DESIGN, MODELING AND ANALYSIS OF A VACUUM CHAMBER FOR HIGH SPEED TURBINE

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Abstract: **High-speed balancing of bladed rotors is usually performed in a VACUUM chamber to avoid high turbulence power loss. VACUUM chamber with integrated burst protection, makes it possible to high-speed balance and spin-test small to medium sized turbo-rotors right on the shop floor. The innovative system design provides a variety of unique features to absorb the energy released when a rotor burst occurs. Safety "crush zones" are engaged and easily restored in the event of a significant burst. In this projects a VACUUM chamber used for high speed turbine will be designed and modeled in 3D modeling will be done in Pro/Engineer. The VACUUM chamber designed will be easy setup for rotors up to 17,500 lbs., up to 67 inches in diameter, at speeds of up to 60,000 RPM. In this project structural, modal analysis and fatigue analysis will be done in Ansys. The present used material for VACUUM chamber is steel. In this project it is replaced with aluminum alloy, brass and acrylic.**

Keywords: **VACUUM chamber, High-speed balancing, modeling, designed.**

I. INTRODUCTION

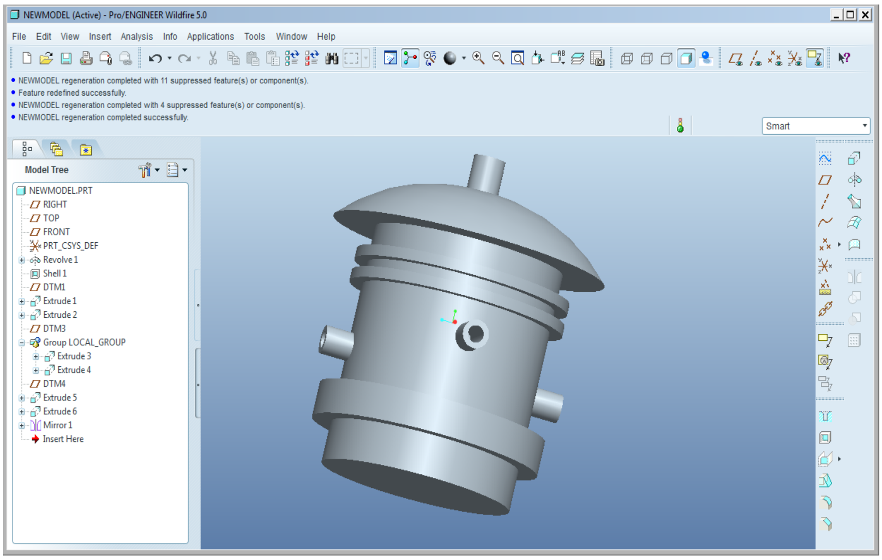
VACUUM Chamber for Testing Of Turbine Blades:

Ever increasing demands of high performance together with reliability of operation, long life and lightweight necessitate consistent development of almost every part of steam turbine blades from a vital part of a turbo machine. Apart from their shape and geometry, on which the performance characteristics of the machine largely depend, their dynamic strength is of considerable importance as far as the reliability operation and life of the engine are concerned. High cycle fatigue plays a significant role in many turbine blade failures. During operation, periodic fluctuations in the steam force occur at frequencies corresponding to the operating speed and harmonics and cause the bladed disk to vibrate. The amplitude of these vibrations depends in part of the natural frequencies of the bladed disk to the forcing frequency. Large amplitude vibration can occur when the forcing frequency approaches or becomes resonant with the natural frequency of the blades. Dynamic stresses associated with near resonant or resonant vibration produce high cycle fatigue damage and can initiate and propagate cracks very quickly. Steam turbine manufacturers typically design and manufacture blades with adequate margins between the forcing frequencies and the fundamental natural frequencies to avoid resonance. The basic design consideration is to avoid or to minimize the dynamic stresses produced by the fluctuating forces. Since these forces are periodic we have to consider several numbers of these harmonics coincides with any of the natural frequencies of the blades. The turbo machinery components, specifically airfoils, are subjected to high variable loads that can cause failure, designing reliable components require in depth vibration and stress analysis. These machines are proving to be the backbones in important sectors such as power, industry (fertilizer, petrochemicals, cements, steels etc.) and defense sector (Naval applications). Further in the present environment of resource crunch and power shortages, where availability/ reliability of the equipment is a matter of topmost priority, one can not afford breakdown in these machines. The breakdown and failures in turbo machinery in addition to their impact on factors mentioned above have far reaching influence such as consequential damages, hazard to public life and most importantly the cost of repairs.

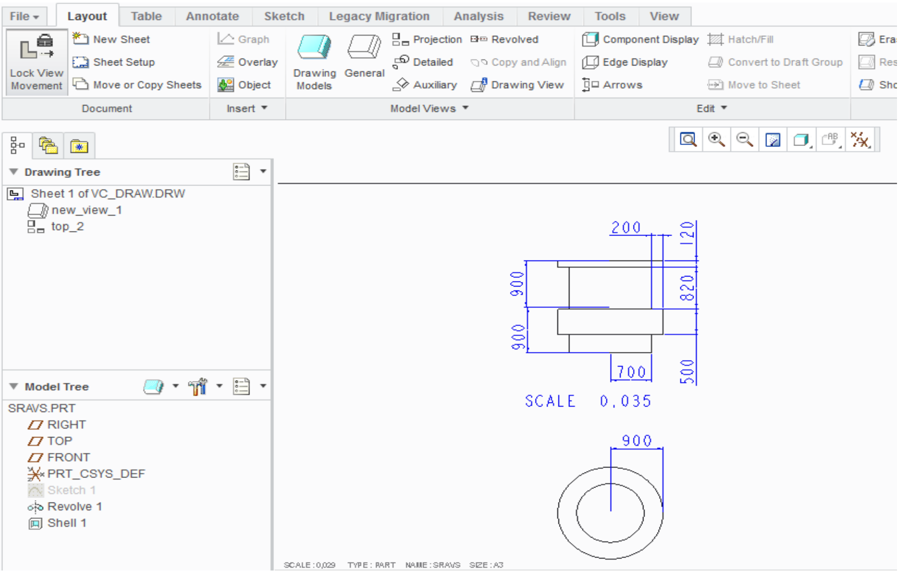
VACUUM Chamber Materials:

VACUUM chambers can be constructed of many materials. "Metals are arguably the most prevalent VACUUM chamber materials. The strength, pressure, and permeability are considerations for selecting chamber material. Common materials are Stainless Steel, Aluminum, Mild Steel, Brass, High density ceramic, Glass, Acrylic

3D MODEL:



2D DRAWING:



Boundary condition of Vacuum Chamber

Area of vacuum chamber $A = \pi d^2/4$

$= 3.14*(1930)^2/4$

$A = 2924046.5\ mm^2$

Force used in vacuum chamber =17500 lbs

lbs converted to Newton's

17500 lbs = 77843.87 N

Pressure = Force / Area

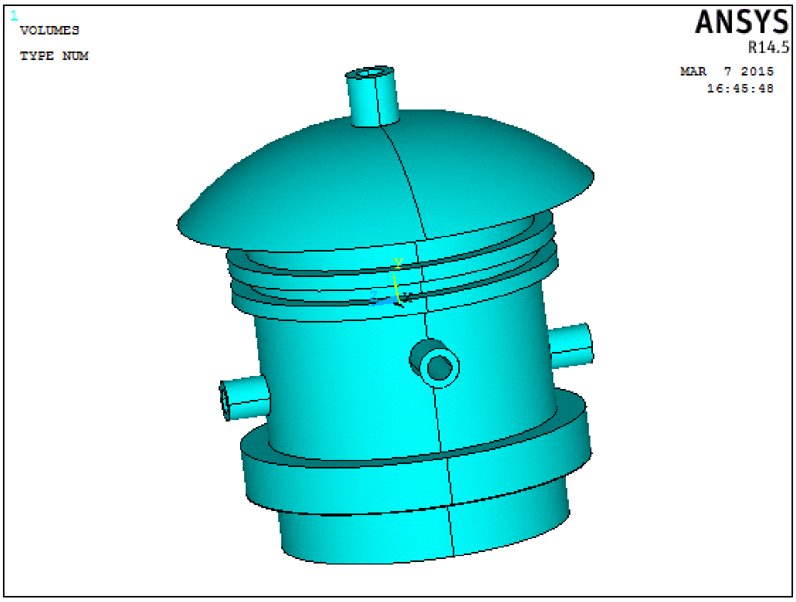
pressure (p) = 77843.87 / 2924046.5

$P = 0.026621\ N/mm^2$

Structural Analysis of VACUUM Chamber

Material – Stainless Steel

Import IGES model



Preprocessor → element type → add/edit/delete → add →solid, 20Node 186 → Ok → close

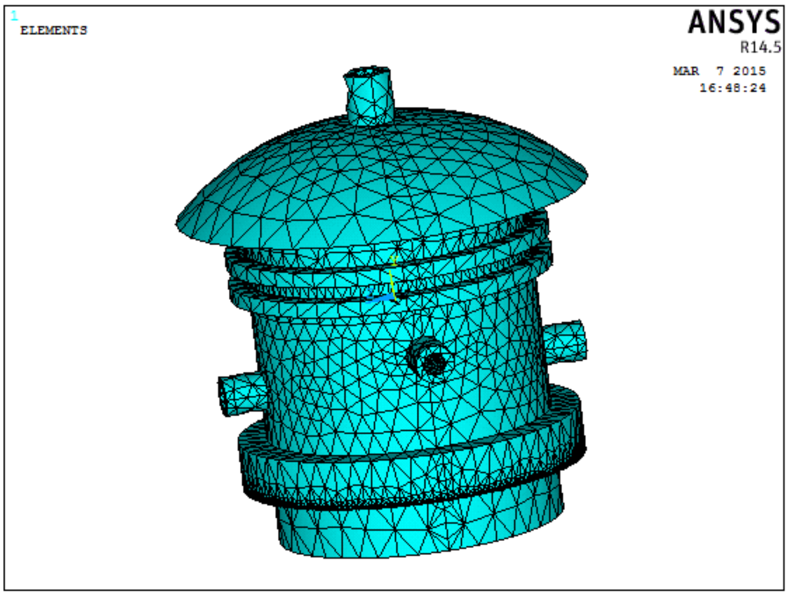
For stainless steel material

Young's Modulus (EX) : 317000Mpa

Poisson Ratio (PRXY) : 0.346

Density : 0.00000901 kg/mm^3

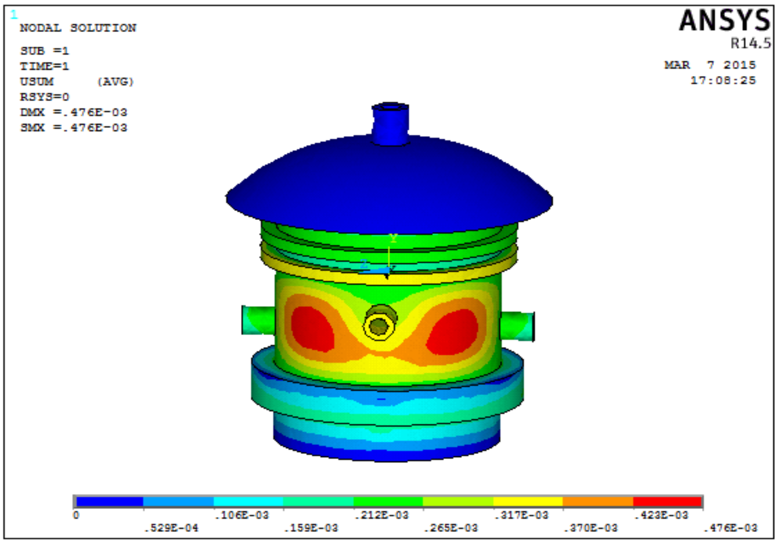
Meshed model



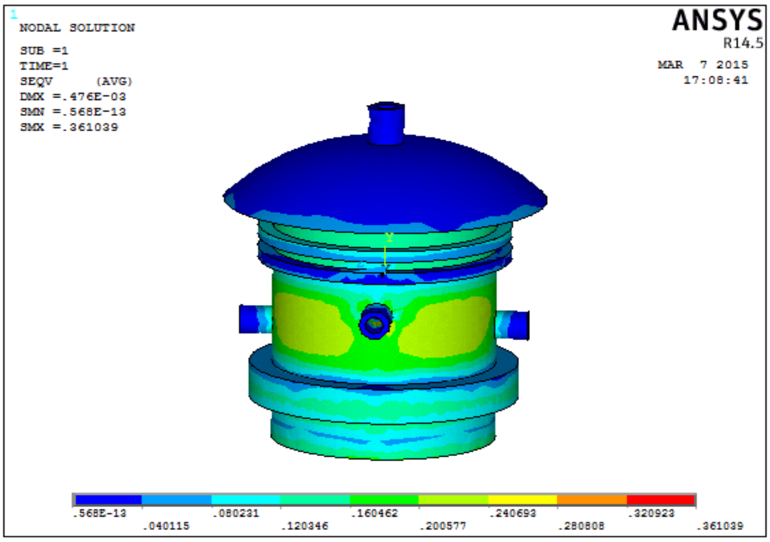
Loads → define loads → apply → structural → displacement → on areas → select area → ok → select all DOF → ok

Loads → define loads → apply → structural → pressure → on areas → select area → ok → enter pressure value 0.00000134N/mm^2→ ok

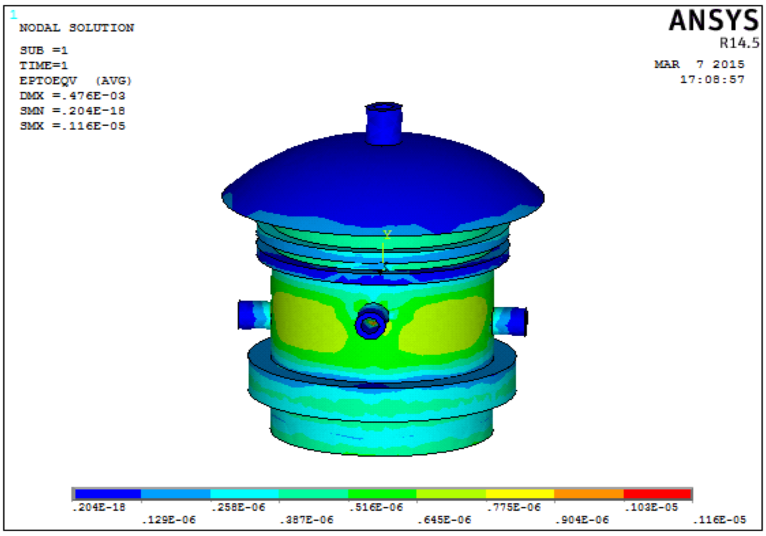
Displacement vector sum



Stress



Strain



Thermal analysis of VACUUM chamber

Material – Stainless Steel

Element Type: solid 20 node 90

Material Properties:

Thermal Conductivity – 34.3W/mK

Specific Heat – 0.620 J/kg K

Density - 0.00000901 kg/mm^3

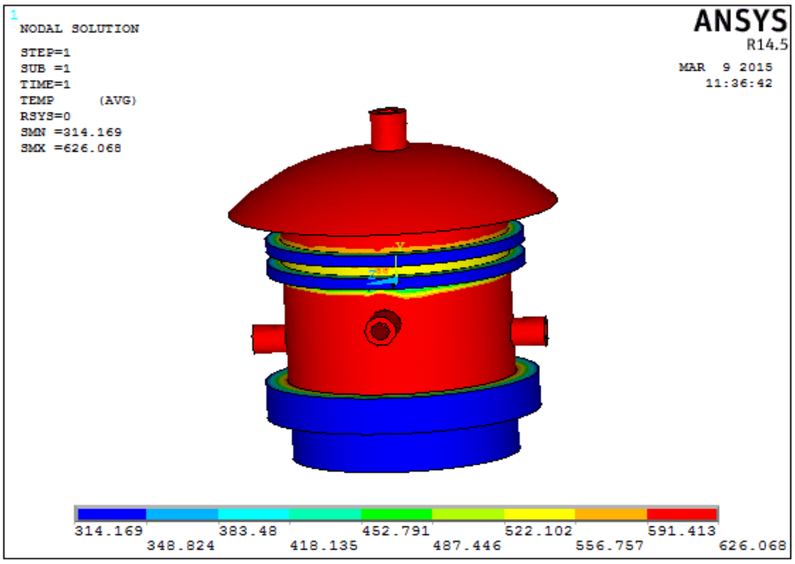
Temperature – 626K

Convection – On Areas

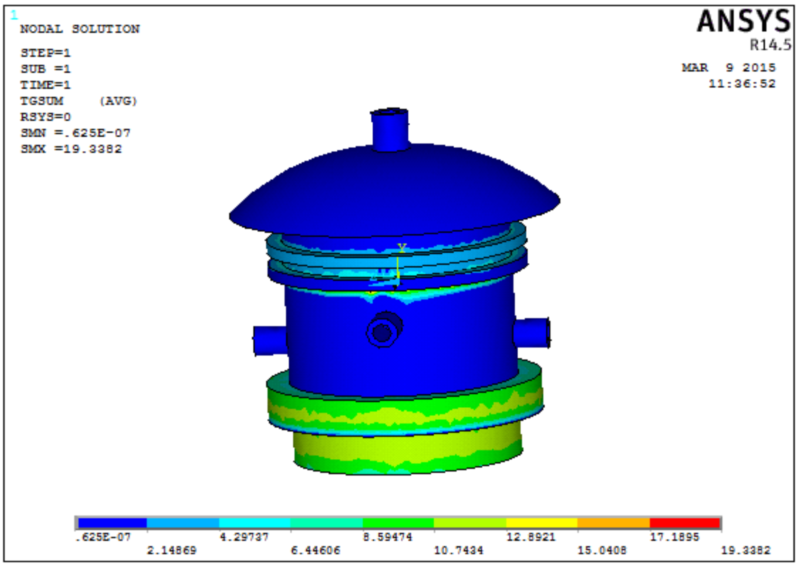
Bulk Temperature – 313K

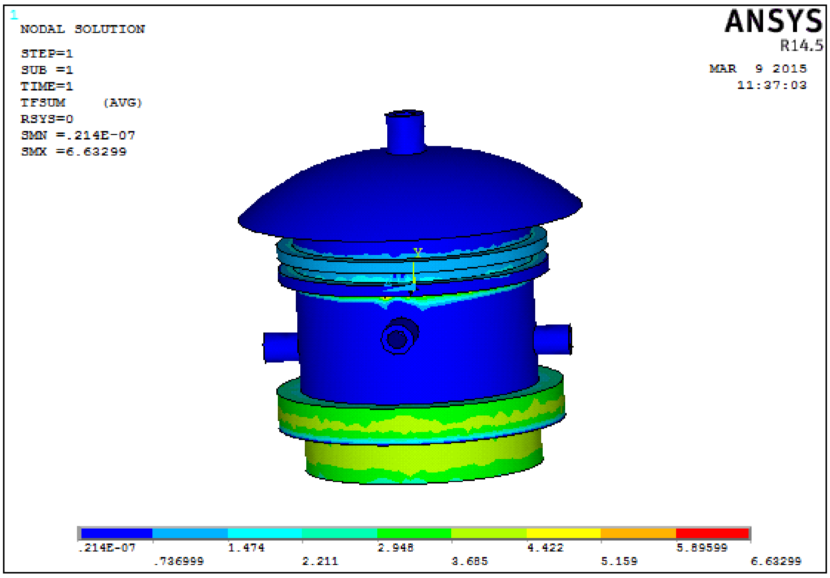
Film Coefficient – 25W/m^{2}K

Nodal Temperature Vector sum



Thermal Gradient Vector sum





Thermal flux vector sum

II. RESULTS TABLE

STRUCTURAL ANALYSIS

Material	Displacement (mm)	Stress (N/mm^2)	Strain
Stainless Steel	0.476E-3	0.361039	0.116E-03
Aluminum	0.00222	0.359678	0.540E-05
Brass	0.00129	0.358101	0.313E-05
Acrylic	0.045665	0.351496	0.110E-03

THERMAL ANALYSIS

Material	Nodal temperature (K)	Thermal Gradient (K/mm)	Thermal Flux (W/mm^2)
Stainless Steel	626.068	19.3382	6.63299
Aluminum	626.073	20.6911	4.34513
Brass	626.072	20.4374	4.76191
Acrylic S	626.082	23.2079	0.440949

III. CONCLUSION

In this project a VACUUM chamber used for high speed turbine will be designed and modeled in 3D modeling will be done in Pro/Engineer. The VACUUM chamber designed will be easy setup for rotors up to 17,500 lbs., up to 67 inches in diameter, at speeds of up to 60,000 RPM. In this project structural, and thermal analysis is done in Ansys. The present used material for VACUUM chamber is steel. In this project it is replaced with aluminum alloy, brass and acrylic. By observing the structural analysis results, the stress values are less than the allowable stress values for all the four materials. Using Aluminum or acrylic will be advantageous since their densities less than steel and brass. By observing thermal analysis results, using aluminum is better since the heat transfer rate is better. So it can be concluded that using aluminum is better than all other three materials.

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