

Investigation of Mechanical Stress and Strain in High-Pressure Steam Turbines under Variable Loading Conditions

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ABSTRACT

The present study is carried out for a steam turbine shaft. Analysis of stresses and strain for mechanical load on a High pressure steam turbine shaft is done by using FEM analysis. A steam turbine rotor is considered. It carries wheels, bearing journals, and other parts connected to it. The function of steam turbine shaft is to transmit the power to driven mechanism. The blades are grooved to shaft at each stage. The mechanical forces on the steam turbine due the velocity of the steam and various mountings on the steam are studied. The tangential, axial and centrifugal forces on the steam turbine are calculated. The material 30CrMoV steel is used for the shaft. The properties of material are applied on the software model. Then suitable boundary conditions are applied on the CAD model of shaft and analysis is carried out by using FEM software ANSYS.

Keywords: Turbine shaft, mechanical load, stress, strain

INTRODUCTION

The steam turbine makes use of potential energy in the steam and converts it into a kinetic energy which in turns rotates the steam turbine shaft. This turbine shaft carries wheels, bearings through which the pressurised steam is passed. Due the mounting and steam velocity centrifugal and mechanical forces exerts on the shaft. The detailed study of these forces is needed for smooth working of the shaft.

Under this project the study of thermal turbine rotor has been carried out. Stresses and strain on the turbine rotor due to mechanical loading is studied

The steam turbine is under the action of Axial, tangential and centrifugal forces.

HP TURBINE

Total stages = 25

Diameter of shaft $d = 500$ mm

Height of blade $h = 200$ mm

Mean diameter of shaft $D_m = 700$ mm

$C_{bl} = \pi \times D \times N / 60$

$= \pi \times 0.7 \times 3000 / 60$

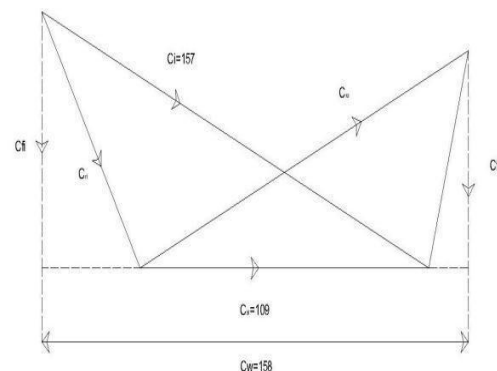
$= 109.9$ m/s $Q = C_{bl}/C_i$ 0.7

$= 109.9/C_i$

$C_i = 157$ m/s

Velocity triangle

Scale: 1 cm = 20 m/s



$$\begin{aligned} \text{Tangential Force} &= M_s \times (C_{wi} + C_{wo}) \\ &= 110 \text{ kg/s} \times 158 \text{ m/s} \\ &= 17380 \text{ N} \end{aligned}$$

$$\begin{aligned} \text{Axial thrust} &= M_s \times (C_{fi} - C_{fo}) \\ &= 110 \text{ kg/s} \times (60 - 52) \text{ m/s} \\ &= 880 \text{ N} \end{aligned}$$

Calculation of centrifugal load

HP Turbine

Blade size : $200 \times 16 \times 16$ mm

Shape : Rectangular

No. of blades : 94/stage Material

: 30CrMoV steel

Density : 7800 kg/m^3

Formula used : mrw^2

M = mass of blade

$$\begin{aligned}
 &= \text{volume} \times \text{density} &&= (0.016 \times \\
 &0.016 \times 0.2) \text{ m}^3 \times 7800 \text{ kg/ m}^3 \\
 &= 0.39936 \text{ kg}
 \end{aligned}$$

MODELLING

Modelling in CREO Parametric 2.0 A 3D Model of High Pressure Turbine (HPT) The High pressure (HP) turbine has total 25 stages. The diameter of shaft is same for all the stages. A rectangular profile blade is considered. The blades are grooved to the shaft. The blades are grooved all around the shaft as per the stages. The size of blades is also same for all the stages.

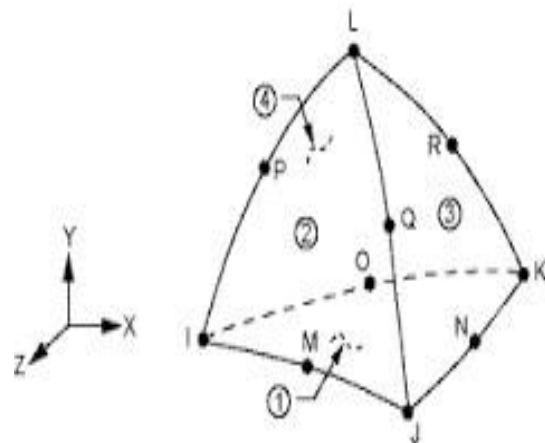


FINITE ELEMENT (FEM) ANALYSIS

The Model of turbine shaft is prepared in creo software. Meshing is done using tetrahedral element Suitable boundary conditions are applied and then analysis is carried out using ANASYS software.

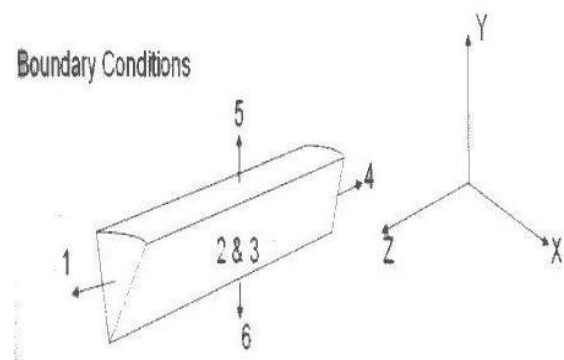
MESHING

Meshing is done using element solid 187 which is a higher order element suitable for meshing the parts having irregular shapes.



BOUNDARY CONDITIONS

Suitable boundary conditions are applied on the part.



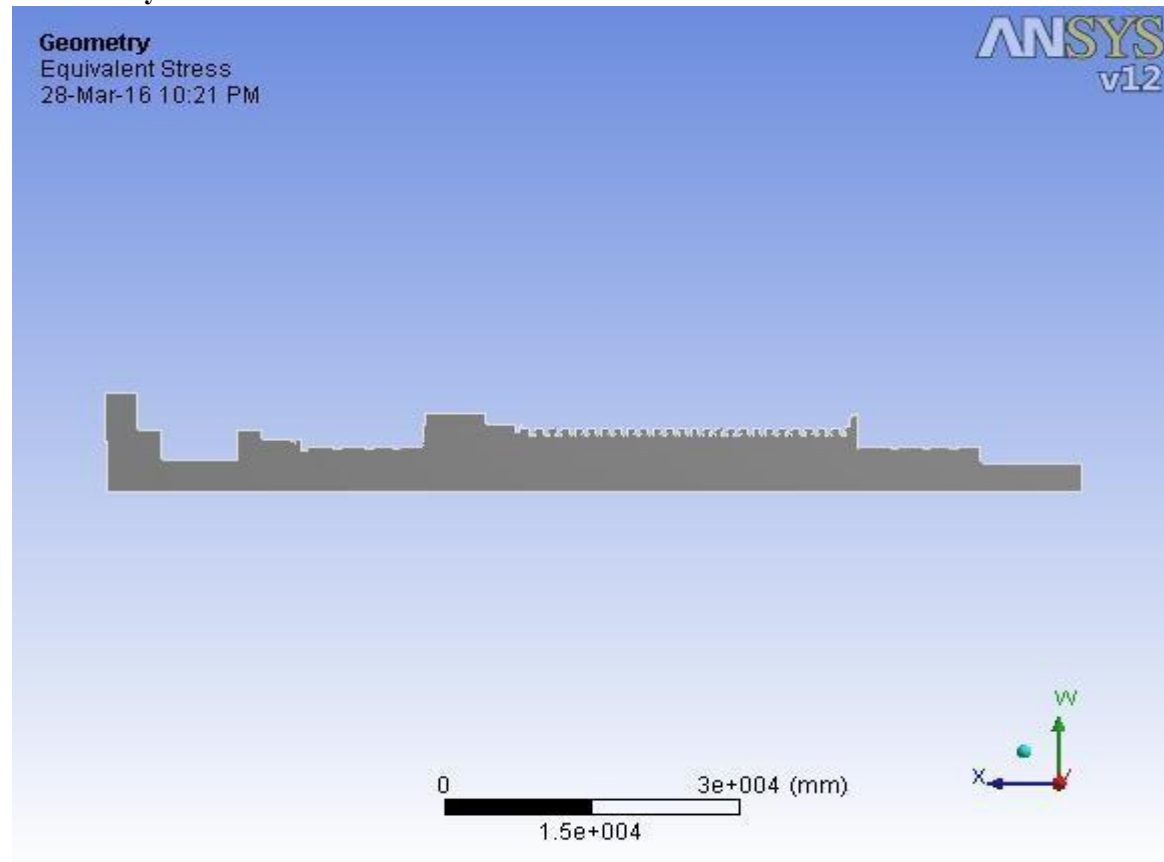
MATERIAL PROPERTIES

30CrMoVSteel material is used for analysis. Material properties are as given below.
 Young's modulus: 214 E × 1000 MPa
 Density : 7800 Kg/m3
 Poisson's ratio : 0.288

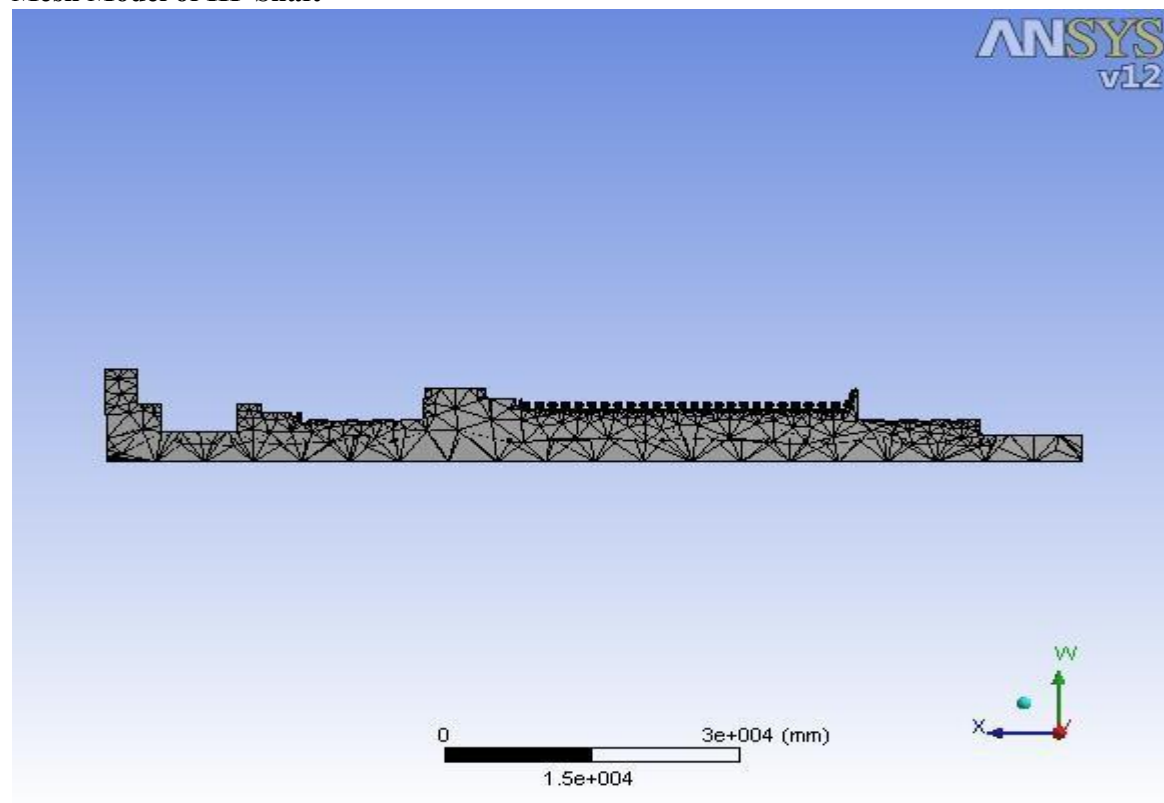
LOAD APPLICATION

A centrifugal, Tangential and axial load is calculated by using mathematical formulas and then it is applied on the turbine shaft.

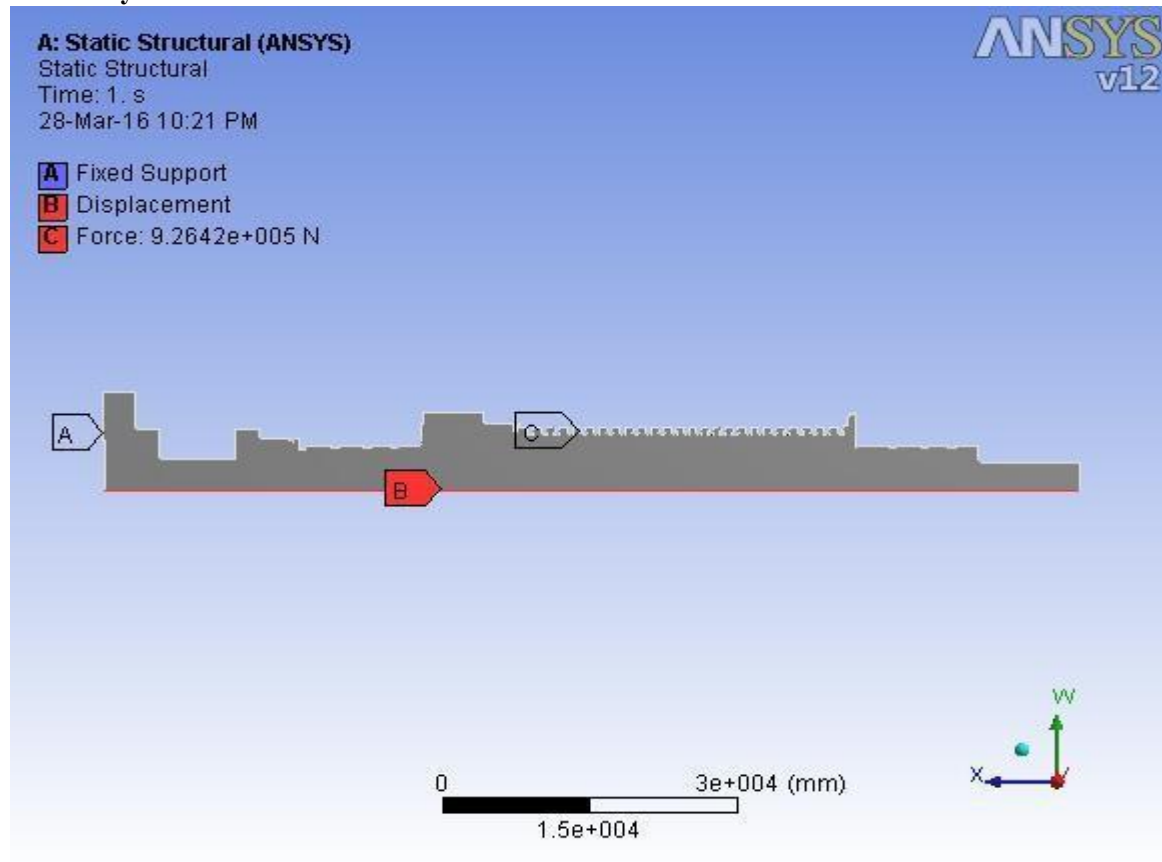
FEM Analysis - HP Shaft



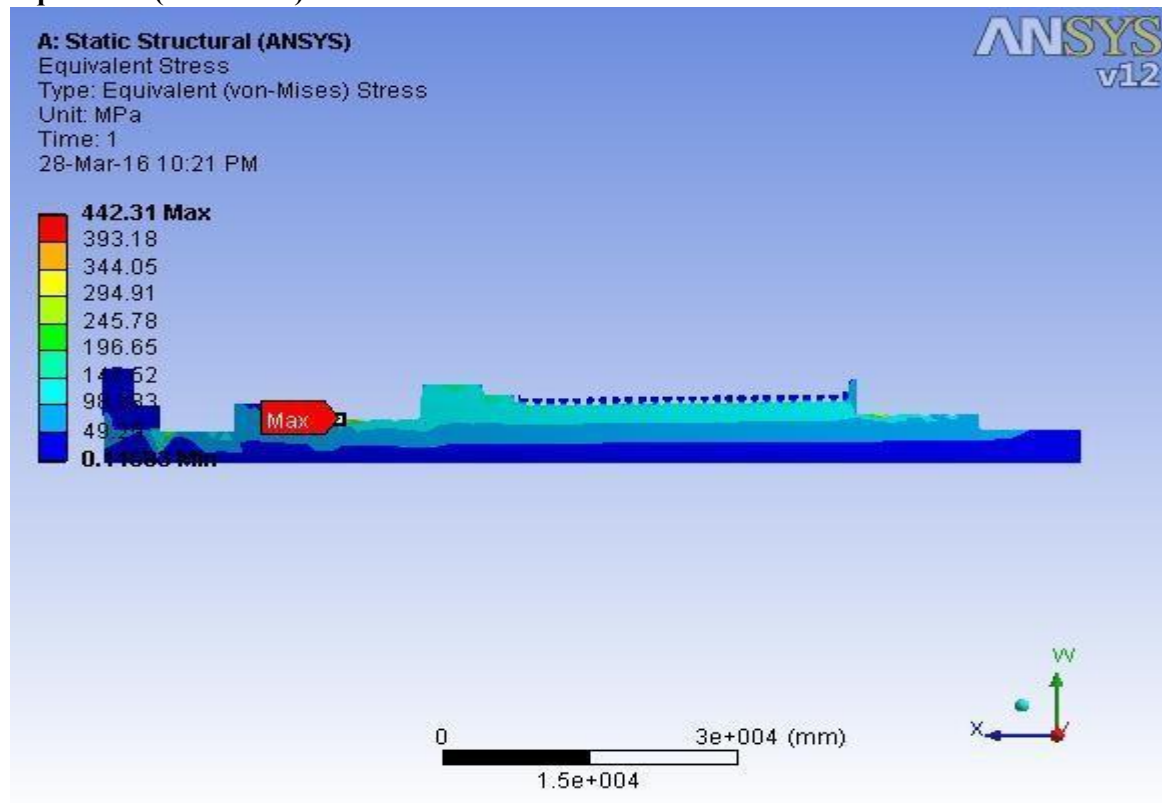
Mesh Model of HP Shaft

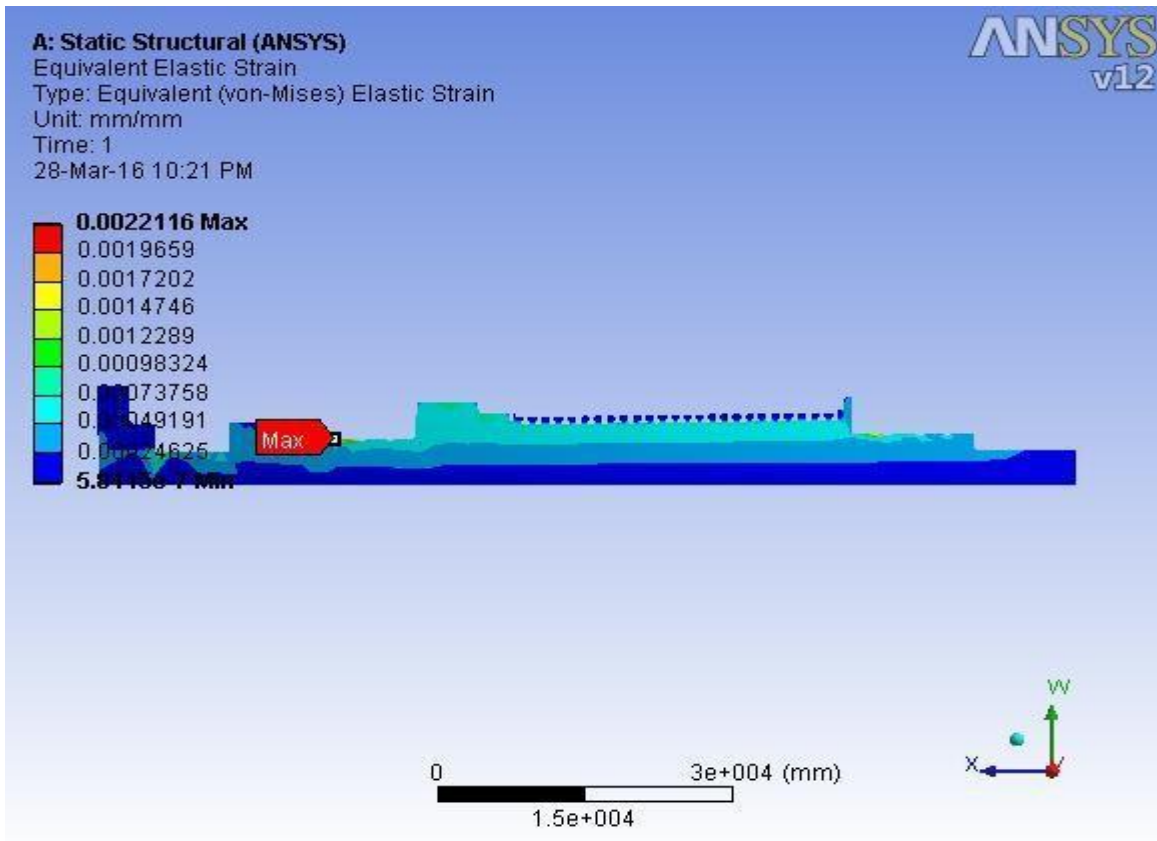


Boundary Condition

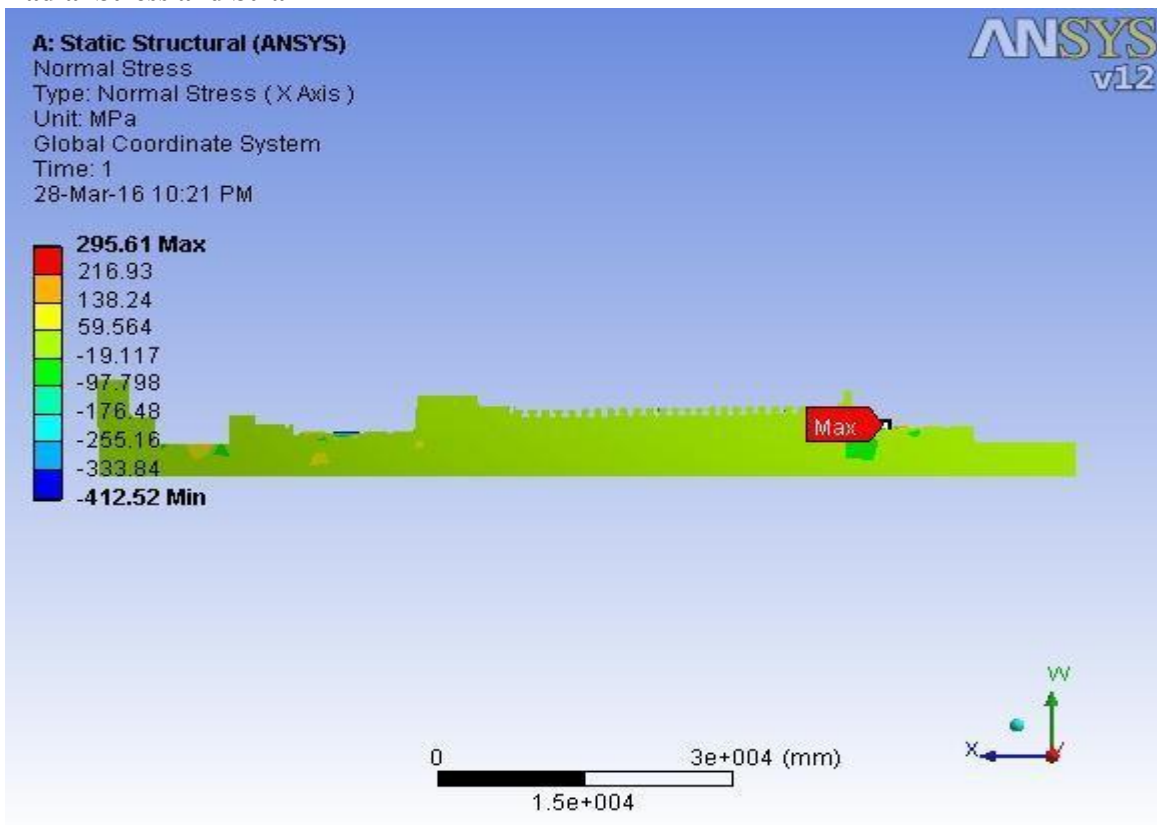


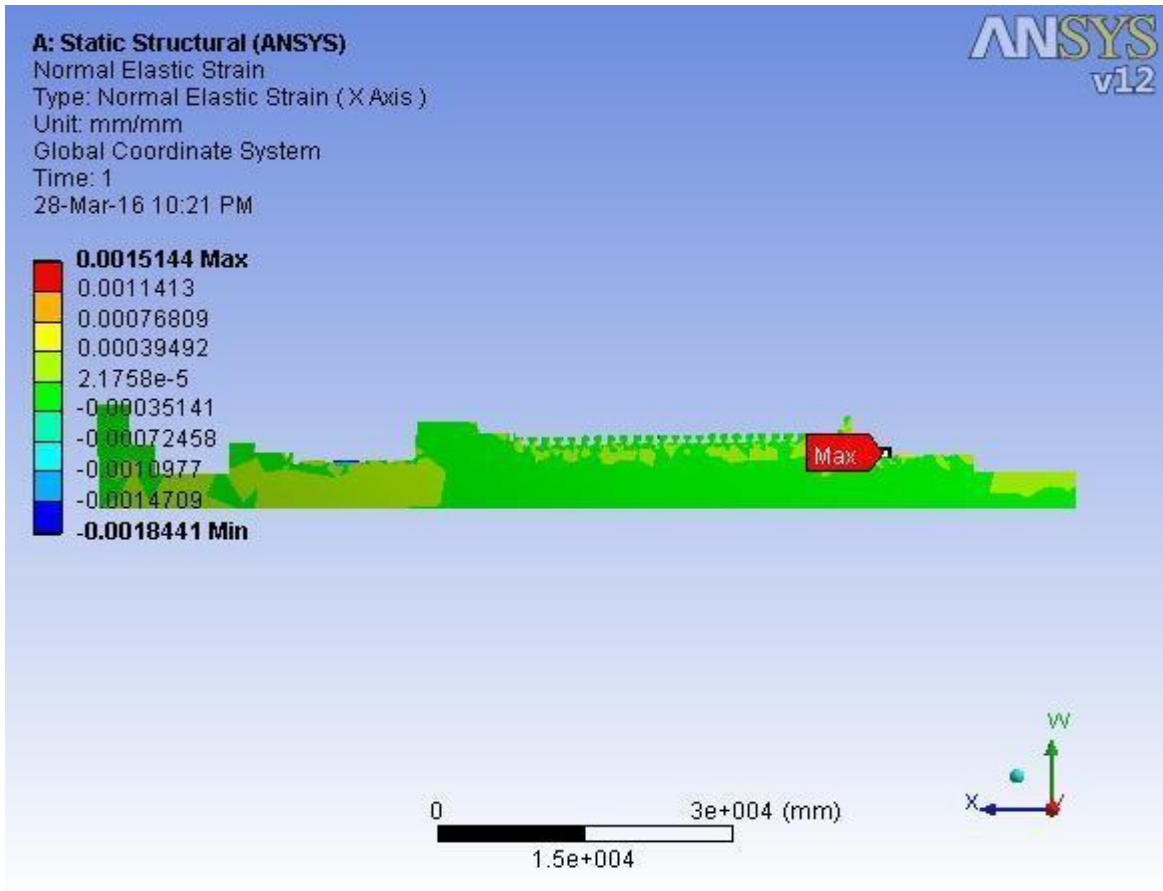
Equivalent (Von Mises) Stress and Strain



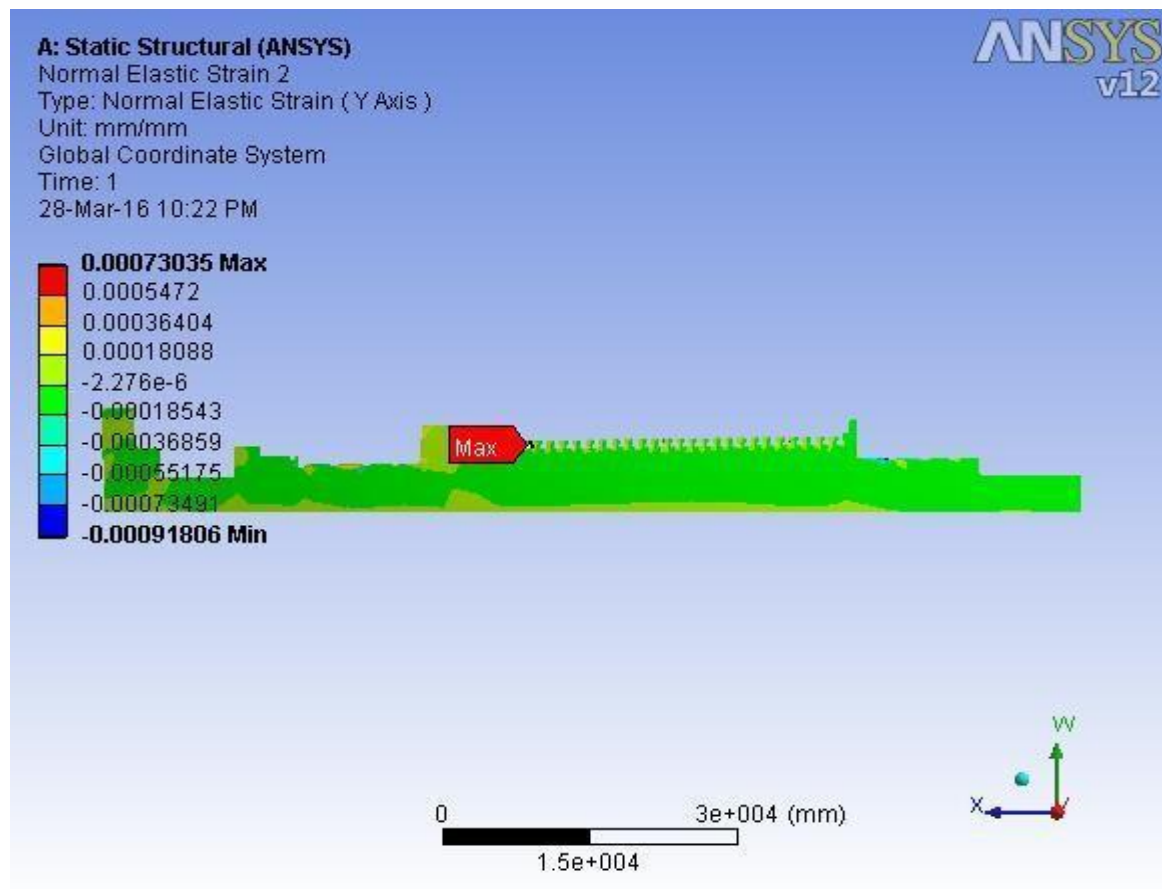
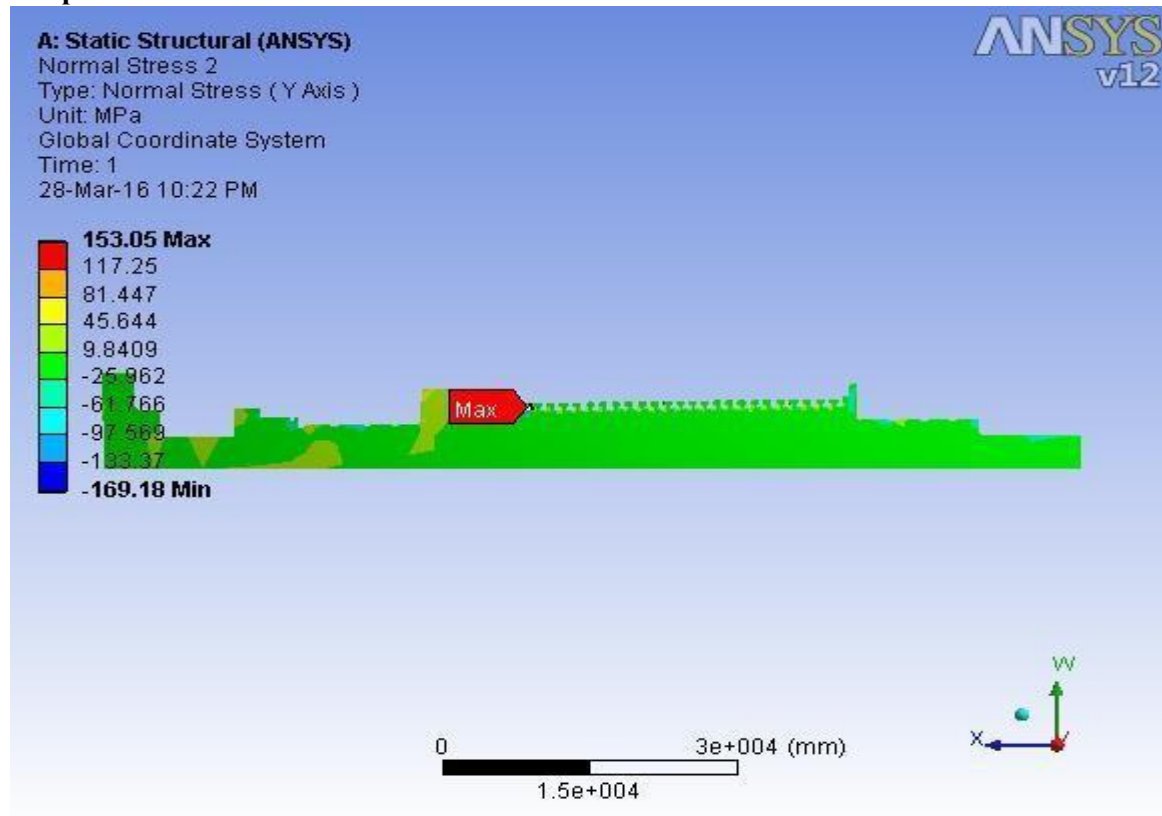


Radial Stress and Strain

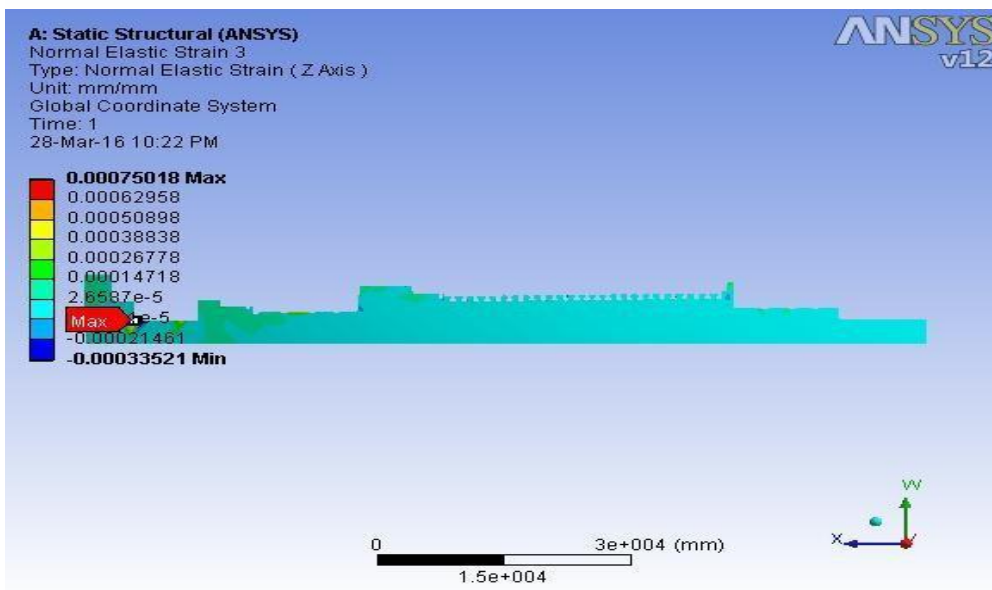
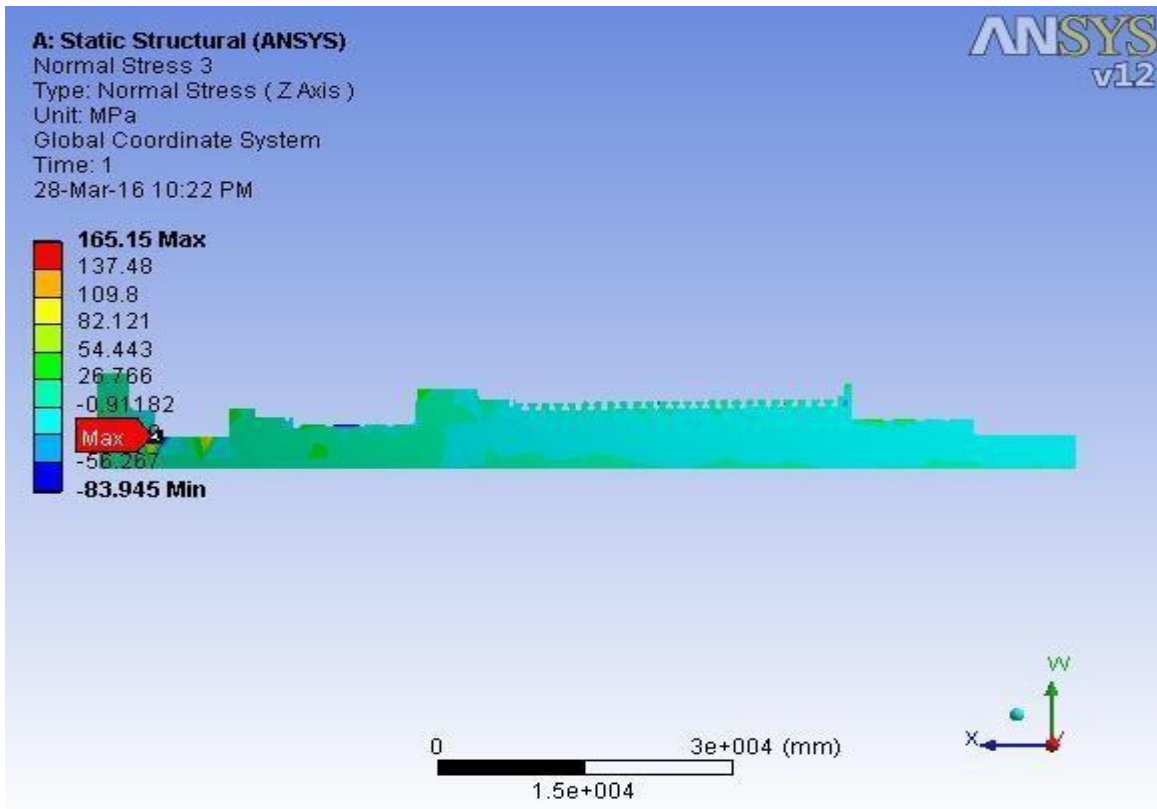




Hoop Stress and Strain



Axial Stress and Strain



FEA Result for HP Shaft

Sr. No.	Particulars	Stress Value (Mpa)	Strain Value
	Max. Equivalent Stress	442.31	0.0022116
	Max. Radial Stress	295.61	0.0015144
	Max. Hoop Stress	153.05	0.00073
	Max. Axial Stress	165.15	0.00075

CONCLUSION

The different types of mechanical forces on the steam turbine shaft are calculated using velocity diagram analytically, then these forces is applied on the software model of HP turbine shaft and the stress and stain are obtained using FEM analysis.

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