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MODELING AND ANALYSIS OF GAS TURBINE ROTOR BLADE

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ABSTRACT - A turbine blade is the individual component which make up the turbine part of a gas turbine. The turbine is a mechanical power generating rotary device which uses power of flowing fluid and converts it into useful work. The aim of the project is to design a turbine blade using 3D modeling software CATIA by using the CMM point data available. CMM data taken from coordinate measuring machine. This project involve structural analysis by applying the angular velocities for various materials in evaluating stresses developed and mode shapes of the blade. CATIA is the standard tool in 3D product design, featuring industry-leading productivity tool that promote best practices in design. Structural analysis performed on the blade using commercial software ANSYS.

Key words: Turbine Blade; Structural Analysis; CMM.CATIA v5, ANSYS 14.5

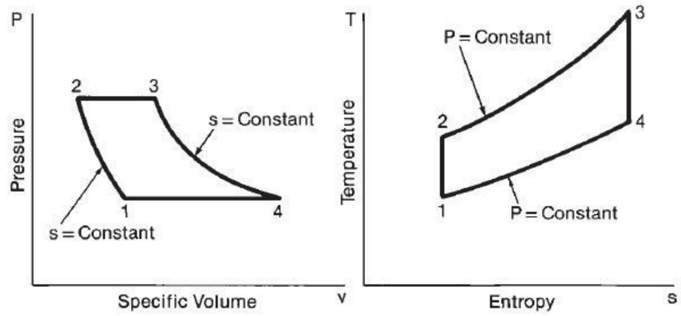
1. INTRODUCTION

1.1 Gas Turbine

The gas turbine is a power plant, which produces a great amount of energy for its size and weight. The gas turbine has found increasing service in the past 40 years in the power industry both among utilities and merchant plants as well as petrochemical industry, and utilities throughout the world. A turbine blade is the individual component which makes up the turbine section of a gas turbine

1.2 Theory of operation

Gases passing through an ideal gas turbine undergo three thermodynamic processes. These are isentropic compression, isobaric (constant pressure) combustion and isentropic expansion. Together these make up the Brayton cycle.



1.3 Principle and Components

Work can be extracted from a gas at a higher inlet pressure to the lower back pressure by allowing it to flow through a turbine. In a turbine as the gas passes through, it expands. The work done by the gas is equivalent to the change of its enthalpy. It is a well known fact that the turbines operate on the momentum principle.

1.4 Types of gas turbine

Normally a turbine stage is classified as

(i) An impulsion stage and

(ii) A reaction stage

1.5 Velocity Triangles of a Single Stage Machine

The flow geometry at the entry and exit of a turbo machine stage is described by the velocity triangles at these stations.

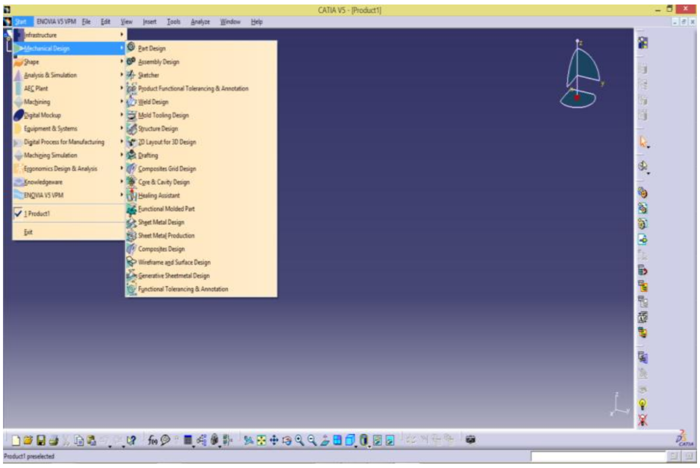
2. METHODOLOGY

To investigate the total deformation difference of turbine blade, we have to simulate the method by the use of few computer aided software. In this method we follow a list of steps to complete the analysis. In our project, there is a need to compare the total deformation difference between the existing blade material and prosed blade material. Different stress which is employed on the turbine blade is calculated by using ANSYS software. But, the design of the blade is carried by using Catia software.

3.DESIGN

Steps to be followed to develop Turbine Rotor Blade.

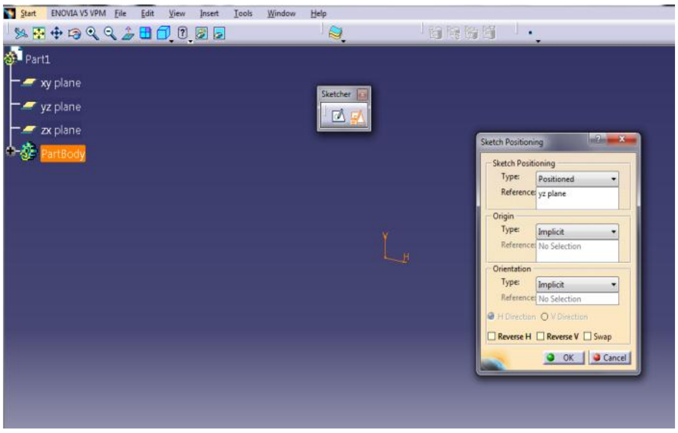
1. Start ⟶ Mechanical design ⟶ Part Design.



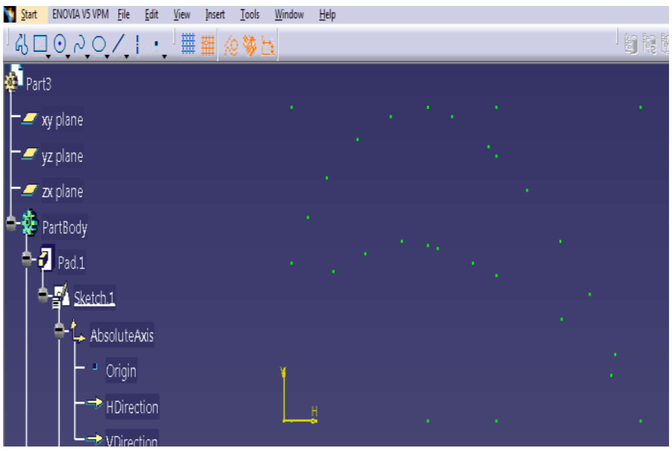
2. Look for a reference point from where all dimensions are controlling

3. Start sketching using sketch tools

4. Taking Y-Z plane as reference plane for sketching.



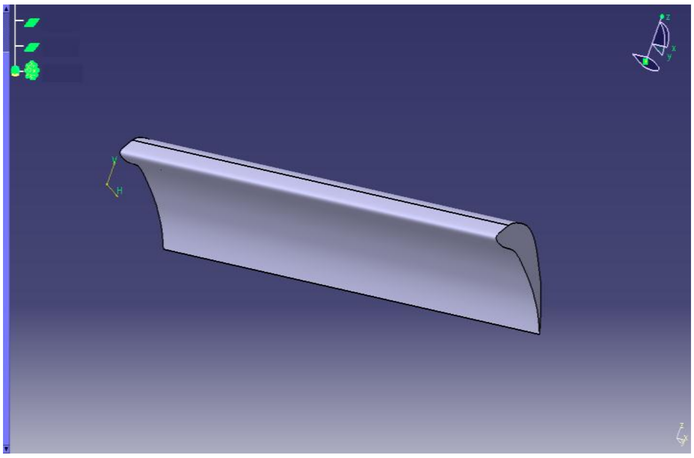
5. By using the CMM point data we are creating construction points of a turbine blade which is in **AEROFOIL** shape.



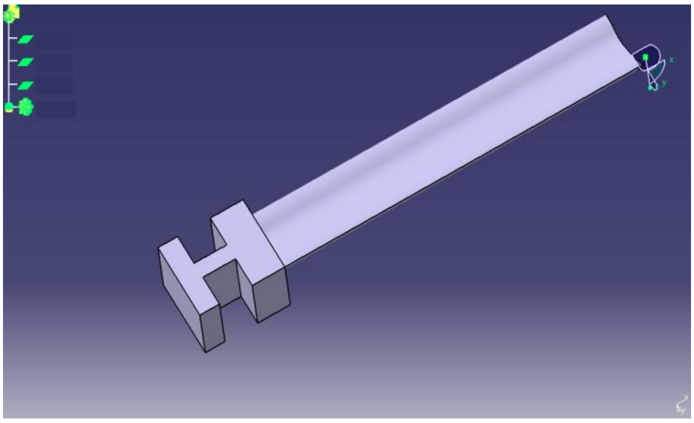
6. By using SP line the construction are joined in order to achive AEROFOIL shape of Rotor Blade.

7. Then this 2-D sketch is converted into a 3-D element by using PAD DEFINITION after exiting the work bench.

8. Then to create the base of the turbine blade work bench is selected and drawn to the required dimensions as mentioned in the specifications.



9. This base which is in shape of I-section is Extruded by using PAD DEFINTION



10. The model of the blade is finished and this file is saved in two formats, one as .CATpart extension file and another as .igs extension .

11. Where, .CATpart is used for drafting. And this drafted file is saved as .CATDrawing as extension file.

4 MATERIAL DATA

Here to find out the best suited material for gas turbine blade three different materials are considered as:

1. Titanium alloy Ti6Al4V
2. Structural steel
3. Titanium alloy Ti-8Al-1Mo-1V

4.1 TITANIUM ALLOY (Ti6Al4V)

Titanium Alloy (Ti6Al4V) > Constants

Density	4.429e-006 kg mm^-3
Specific Heat	5.26e+005 mJ kg^-1 C^-1

Titanium Alloy (Ti6Al4V) > Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus GPa	Shear Modulus GPa
	110000	0.33	125	43

Titanium Alloy (Ti6Al4V) > Bilinear Isotropic Hardening

Yield Strength MPa	Tangent Modulus MPa	Temperature C
1480	2160	1878

4.2 STRUCTURAL STEEL

Structural Steel > Constants

Density	7.85e-006 kg mm^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm

Structural Steel > Compressive Yield Strength

Compressive Yield Strength MPa
250

Structural Steel > Tensile Yield Strength

Tensile Yield Strength MPa
250

4.3 TITANIUM ALLOY Ti-8Al-1Mo-1V

Titanium Alloy > Constants

Density	4.62e-006 kg mm^-3
Coefficient of Thermal Expansion	9.4e-006 C^-1
Specific Heat	5.22e+005 mJ kg^-1 C^-1
Thermal Conductivity	2.19e-002 W mm^-1 C^-1
Resistivity	1.7e-003 ohm mm

Titanium Alloy > Compressive Yield Strength

Compressive Yield Strength MPa
930

Titanium Alloy > Tensile Yield Strength

Tensile Yield Strength MPa
930

Titanium Alloy > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
1070

Titanium Alloy > Isotropic Secant Coefficient of Thermal Expansion

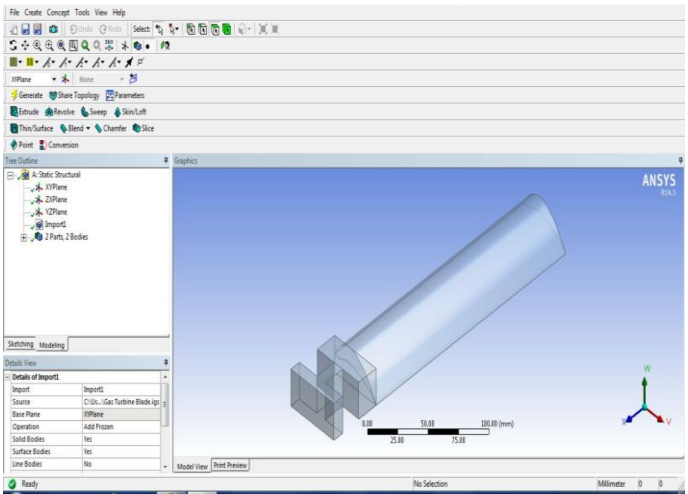
Reference Temperature C
22

5.ANALYSIS

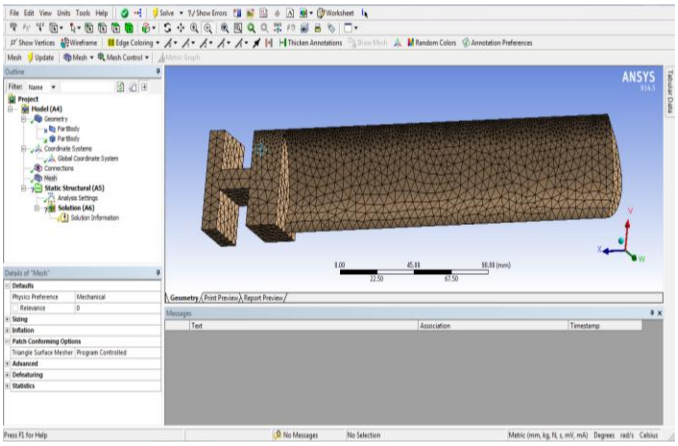
STRUCTURAL ANALYSIS:

The structural analysis is the most common analysis of finite element method, which accomplishes various structures such as bridges, naval, aeronautical, mechanism housing and mechanism components such as possible in ANSYS software. Here in our project Static analysis is done on different materials to find out

5.1 Imported Solid Model of Gas Turbine blade



5.2 MESHED SOLID MODEL

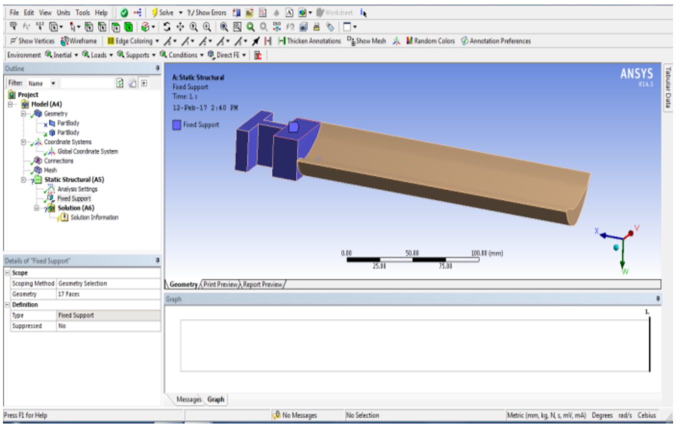


5.3 BOUNDARY CONDITIONS

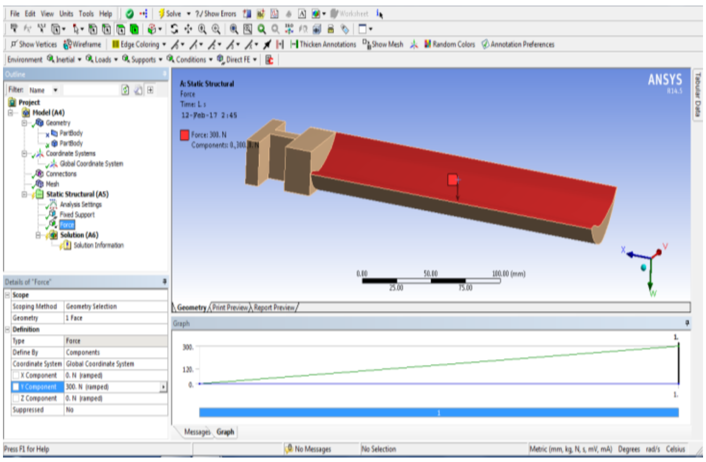
This is the place where different conditions are employed on the gas turbine blades which are:

1. Fixed Support,
2. Load and
3. Thermal condition

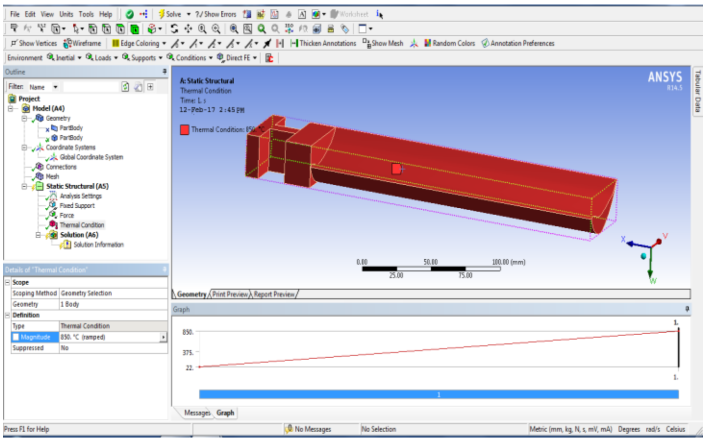
5.3.1 FIXED SUPPORT



5.3.2 LOAD ON GAS TURBINE ROTOR BLADE

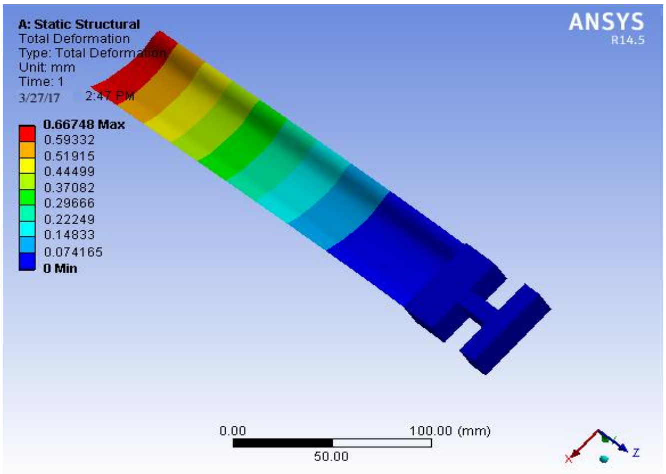


5.3.3THERMALCONDITION

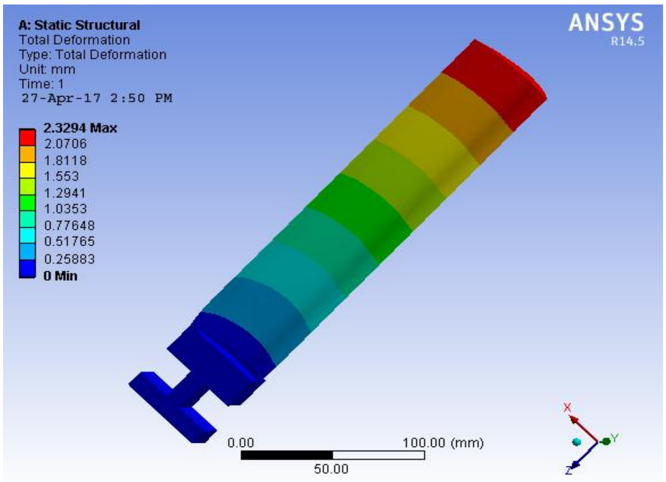


5.4 Total Deformation acting on different types of materials

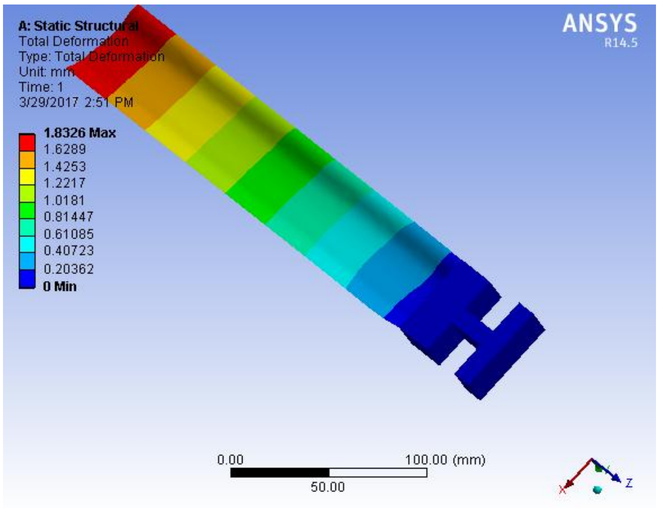
5.4.1 TITANIUM ALLOY Ti6Al4V



5.4.2 STRUCTURAL STEEL

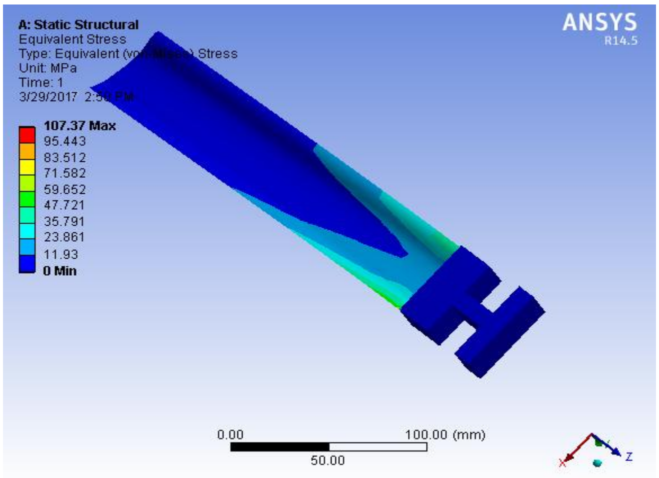


5.4.3 TITANIUM ALLOY Ti-8Al-1Mo-1V

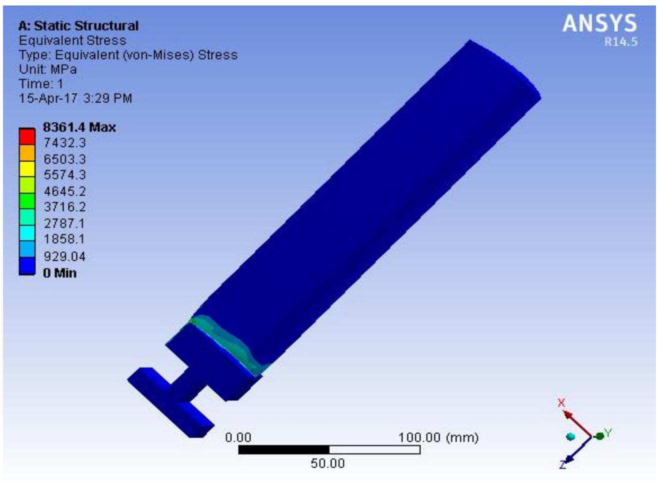


5.5 MAX VON MISSES STRESSES INDUCED ON DIFFERENT MATERIALS

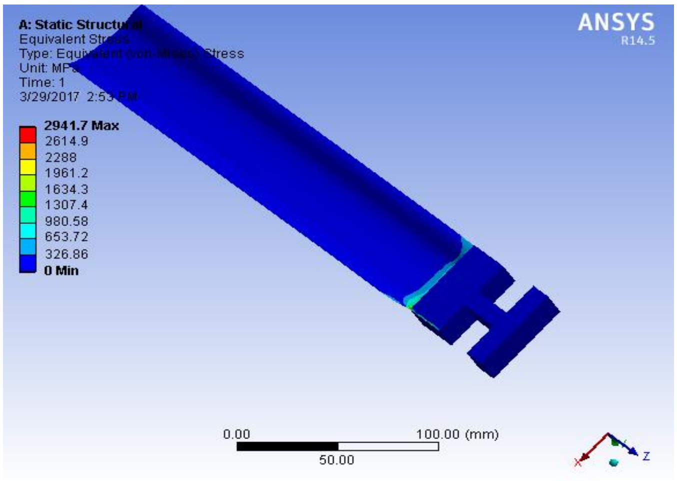
5.5.1 TITANIUM ALLOY Ti6Al4V



5.5.2 STRUCTURAL STEEL



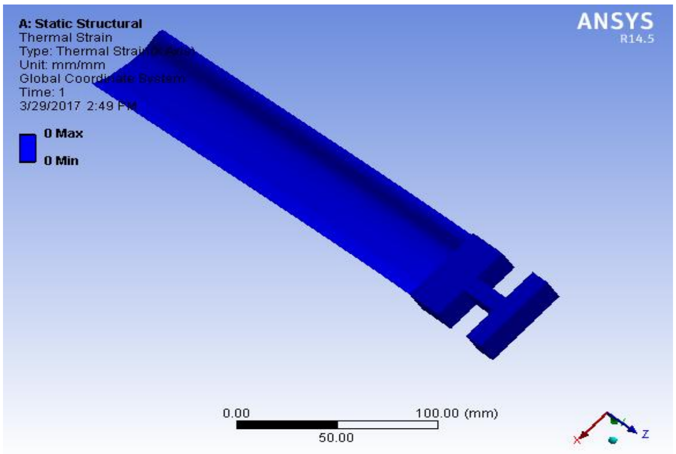
5.5.3 TITANIUM ALLOY Ti-8Al-1Mo-1V



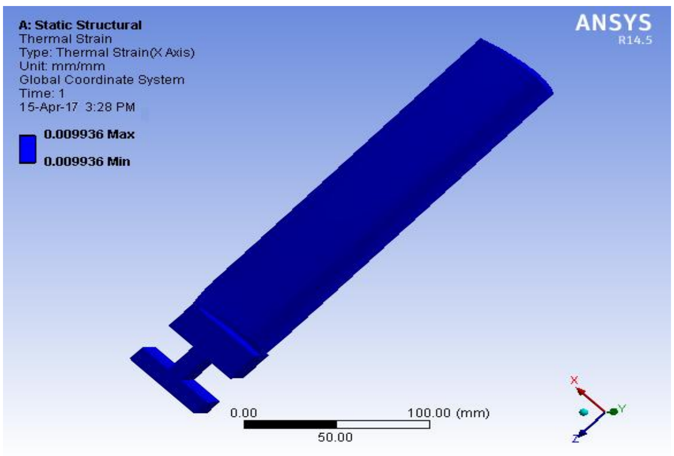
5.6 THERMAL STRAIN INDUCED ON DIFFERENT MATERIALS

Thermal strain can be defined as the deformation of a material caused due to the temperature change occurred on it.

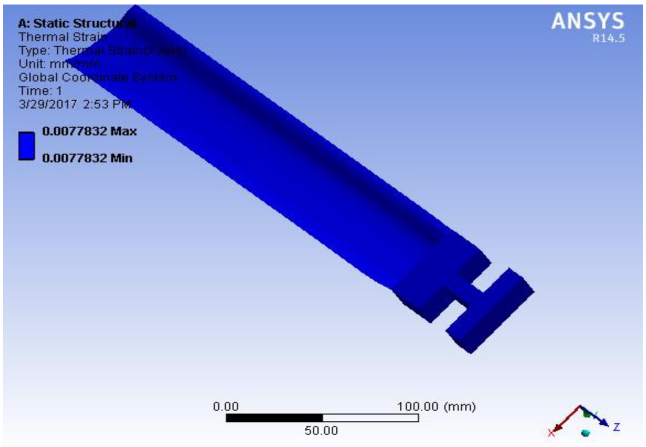
5.6.1 TITANIUM ALLOY Ti6Al4V



5.6.2 STRUCTURAL STEEL



5.6.3TITANIUM ALLOY Ti-8Al-1Mo-1V



6. RESULTS AND DISCUSSION

RESULT TEBLES

Table 6.1 Results for titanium alloy (Ti6Al4V)

Object Name	Total Deformation	Von Mises Stress	Equivalent Elastic Strain	Shear Elastic Strain	Thermal Strain
Minimum	0 mm	0 MPa	2.253e-004 mm/mm	2.3363e-005 mm/mm	0. mm/mm
Maximum	0.66748 mm	107.37 MPa	1.1265e-003 mm/mm	1.1682e-004 mm/mm	0. mm/mm

Table 6.2 Results for structural steel

Object Name	Total Deformation	Equivalent Elastic Strain	Shear Elastic Strain	Thermal Strain	Von Mises Stress
Minimum	0. mm	0. mm/mm	-1.1843e-002 mm/mm	9.936e-003 mm/mm	0 MPa
Maximum	2.3294 mm	4.4757e-002 mm/mm	2.9346e-002 mm/mm	9.936e-003 mm/mm	8361.4 MPa

Table 6.3 Results for titanium alloy Ti-8Al-1Mo-1V

Object Name	Total Deformation	Von Mises Stress	Equivalent Elastic Strain	Shear Elastic Strain	Thermal Strain
Minimum	0. mm	0 MPa	0. mm/mm	-1.2292e-002 mm/mm	7.7832e-003 mm/mm
Maximum	1.8326 mm	2941.7 MPa	3.4002e-002 mm/mm	3.3465e-002 mm/mm	7.7832e-003 mm/mm

7. CONCLUSION

In this project we have designed a rotor blade which is used as gas turbine rotor blade. This analysis has been done on Titanium alloy Ti6Al4V, structural steel, Titanium alloy Ti-8Al-1Mo-1V by varying boundary conditions on them. This was successfully performed by using ANSYS 14.5 analysis software.

By observing the analysis results, the analyzed stress values are less than their respective yield stress values. So our design is safe enough to be used in the real-time application. Here, titanium alloy and structural steel are used in the manufacturing of the blades; Titanium alloy Ti-8Al-1Mo-1V gives better results where structural steel is not satisfactory. But, Titanium alloy Ti6Al4V shows even better results than the regular Titanium alloy Ti-8Al-1Mo-1V.

By the Analysis results, Total deformation of Ti6Al4V gives 0.66748 when compared to Structural steel 2.3294 and Ti-8Al-1Mo-1V 1.8326. Thermal Strain of Ti6Al4V gives 0 mm//mm when compared to structural steel 0.009936 and Ti-8Al-1Mo-1V 0.0077832. Von Mises Stress of Ti6Al4V gives 107.37 MPa when compared to Structural Steel 8361.4 MPa and Ti-8Al-1Mo-1V 2941.7 MPa

So, by this we can conclude that, Titanium alloy Ti6Al4V shows better results under these simulated conditions than the other two materials. And hence, this is the best material to be used for the manufacturing of the blade and also it is safe.

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