deformation of Titanium T6:-0.04775mm

Total heat flux

- Total heat flux generated in sic:- 7.23*10^{-5}w/mm^2
- Total heat flux generated in Titanium T6:- 2.48*10^{-5}w/mm^2

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