International Journal on Emerging Technologies (Special Issue on NCRIET-2015) **6**(2): 229-234(2015)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Optimization of Location and Size of Opening in a Pressure Vessel Cylinder for Spherical and Elliptical Head

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(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Pressure vessel cylinders find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and fluid supply systems in industries. The failure of pressure vessel may result in loss of life, health hazards and damage of property. In addition to the pressure, the pressure vessels area also subjected to support loads that may be steady or variable, piping reactions, and thermal shocks which require an overall knowledge of the stresses imposed by these conditions on various vessel shapes and appropriate design means to ensure safe and long life. Basic considerations in the design of pressure vessel include recognition of most likely modes of failure, stresses induced due to temperature and pressure, selection of suitable material capable of withstanding the effects of pressure and thermal loads and effects of environment and effect of concentration of stresses. In the present work, emphasis is on effect of stress concentration. It will be shown that an appropriate location and size of the opening in a pressure vessel results in minimizing the stresses induced due to the stress concentration resulting from the end flanges and other attachments. In this present work the main aim is to design and optimize the spherical and elliptical head profile with hole on the head, also Analysis the above profiles for various stress parameter.

Keywords: PROE, ANSYS, VON-MEISES, displacement etc

I. INTRODUCTION

The term pressure vessel referred to those reservoirs or containers, which are subjected to internal or external pressures. The pressure vessels are used to store fluids under pressure. The fluid being stored may undergo a change of state inside the pressure vessels as in case of steam boilers or it may combine with other reagents as in chemical plants. Pressure vessels find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and in water, steam, gas and air supply system in industries.

The material of a pressure vessel may be brittle such as cast iron, or ductile such as mild steel.

A. High pressure vessels

High Pressure vessels are used as reactors, separators and heat exchangers. They are vessel with an integral bottom and a removable top head, and are generally provided with an inlet, heating and cooling system and also an agitator system. High Pressure vessels are used for a pressure range of 15 N/mm^2 to a maximum of 300 N/mm^2. These are essentially thick walled cylindrical vessels, ranging in size from small tubes to several meters diameter. Both the size of the vessel and the pressure involved will dictate the type of construction used.

B. The following are few methods of construction of high-pressure vessels

(i) A solid wall vessel produced by forging or boring a solid rod of metal.
(ii) A cylinder formed by bending a sheet of metal with longitudinal weld.
(iii) Shrink fit construction in which, the vessel is built up of two or more concentric shells, each shell progressively shrunk on from the inside outward. From economic and fabrication considerations, the number of shells should be limited to two.
(iv) A vessel built up by wire winding around a central cylinder. The wire is wound under tension around a cylinder of about 6 to 10 mm thick.
(v) A vessel built up by wrapping a series of sheets of relatively thin metal tightly round one another over a core tube, and holding each sheet with a longitudinal weld. Rings are inserted in the ends to hold the inner shell round while subsequent layers are added. The liner cylinder generally up to12 mm thick, while the subsequent layers are up to 6 mm thick.

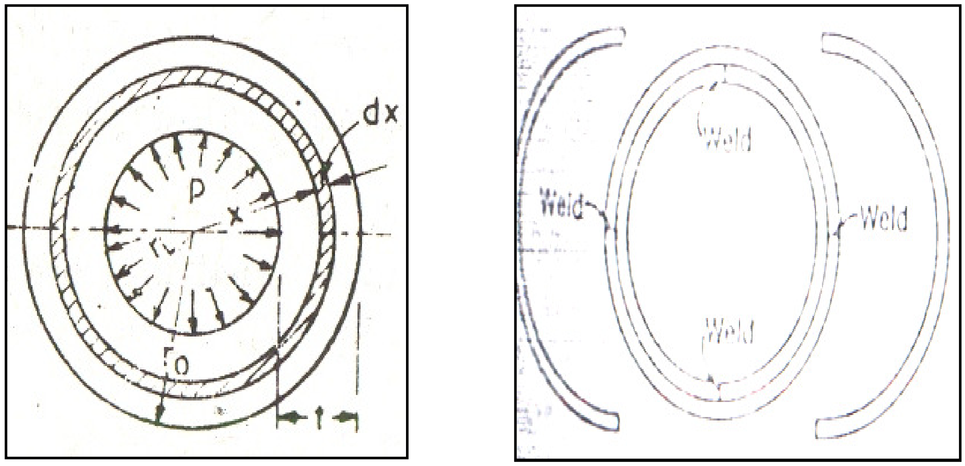


Fig. 1. Types of High Pressure Vessel.

II. LITERATURE SURVEY

M. Javed Hydera, M. Asifb researched on the location and size of opening (hole) in a pressure vessel cylinder using ANSYS. Analysis is performed for three thick-walled cylinders with internal diameters 20, 25 and 30 cm having 30 cm height and wall thickness of 20 mm. It is observed that as the internal diameter of cylinder increases the Von Misses stress increases.

Rashmiranjannath is proposed to conduct stress analysis of a thick walled cylinder near the radial hole on the surface. The literature indicated that there will be a ductile fracture occurring in such cases. The radial holes cannot be avoided due to various piping attachments.

Ping XUet.al introduced into the fitness function, an improved genetic algorithm (GA) is proposed to perform the optimal design of a pressure vessel which aims to attain the minimum weight under burst pressure constraint.

Siva Krishna Raparla T. Seshaiah designed and analysed the multilayer high pressure vessels features of multilayered high pressure vessels, their advantages over mono block vessel are discussed. Various parameters of Solid Pressure Vessel are designed and checked according to the principles specified in American Society of Mechanical Engineers (A.S.M.E) Sec VIII Division 1. Various parameters of Multilayer Pressure vessels are designed and checked according to the principles specified in American Society of Mechanical Engineers (A.S.M.E) Sec VIII Division 1.

3. Design of solid walled pressure vessel

A solid wall vessel consists of a single cylindrical shell, with closed ends. Due to high internal pressure and large thickness the shell is considered as a 'thick' cylinder. In general, the physical criteria are governed by the ratio of diameter to wall thickness and the shell is designed as thick cylinder, if its wall thickness exceeds one-tenth of the inside diameter.

Design data

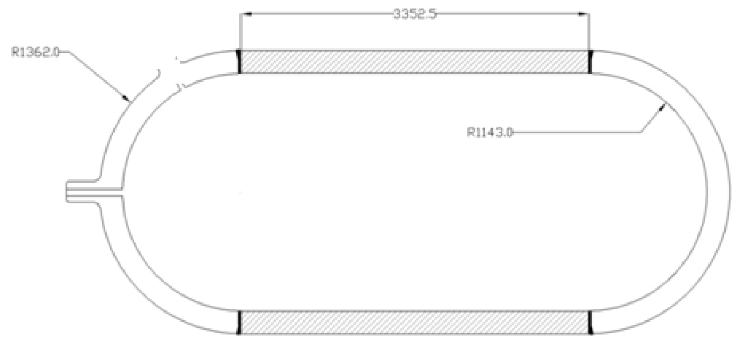
Drawing of solid wall pressure vessel

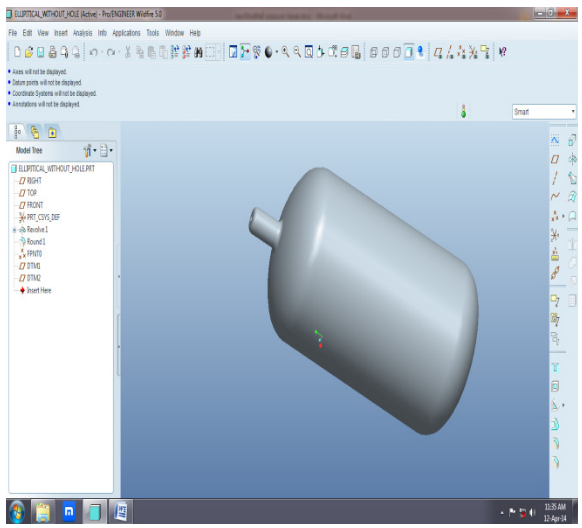
Design Pressure	P	-	21 N/mm^2, Hydrogen
Design Temperature	T	-	20^{0}C
Design Code		-	ASME Sec.VIII Division-1
Inside Radius of vessel	R_i	-	1143 mm
Inside Diameter of vessel, D_i	-	2286 mm	
Joint Efficiency	J	-	1
Safety Factor	F.S	-	4
Corrosion Allowance, C.A	-	3.0 mm	

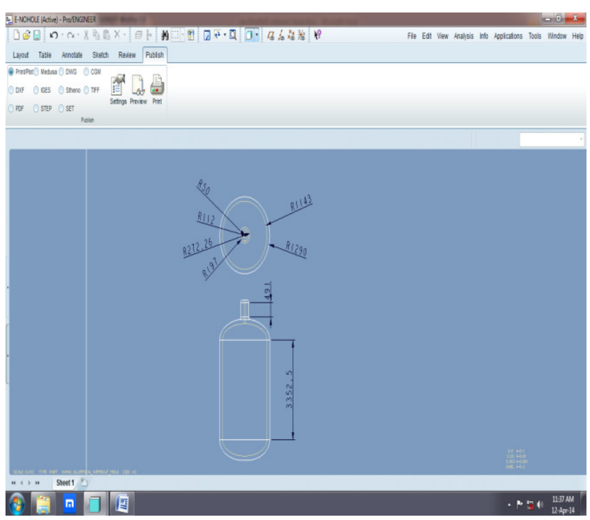
Allowable Stress value: Vessel & Dished Ends: 123 N/mm^2

III. 3D MODELS

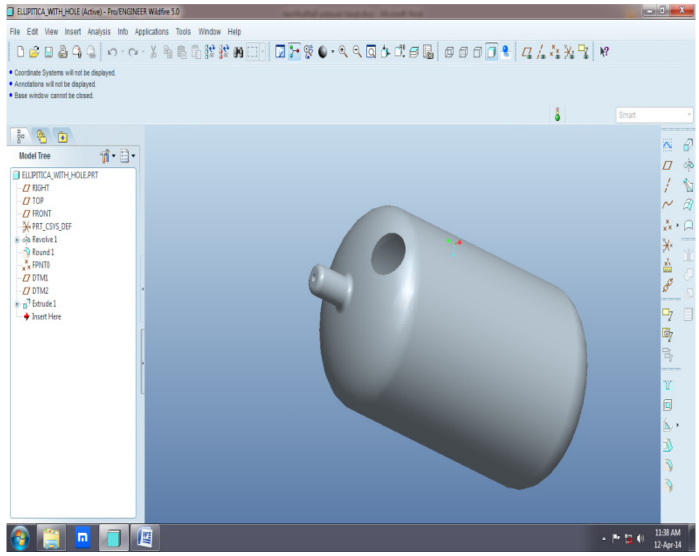
Elliptical Head With No Hole

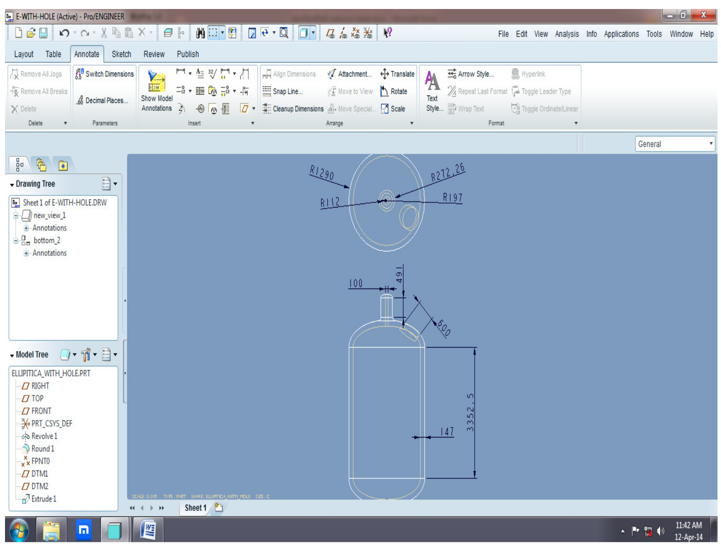


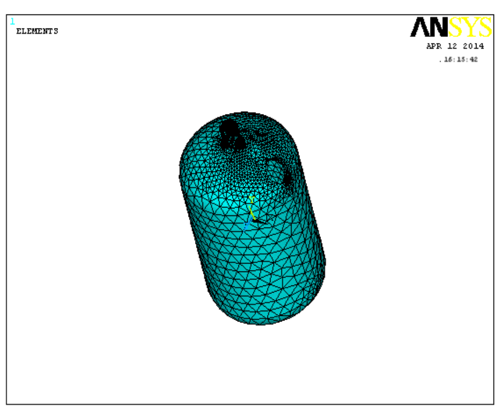




Eliipitical Head with Hole

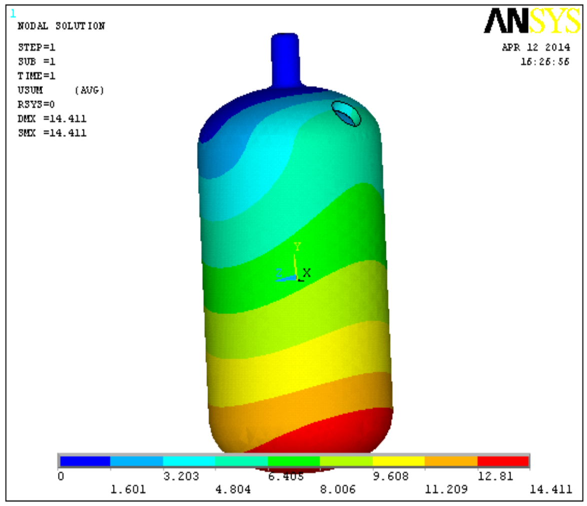






iv. RESULT AND DISCUSSION

Displacement



Spherical

	500mm DIA, DISTANCE-500mm	DIA 400mm, DISTANCE-400mm	450mm DIA, DISTANCE-350mm
Displacement (mm)	11.682	6.146	7.367
Stress (N/mm^{2})	499.219	619.242	661.739
Strain	0.003401	0.004317	0.004583

Elliptical

	550mm DIA, DISTANCE-700mm	500mm DIA, DISTANCE-750mm	DIAMETER-450mm, DISTANCE- 350mm
Displacement (mm)	17.494	15.246	14.411
Stress (N/mm^{2})	1349	1208	907.861
Strain	0.009381	0.008418	0.006356

THERMAL ANALYSIS FOR SPHERICAL ORIGINAL

MATERIAL – STEEL

Set Units - /units, si, mm, kg, sec, k.

File- change Directory-select working folder

File-Change job name-Enter job name

Select element-Solid-20node 90

Material Properties

Thermal Conductivity – 19.0 W/ m°k

Specific Heat- 0.448 J/g °c

Density – 7.85 g/cc

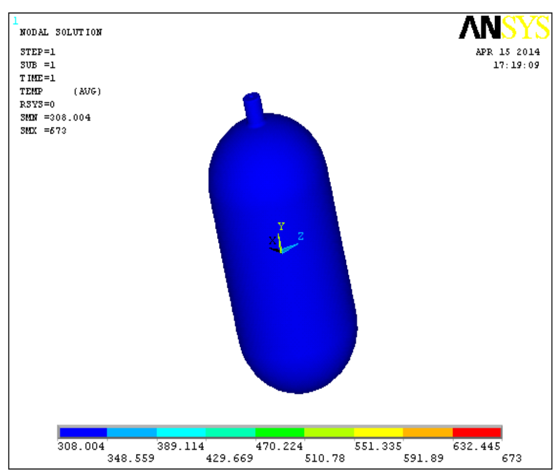
Loads

Apply Thermal-Temperature- on Area=673 K

Convections – on Area-Film Co-efficient – 0.039w/m^2 k

Bulk Temperature – 303 k

TEMPERATURE



CONCLUSION

In this project, a pressure vessel is designed according to the company specifications. 3D modelling is done in Pro/Engineer. The pressure vessel head used is in the shape of spherical head without hole. In this we are replacing with elliptical head and also by taking holes. Analysis is done on the pressure vessel to verify the strength. Analysis is done for elliptical and spherical heads, without and with holes and also by changing the diameters and distances of hole. By observing the analysis results of without and with holes, for the spherical head without hole less stress is developed 290.64MPa, the stress value is less than ultimate stress value of the material. By observing the results by changing the diameter and distance of holes, the spherical head pressure vessels is analyzed with less stress values than elliptical head. The spherical head with hole diameter of 500mm and distance of 500mm is better since the stress value 499.219 is equal to the ultimate stress value. The other pressure vessels are not safe since the analyzed stress values are more than the ultimate stress value of material. Thermal analysis is done on the optimized pressure vessel to determine the heat transfer rates. The heat transfer rate is 9.313W/mm^{2}for spherical head and 7.794 W/mm^2 for elliptical head. The heat transfer rate is more for spherical head than elliptical head.

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