

Structural and Thermal Analysis of Super Alloys using Gas Turbine Blades

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ABSTRACT: The main objective of these project material composition of turbine blades. Gas turbine is in used for power generation .advanced gas turbine engine operate at high temperatures (1200-15000° C)to improve thermal efficiency and power output .the chemical composition of material to withstand high temperature corrosion resistance and tensile properties. Turbine blades using the Nickle based alloys Inconel 718 and N-155.it is low melting point .in these project using super alloys.MAR M247 and Ti alloys (R50250) RMI-6AL-4V alloy. It has the high young's modulus, good thermal conductivity, high ultimate strength. In these turbine blade was designing by CATIA V5 software. The numerical analysis using the ANSYS software. These software using the structural and thermal analysis of the material. The structural analysis of equalent stress tensile strength of the material. Thermal analysis of temperature distribution,temperature cross section, deformation of material.

KEYWORDS: Gas turbine blade , high temperature, Ni alloys, super alloys, CATIA V5, ANSYS

I.INTRODUCTION

A turbine is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Turbines can have very high power density (i.e. the ratio of power to weight, or power to volume). This is because of their ability to operate at very high speeds. A working fluid contains potential energy (pressure head) and kinetic energy (velocity head). Impulse turbines change the direction of flow of a high velocity fluid or gas jet. The resulting impulse spins the turbine and leaves the fluid flow with diminished kinetic energy. There is no pressure change of the fluid or gas in the turbine blades (the moving blades), as in the case of a steam or gas turbine; the entire pressure drop takes place in the stationary blades (the nozzles). Reaction turbines develop torque by reacting to the gas or fluid's pressure or mass. The pressure of the gas or fluid changes as it passes through the turbine rotor blades. A pressure casing is needed to contain the working fluid as it acts on the turbine stage(s) or the turbine must be fully immersed in the fluid flow (such as with wind turbines). The casing contains and directs the working fluid and, for water turbines, maintains the suction imparted by the draft tube. Francis turbines and most steam turbines use this concept.^[2]

II. GEOMETRICAL CONFIGURATIONS

The Boeing Company used CATIA V3 to develop its 777 airliner, and is currently using CATIA V5 for the 787 series aircraft. They have employed the full range of Dassault Systems 3D PLM products — CATIA, DELMIA, and ENOVIA LCA— supplemented by Boeing developed applications. The development of the Indian Light Combat Aircraft has been using CATIA V5.Chinese Xian JH-7A is the first aircraft developed by CATIA V5, when the design was completed on September 26, 2000. European aerospace giant Airbus has been using CATIA since 2001. Canadian aircraft maker Bombardier Aerospace has done all of its aircraft design on CATIA. The Brazilian aircraft company,

EMBRAER, use CATIA V4 and V5 to build all airplanes. Vought Aircraft Industries use CATIA V4 and V5 to produce its parts. The British Helicopter company, Westland, use CATIA V4 and V5 to produce all their aircraft. Westland is now part of an Italian company called Finmeccanica the joined company calls themselves Augusta Westland. The main supplier of helicopters to the U.S Military forces, Sikorsky Aircraft Corp, uses CATIA as well. We decided to use CATIA version because of its simplicity and user friendly options, compared with other software's CATIA is easy and more advanced; it is specially designed software for aerospace applications.

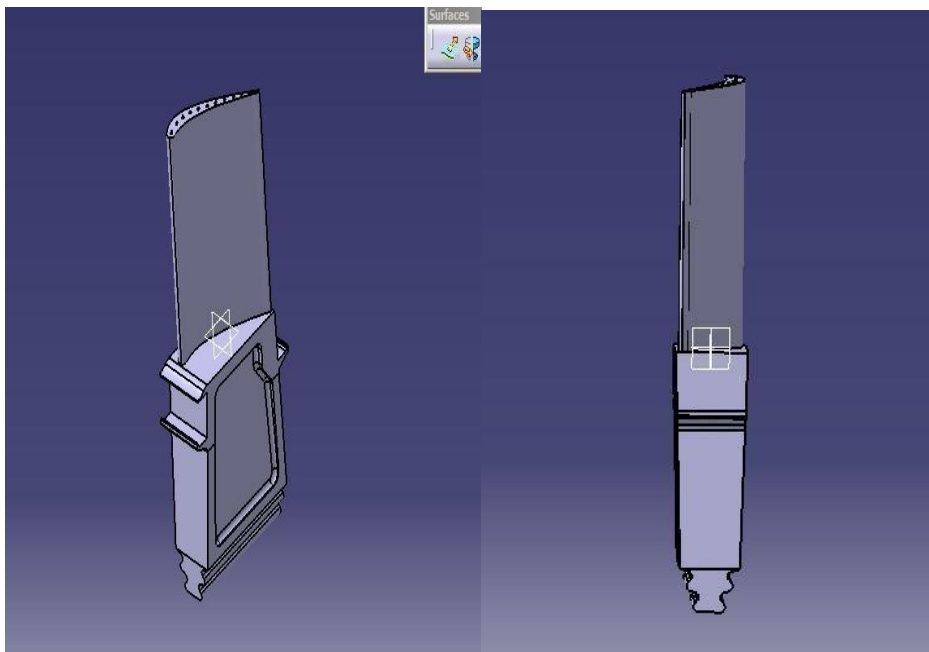


Fig 1.1 Modelling of turbine blade

Selection of material for rotor:

This chapter discuss about the criteria of selection of turbine rotor material and details about super alloys which is very common in usage in now days in aerospace & mechanical industries.

The turbine material should have following characteristics

1. Melting point should be always much higher than operation temperature of turbine (1040°C) and Excellent Elevated Temperature Properties
2. Thermal strain induced d should be lesser
3. Elevated Strength-to-Density Ratio (high structural efficiency)
4. Low Density (roughly half the weight of steel, nickel and copper alloys)
5. Exceptional Corrosion Resistance(superior resistance to chlorides, seawater and sour and oxidizing acidic media and exhaust gases)^[13]

The selected material for analysis purpose is

I. Ti ALLOY -(R50250) - RMI - 6AL-4V ALLOY

Super alloys:

The material system consist of two or more base metal constituents which are combine in definite proportion homogenous throughout having superior mechanical property and can withstand high temperature with minimum thermal strain is called as SUPER ALLOY .it include a composition of metals includes nickel-, ironnickel-, and cobalt-base corrosion-resistant alloys generally used at temperatures above around540 °C (1000°F). The iron-nickel-base super alloys are an extension of stainless steel technology and generally are wrought, i.e., formed to shape or mostly to shape by hot rolling, forging, etc. The cobalt-base and nickel-base super alloys, on the other hand, may be either wrought or cast depending on the application or the alloy composition involved.

The stainless steels, nickel–chromium alloys and cobalt dental alloys that evolved into the super alloys used chromium to provide elevated temperature corrosion resistance [14], [15].

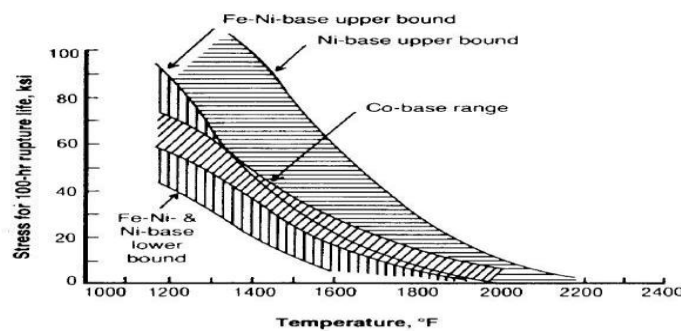


Figure 15 creep curvature of super alloys

MATERIAL PROPERTY OF Ti ALLOY					
DENSITY(KG/M ³)	YOUNGS MODULUS (Gpa)	POISSONS RATIO	SPECIFIC HEAT J/Kg°C	MELTING POINT °C	
4510	103	0.26	520	1670	
COMPOSITION OF ALLOY					
C	N	O	Fe	H	Ti
0.08	0.03	0.18	0.2	0.15	0.36

MAR M 247 alloy Composition:

Table: composition of MAR M 247 alloy

COMPOSITION IN %												
C	Ni	Cr	Co	Mo	Fe	Al	B	Ti	Ta	W	Zr	Other
0.15	59	8.225	10	0.7	0.5	5.5	0.015	1	3	10	0.05	1.5

The material property chart

Table: material property of MAR M 247 alloy

density (ρ)	youngs modulus E	poissons ratio (ν)	thermal conductivity (C)	specific heat (Cp)
kg/m ³	GPa	—	w/mk	KJ/kg K
5830	1.44	0.3	12.3	461
ultimate strength (Mpa)		Rupture strength (Mpa)		bulk modulus (K)
100 hr time	1000 hr time	100 hr time	1000 hr time	Gpa
at 538 °C	at 1093 °C	at 538 °C	at 1093 °C	1.2
965	1035	185	125	

FINITE ELEMENT METHOD

Description:

Finite element method is a powerful numerical discretization technique for approximate solution of continuum mechanics problems or complex problems. Analytical method of solving many engineering problems is not possible as it involves mathematical expressions that give the value of the desired unknown quantity at any location in a body and as a result the solution can be obtained only for certain simplified situations. For problems involving complex structures and boundary conditions, numerical methods provide approximate but acceptable solutions.

In numerical solutions, a body or a structure is divided into an equivalent system of smaller bodies or units with finite degrees of freedom, a process that is termed as discretization. The assemblage of such units represents the original body. Each unit is called element and these elements are interconnected at joints, which are called nodes or nodal points. Instead of solving the problem for the entire body in one operation, an approximate admissible solution is constructed for each element and the solution continuity is maintained at the inter element boundaries. The properties of elements are formulated and combined to obtain the solution for the entire structure. This forms the basis of Finite element method.

III.FINITE ELEMENT MODELING STRUCTURAL ANALYSIS OF TURBINE BLADE

Geometric modeling:

Geometric modeling is defined as per computer compatible mathematical description of an object.

The structure is modelled using basic image entities such as points, lines, areas and finite number of elements. Again the choice of elements is influenced by geometry of the body, loads acting on the body and number of degrees of freedom required to describe a system.

Discretization:

Discretization of the continuum can be defined as dividing the continuum into finite number of elements. Again the choice of elements is influenced by the geometry of the body, loads acting on the body and number of degrees of freedom required to describe a system.

Selection of displacement model:

In FEM, solution to a problem is obtained by dividing the region into small elements and approximating the solution over the sub region of the element by using a polynomial.

It is generally not possible to select a displacement model or function that can represent exactly the actual variation of the element. To overcome this problem, more number of terms in the displacement functions is to be used.

Derivation of element stiffness matrix:

Using variation principles like principle of minimum potential energy, the stiffness matrix is obtained. The stiffness matrix consists of coefficients of equilibrium equation derived and also the material and geometric properties of the element.

The equilibrium equation between the element stiffness matrix k , element nodal force vector f and the displacement associated with the nodes of the element is given by

$$[k]\{q\} = \{f\} \text{ Assembly of}$$

element stiffness matrices:

This is the process of obtaining the overall or the global stiffness matrix and force vector for the entire structure. The global stiffness matrix, global force vector and displacements are related as

$$[K]\{Q\} = \{F\}$$

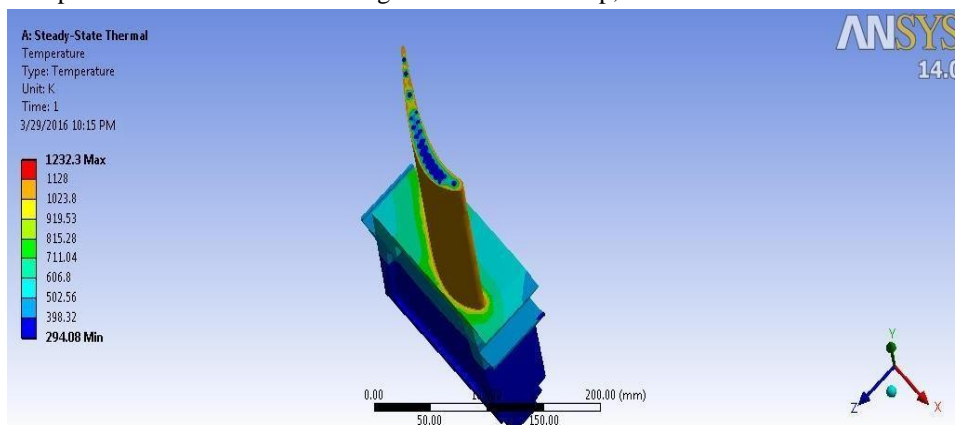
This relation gives a set of simultaneous equations.

Solutions for unknown displacements:

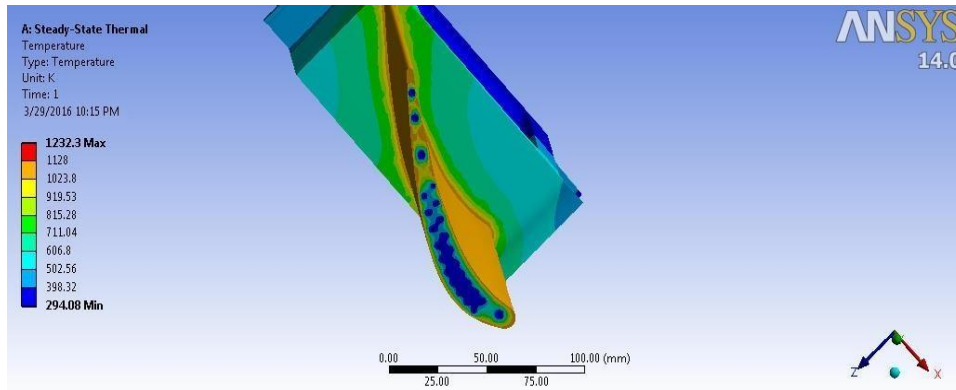
By satisfying proper boundary conditions, which suitably alter the equilibrium equations obtained in the previous steps, solutions are obtained for the set of equilibrium equations. Hence the unknown displacements are obtained.

Computation of element stresses and strain:

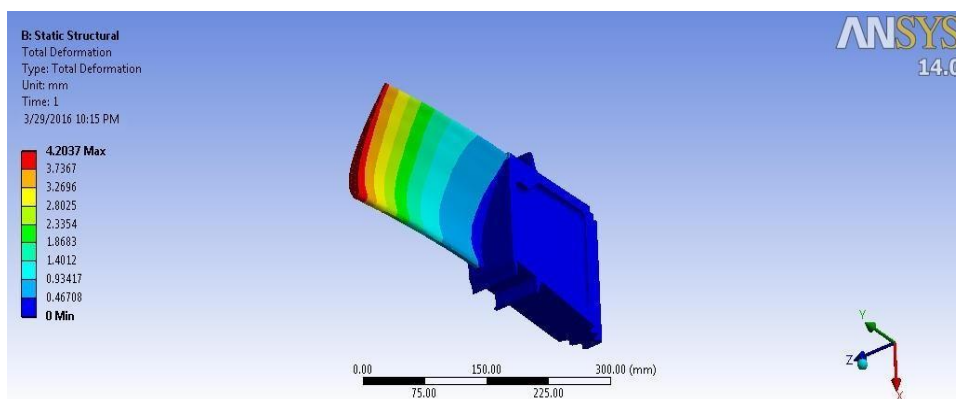
Once the displacements are found out using suitable relationship, stress strain values are obtained.



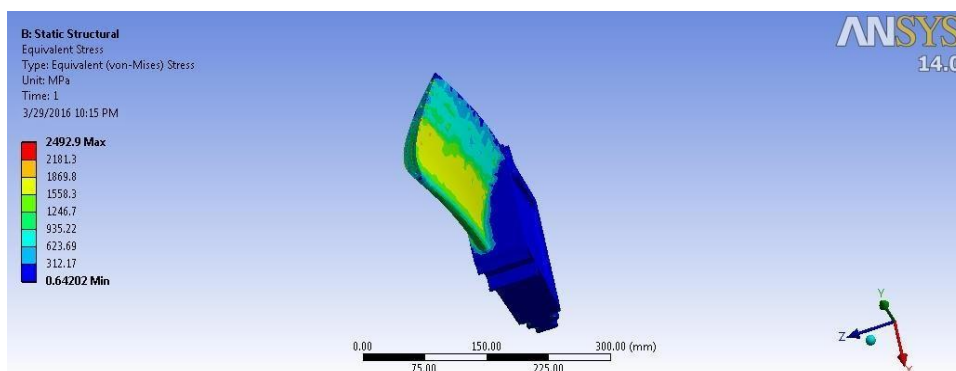
Temperature distribution (Ti ALLOY)



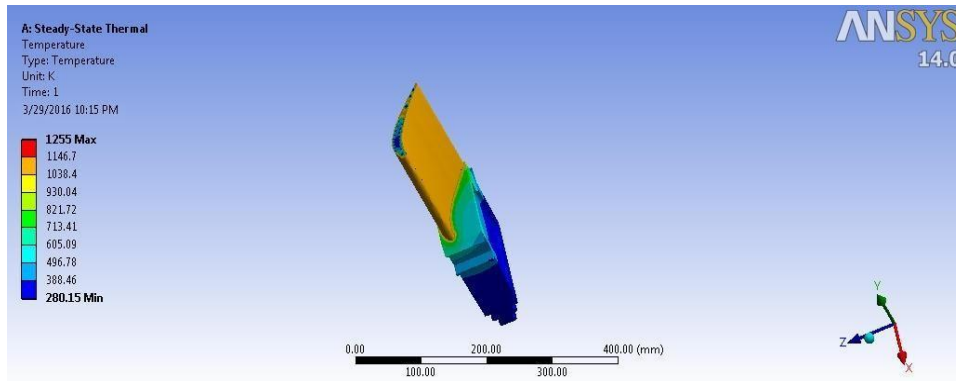
Temperature cross section (Ti ALLOY)



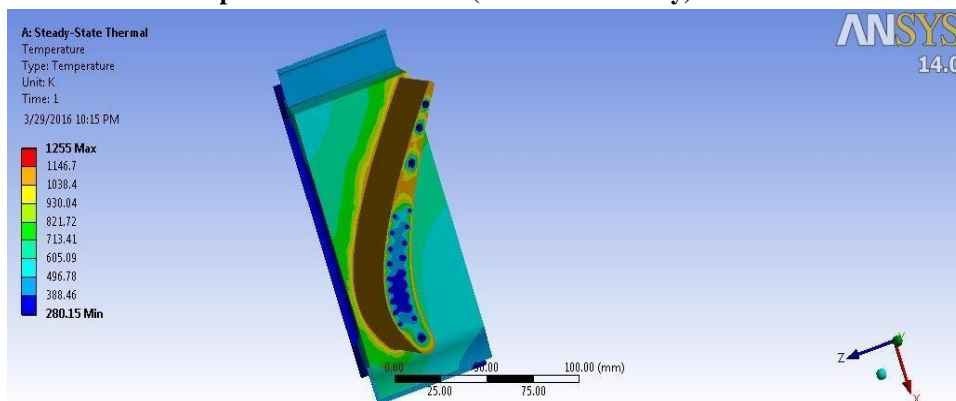
Deformation (Ti ALLOY)



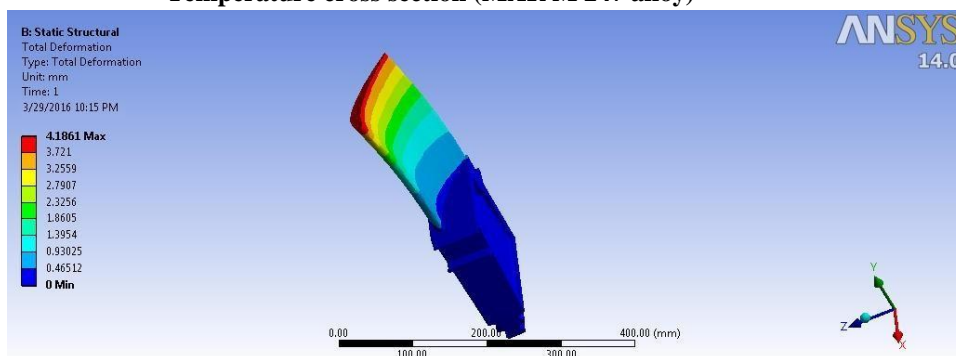
Equivalent Stress (Ti ALLOY)



Temperature Distribution (MAR M 247 alloy)



Temperature cross section (MAR M 247 alloy)



Deformation (MAR M 247 alloy)

IV. CONCLUSION

Numerical analysis was done to optimize the internal blade cooling passage and hole configuration, also to improve the effectiveness of blade heat transfer. Coupled structural and thermal analysis for various hole configuration, the results shows that configuration- 4 (1.5 mm hole diameter and 2.5mm from the surface) provides effective heat transfer than the existing hole configuration and in the meantime there is no change in the structural performance. This shows the Ti alloy is best to using turbine alloy

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S.No	Model	Temperature (K)	Deformation (mm)	Stress (Mpa)
1	Ti ALLOY	1128	4.2	1869
2	MAR M 247 alloy	1146	4.18	1859

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