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Study of different type reinforcement in cylindrical pressure vessel

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Abstract

Due to practical requirements, pressure vessels are often equipped with openings of various shapes, sizes and positions. Vessels have openings to accommodate manholes, handholds, and nozzles. Openings vary in size from small drain nozzles to full vessel size openings with body flanges. The openings cannot be avoided because of various piping or measuring gauge attachments. To avoid failure in the opening area, compensation or reinforcement is required. The additional material is deemed effective in carrying the higher loads. On most vessels, it is provided on the outside of the vessel. In some vessels, the reinforcement appears inside, while in others both inside and outside regions are reinforced. The main purpose of this paper is to perform a stress analysis on thin-walled pressure vessels with different type of the reinforcement and optimize the suitable reinforcement for opening using finite element analysis software namely, ANSYS. General applications of Thin-walled cylinders are commonly used as structural members (e.g., hollow structural sections), piping systems, members of offshore platforms, cooling towers, aircraft fuselages, naval halls of submarines, high pressure reactor vessels used in metallurgical operations, process plants etc.

1. Introduction

The introduction of a nozzle in a pressure vessel is a common requirement. The resulting discontinuity in the geometry introduces high stress concentrations in the region, thereby reducing the capacity of the vessel to withstand an internal pressure. If the vessel is to retain a significant percentage of its original capacity, additional material - "Reinforcement" should be provided around the curve of the intersection. [1] The determination of stresses in the region of opening is complicated because of the sudden discontinuity in the structure. [2] The different approaches that have been tried for the solution of this structural problem can be categorized as:

1. Analytical approaches using differential equations.
2. Limit analysis techniques.
3. Experimental studies employing model or component specimens.
4. Numerical analyses using computer oriented procedures such as Finite Element Analysis. [3]

To avoid failure in the opening area, compensation or reinforcement is required. The additional material is deemed effective in carrying the higher loads. On most vessels, it is provided on the outside of the vessel. In some vessels, the reinforcement appears inside, while in others both inside and outside regions are reinforced. On many vessels, however, the arrangement is such that no reinforcement can be placed on the inside because of interfering components.

2. Purpose of analysis

High stress concentrations exist in opening or nozzle area poses the "weakest link in the chain", therefore it requires careful attention during design in order to maintain the safety of the structure. It is highly uneconomical and impractical to let the high local stresses of this region govern the design. [4] This high stress concentration in opening area is avoided, if provided with proper reinforcement. So it is important to carry out the study of effect of reinforcement on stress distribution near the opening area. [5] To carry out an in depth investigation of the effect of reinforcement around the opening of the cylindrical pressure vessel, is to determine an efficient configuration design for the reinforcement.

To study such configuration design or different types of the reinforcement a general numerical method Finite element method is choose. The finite element method is now firmly established as the general numerical method to be used for obtaining a solution for complicated structures. The subdivision process of the method allows the specification of complicated configurations, abrupt changes in properties and even irregular geometrical boundaries. Moreover, the finite element method is one of the most efficient methods for the solution of structural nonlinearities.

3. Type of analysis done and Problem Specification

Structural analysis is choosing for the study of this problem. Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

Design Pressure = 700 Psi = 5 Mpa
Shell diameter = 60 in
Shell thickness = 1.5 in
Opening diameter = 8 in
Nozzle height = 6 in

4. FEA Model

In the present study the effect of various configurations of reinforcement on the structural response is studied by utilizing the finite element method. The structural modeling is done using ANSYS12 commercial code.

4.1 Model Building:

Model before meshing of pressure vessel is as follows:

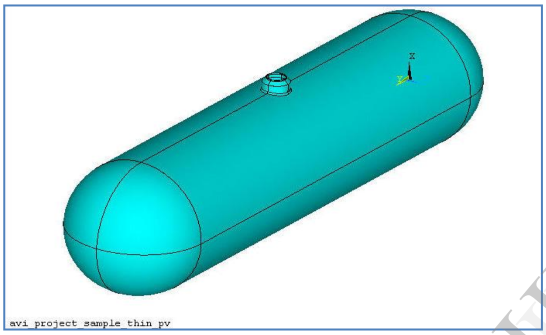


Figure.1 FEA model of pressure vessel

4.2. Element selection and Meshing

An important aspect contributing to the accuracy of the finite element technique is the selection of the right type of element. The element type selected for finite element analysis of pressure vessel is SHELL 63. SHELL63 has both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. Stress stiffening and large deflection capabilities are included. A consistent tangent stiffness matrix option is available for use in large deflection (finite rotation) analyses.

It is well recognized that for a three dimensional structure such as opening/nozzle in cylindrical pressure vessel the finite element mesh generation is one of the most formidable tasks that must be undertaken. For meshing the model we have used mesh size that is e-size as 5. Efficient use of the finite element method is achieved by using an optimum size of mesh with proper degrees of freedom at the nodes, depending upon the behavior of the structural response under consideration. It is desirable to have a finer mesh for accuracy.

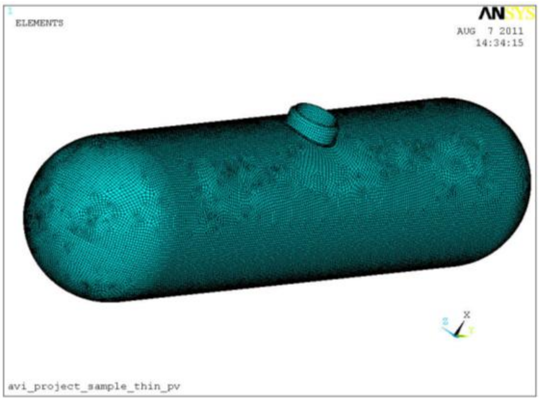


Figure.2 Mesh model of pressure vessel

4.3 Boundary Conditions and application of load:

The boundary conditions applied such as nodes in the support area is fixed in one side & other is fixed in Y-direction so that the rolling support is create in X-direction and internal pressure of 700 Psi is applied to the vessel and the analysis is performed to see the stresses in saddle and in the vessel. Figure show the detail idea about the boundary conditions & applied load.

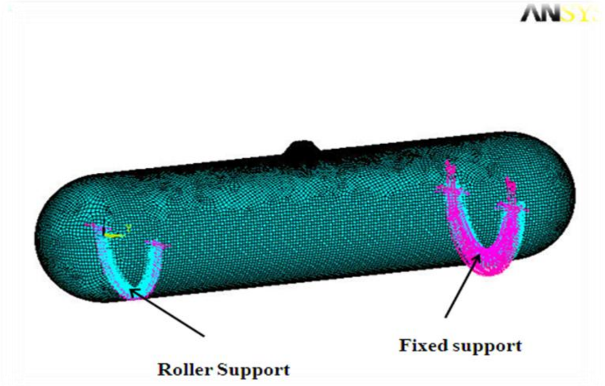
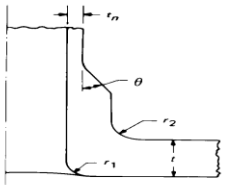


Figure.3 Boundary conditions applied to pressure vessel

5. Result of FEA

Case 1:- First type of reinforcement is shown below having the dimensions

- Height = 6 in
- Nominal thickness (tn) = 0.25 in
- Actual thickness Tn = 1.75in
- Shell thickness = 1.5 in
- $\theta = 35°$, $r_1 = 0.65$ and $r_2 = 0.75$



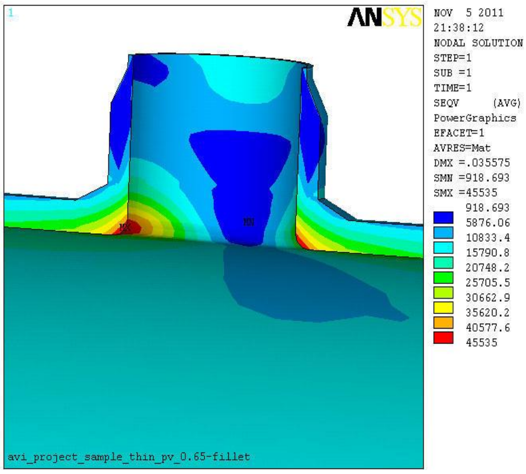
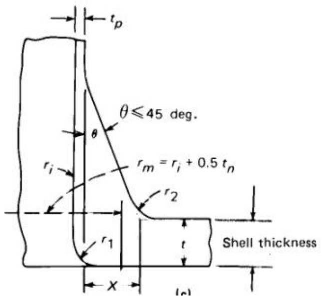


Figure.4 equivalent stress in first type of reinforcement

Case2:- second type of reinforcement is show below having the dimensions as

- Height = 6 in
- Nominal thickness (tp) = 0.25 in
- Actual thickness Tp = 1.75in
- Shell thickness = 1.5 in
- $\theta = 35°$, r_1= 0.65 and r_2= 0.75



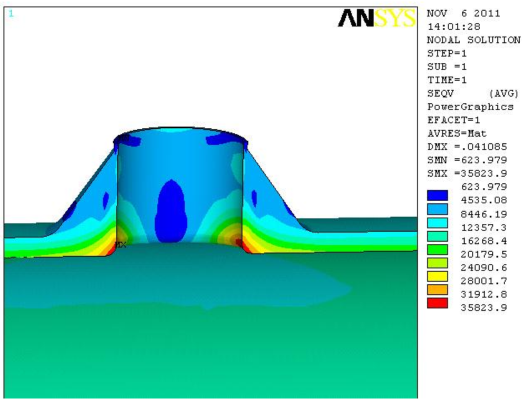
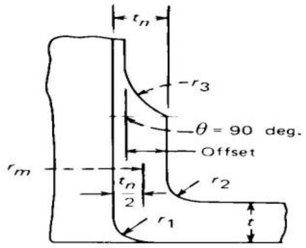


Figure.5 equivalent stresses in second type of reinforcement

Case3:- Third type of reinforcement is show below having the dimensions as

- Height = 6 in
- Nominal thickness (tp) = 0.25 in
- Actual thickness Tp = 2 in
- Shell thickness = 1.5 in
- $\theta = 90°$, r_1= 0.65in, r_2= 0.75in, r3=1.75 in.



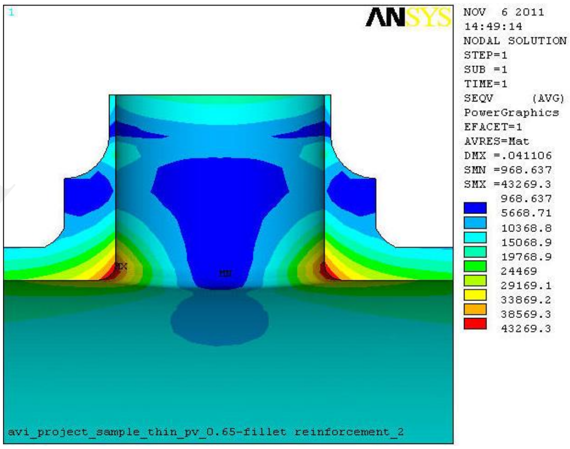
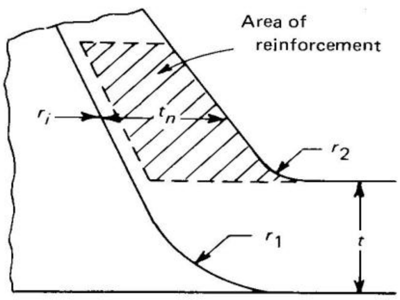


Figure.6 equivalent stresses in third type of reinforcement

Case4:- Third type of reinforcement is show below having the dimensions as

- Height = 6 in
- Actual thickness Tp = 3 in
- Shell thickness = 1.5 in
- r_1= 0.65in, r_2= 0.75in.



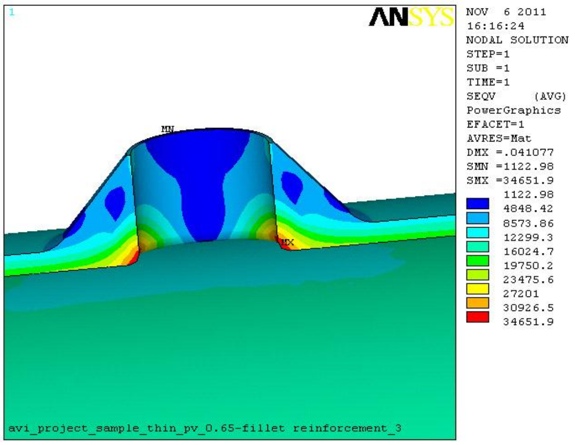


Figure.7 Equivalent Stress in forth type of reinforcement

6. Summary Table

From above ANSYS results summary table is drawn for all Reinforcement configurations. We have checked stresses in different type of reinforcement for the particular case of pressure vessel and from the results in ANSYS the stress value are less in second and forth type of reinforcement configuration when area near the opening is increase the stresses are minimum and the stress value are maximum in opening when area is minimum. Following table shows values of stress in nozzle area for different reinforcement.

Table.1 summary table

Reinforcement type	Stress (Mpa)
1	313.73
2	246.82
3	298.12
4	238.74

7. Conclusion:

High stress concentration develops at the junction of the intersecting of nozzle to cylindrical shells. The amount of different type of reinforcement around the opening/nozzle introduces a considerable reduction in these high stress fields. From the FEA result it is seen that the stress concentration in reinforcement type second and forth is considerably minimum as compare to other. The wall thickness of the second and forth reinforcement is large as compare to other two, so the stress are minimum in that area. From this it is clear that reinforcement or nozzle having wall thickness larger has the minimum stress concentration in that area. So for that we get minimum equivalent stresses (246.82Mpa, 238Mpa) in second and forth type of reinforcement. So for particular case both the reinforcement having low stress concentration is suitable.

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