RESEARCH PAPER | Engineering | Volume : 3 | Issue : 9 | Sept 2013 | ISSN - 2249-555X

Thermal Analysis of Low Prssure Boiler Drum (Pressure Vessel) Using Finite Element Analysis

KEYWORDS: FEM, Pressure vessel, Transient Thermal analysis

Prof. Vishal Saidpatil
Assistant Professor, Mechanical Engineering Department, NBNSSOE, Pune

Prof. S. M. Jadhav
Assistant Professor, Mechanical Engineering Department, NBNSSOE, Pune

ABSTRACT *This paper presents the guideline in thermal analysis for pressure vessel. Secondary stresses (thermal) of pressure vessel are obtained by Finite Element analysis approach. The aim of this Paper is to design and analyze the pressure vessel using ASME Code and to optimize using FEA approach. In this paper the operating conditions for cylindrical pressure vessel are 5 bar pressure and 250oc temperature.*

1. Introduction

Thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are: The temperature distributions, amount of heat lost or gained thermal gradients and thermal fluxes. It further divides in two types, steady-state thermal analysis and transient thermal analysis. Fluid analysis or Computational Fluid dynamics analysis is used to determine the flow distribution and temperature of a fluid. Pressure vessels are subjected to high amount of thermal shocks. The basic boiler consists of inlet for cold water known as cold end and the other outlet for hot water known as hot end. In order to study the temperature distribution inside the vessel and to know the response of the vessel, thermal stress analysis or shocks thermal analysis is carried out.

2. Thermal Analysis Model

For thermal analysis the nozzle is not considered as the flow inside the shell is to be analyzed. As the pressure inside the vessel is not changing it applies constant thermal loads. Hence the problem is analyzed as steady-state thermal problem. Thermal analyses are used to study thermal loadings and their resulting temperatures, heat transfer rates, displacements and stresses. These analyses are broken into two main types, steady state and transient. Steady state analysis will determine the energy balanced state at an infinite period in time without any detail on what happens while progressing to this point. Transient thermal analysis is able to analyze the heat flow through a body on a step by step basis allowing temperature effects to be observed over time. Steady state analysis is used to observe the effects of thermal loadings once the object in question has reached a constant, or steady state. This is useful to determine sustained temperatures, heat transfer rates, displacements and stresses. Steady state analysis is also useful to determine thermal loads and material properties to obtain a final desired result. As a steady state analysis only provides a final continuous result it only requires a single computation making it a very efficient solver.

3. Finite Element Model

A fine mesh of the vessel is created eliminating the nozzle.

- Element Type: In order to model the thermal stress induced and thermal bending stress SHELL131 is selected. Also the SHELL131 is applicable for steady state thermal analysis. In order to study the conducting behaviour it can be replaced with SHELL63 or vice versa.
- Element size is selected to 50
- A fine mesh is modelled throughout the vessel.
- The model is checked using quality-index

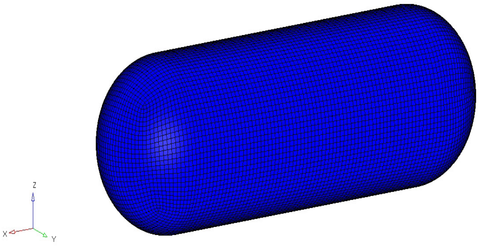

Fig 1 Meshed Model without Nozzle

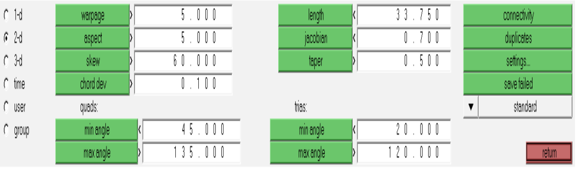

Fig. 2: Quality Check Parameter

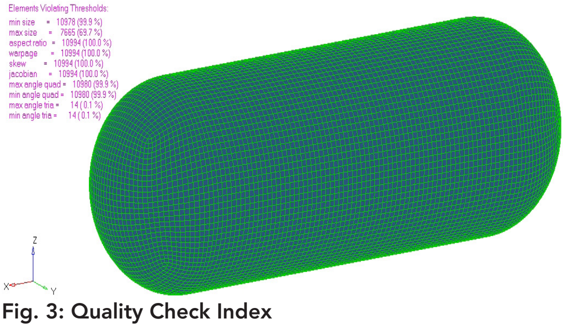

Fig. 3: Quality Check Index

4. TEMPERATURE DISTRIBUTION

The measurement of heat flux can be calculated by measuring a temperature difference over the vessel. For efficient operation, the boiler should be able to absorb maximum amount of heat.

The water getting inside is getting heated up and flows to the other end taking away the heat. Hence the problem is treated as a convection problem. However, conduction is modelled over a surface using shell elements.

Input: Total heat = 1000KW, Convection film coefficient, h = 25 W/m2K

Volume : 3 | Issue : 9 | Sept 2013 | ISSN - 2249-555X

Temperature at hot end = 250°C and Cold end = 25°C, Ambient temperature = 35°C … (All the temperatures are converted to degree Kelvin and mm)

Loads and Boundary conditions: The total heat is distributed in the cylinder into four sections viz. 10%, 20%, 30% and 40% from cold end to the hot end. The temperature at the hot and cold ends is applied over the elements of the shell. The heat generated is calculated by dividing total heat over volume of cylinder and applied as body loads. The boundary conditions applied are convection film coefficient and thermal conductivity of material, 17 W/mK. Ambient temperature is applied on nodes of the both hemispherical ends. at the hot and cold ends is applied over the elements of the shell. The heat generated is calculated by dividing total heat over volume of cylinder and applied as body loads. The boundary conditions applied are convection film coefficient and thermal conductivity of material, 17 W/mK. Ambient temperature is applied on nodes of the both hemispherical ends.

$H = Q/(\pi d^2 L/4)$

Where,

L= length of each section = 750mm

Q = Total heat = 1000KW

d = diameter of vessel = 1500mm

Applying the heat distribution through different proportions,

Through first portion

$q_1 = 10\ \%\ \text{of}\ Q/(\pi d^2 L/4)$

$= 7.545e\text{-}5\ w/m^3$

Through first portion

$q_2 = 20\ \%\ \text{of}\ Q/(\pi d^2 L/4)$

$= 1.509e\text{-}4\ w/m^3$

Through first portion

$q_3 = 30\ \%\ \text{of}\ Q/(\pi d^2 L/4)$

$= 2.263e\text{-}4\ w/m^3$

Through first portion

$q_4 = 40\ \%\ \text{of}\ Q/(\pi d^2 L/4)$

$= 3.018e\text{-}4\ w/m^3$

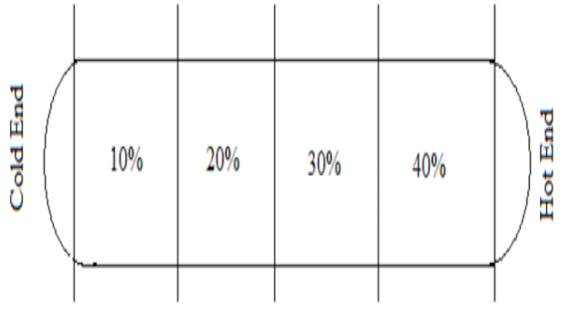

Fig 4 Temperature Zones

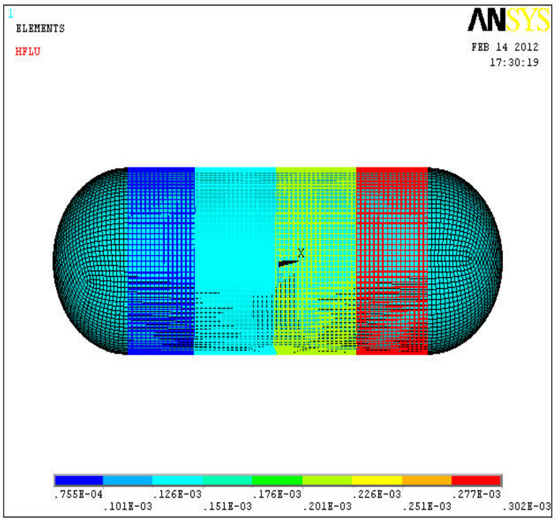

Fig. 5: Boundary condition for thermal analysis

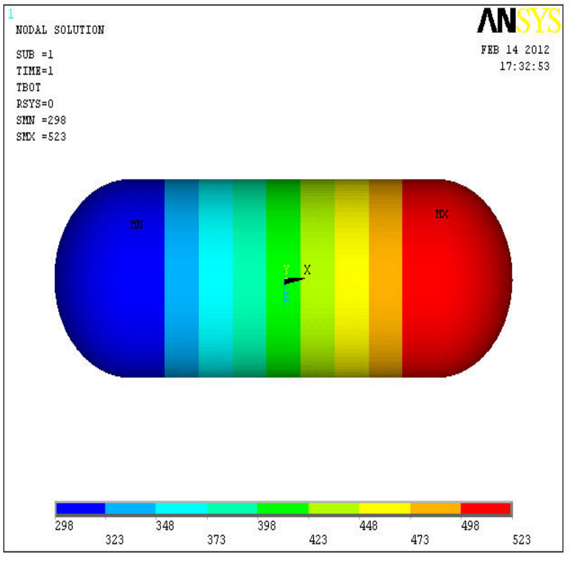

Fig. 6: Layer temperature TBOT

Figure 6 shows heat transfer through proportions indicating the temperature distribution on undergoing thermal analysis for following are the observations

- Temperature distribution through the vessel is at uniform rate.
- At Inlet the temperature applied is up to 298K where as ambient temperature is 308K. As atmosphere is having higher temperature partial expansion of the material occurs causing deformation. Since the difference is not too high the deformation is very low.
- Later in the next region i.e. from 323K to 340K the temperature difference from ambient is not too far hence the temperature distribution is almost uniform. This zone is the safest. i.e. at 10% of heat generation.
- Later stage when heat generation is between 20 to 30% temperature goes up to 398K. Here the difference between temperature in vessel and ambient is bit higher. As temperature inside the vessel is higher partial than the exterior ambient temperature contraction begins.
- Later on as the heat generation reaches 40% maximum of heat is transferred through the fluids temperature in the inner walls are very high i.e. 473K than the ambient.

Volume : 3 | Issue : 9 | Sept 2013 | ISSN - 2249-555X

- At the extreme exit the temperature is at 523K where as outer ambient temperature is at 308K contraction occurs at the surface, hence there are chances of causing residual stress. Since it is a closed surface, if any change in cross section at the exit is incorporated residual stress are very high.
- From this thermal analysis followings outputs are obtained which are in the tabular form.

Table 1: Results from Thermal Analysis

	Heat flux (w/m^3)	Temperature Distribution (° K)
Zone 1 of 10%	7.545e-5	298-348
Zone 2 of 20%	1.509e-4	348-398
Zone 3 of 30%	2.263e-4	398-448
Zone 4 of 40%	3.018e-4	448-523

- ➢ The model is constrained at the two supports.
- ➢ The nodular plot for the thermal stress is shown below.

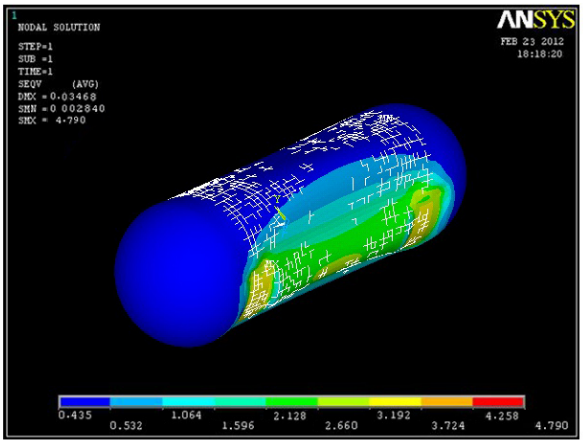

Fig. 7: Nodal Plot for Von Misses Stress in Thermal Analysis

CONCLUSION

The study shows that in pressure vessel thermal stress are developed. After investigating different methods it should be concluded that thermal stresses are the secondary stresses in the pressure vessel which are developed because of thermal distribution, heating and cooling effects. The thermal stresses analyzing by different finite element methods gives secondary stresses in the pressure vessels.

REFERENCE [1] A.Lietzmann, J. Rudoiph, E. Weib "Failure modes of pressure vessel components and their consideration in analyses", Chemical Engineering and Processing 35 (1996) 287-293. | [2] K.Tamil Mannan, Rakesh Saxena,R. Murugavel an P.L.Sah, "Stress Analysis of Conical Shell Skirt Support For High Pressure Vessel Using Finite Element Method", Multidiscipline Modelling in Mat. | and Str.5(2009)355-362. | [3] Jinhua Shi,D.Mackenzie & J.T.Boyle, A Method of Estimating Limit Loads by Iterative Elastic Analysis. Torisphericai Heads Under Internal Pressure , Int. J. Pres. Ves. & Piping 53 (1993) 121-142. | [4] ASME Code, Section VIII, Division 1,2007 A-08. | [5] Moss D.R.Pressure Vessel design manual Third edition.