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DESIGN AND OPTIMIZATION OF SIZE, LOCATION OF OPENING IN A PRESSURE VESSEL CYLINDER AND HEMI SPHERE BY USING ANSYS

S. Swathi*[1] & K. Arun Kumar[2]
*[1]M.Tech Student, Department of Mechanical Engineering, Raghu Engineering College, Visakhapatnam, India.
[2]Assistant professor, Department of Mechanical Engineering, Raghu Engineering College, Visakhapatnam, India

Keywords: *Pressure vessel, von misses stress, optimization, finite element analysis, CATIA, ANSYS.*

ABSTRACT
A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The main objective of the research work is to optimize the location and size of opening (hole) in a pressure vessel cylinder and hemi sphere dish end using ANSYS. Analysis is performed for three thick-walled cylinders and hemi spheres with internal diameters 20, 25 and 30 cm having 30 cm height (cylinder) and wall thickness of 20 mm. It is observed that as the internal diameter of cylinder increases the Von Misses stress increases. Optimization of hole size is carried out by making holes having diameter of 4, 8, 10, 12, 14, 16 and 20 mm located at center in each of the three cylinders and Hemispheres, and it is observed that initially Von Misses stress decreases and then become constant with hole size. Lastly, optimization of location of hole is carried out by making a 14 mm hole located at 1/16, 1/8, 2/8, 3/8 and 4/8 of cylinder height from top in all the three cylinders, and different angles like 10^0, 30^0, 45^0, 60^0 & 90^0 on Hemisphere dish end.

INTRODUCTION
Pressure vessels 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. 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. They allow for the mounting of equipment, the insertion of instrumentation, and the connection of piping facilitating the introduction and extraction of content but they also lead to the high stress concentration which leads to the failure of pressure vessel. Openings in pressure vessels are frequent, in fact all riveted constructions make use of such means of fabrication, and all vessels must have openings. These geometric discontinuities alter the stress distribution in the neighborhood of discontinuity so that elementary stress equations no longer prevail. Such discontinuities are called stress raisers and the regions in which they occur are called the areas of stress concentrations.

A pressure vessel is a container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The pressure differential is dangerous, and fatal accidents have occurred in the history of pressure vessel development and operation. Consequently, pressure vessel design, manufacture, and operation are regulated by engineering authorities backed by legislation. For these reasons, the definition of a pressure vessel varies from country to country, but involves parameters such as maximum safe operating pressure and temperature, and are engineered with a safety factor, corrosion allowance, minimum design temperature (for brittle fracture), and involve nondestructive testing, such as ultrasonic testing, radiography, and pressure tests, usually involving water, also known as a hydro test, but could be pneumatically tested involving air or another gas. The preferred test is hydrostatic testing because it's a much safer method of testing as it releases much less energy if fracture were to occur (water does not rapidly increase its volume while rapid depressurization occurs, unlike gases like air, i.e. gasses fail explosively). In the United States, as with many other countries, it is the law that vessels over a certain size and pressure (15 PSI) be built to Code, in the United States that Code is the ASME Boiler and Pressure Vessel Code (BPVC), these vessels also require an Authorized Inspector to sign off on every new vessel constructed and each vessel has a nameplate with pertinent information about the vessel such as maximum allowable working pressure, maximum temperature, minimum design metal temperature,

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what company manufactured it, the date, it's registration number (through the National Board), and ASME's official stamp for pressure vessels (U-stamp), making the vessel traceable and officially an ASME Code vessel.

MATERIALS

Many pressure vessels are made of steel. To manufacture a cylindrical or spherical pressure vessel, rolled and possibly forged parts would have to be welded together. Some mechanical properties of steel achieved by rolling or forging, could be adversely affected by welding, unless special precautions are taken. In addition to adequate mechanical strength, current standards dictate the use of steel with a high impact resistance, especially for vessels used in low temperatures. In applications where carbon steel would suffer corrosion, special corrosion resistant material should also be used. Some pressure vessels are made of composite materials, such as filament wound composite using carbon fiber held in place with a polymer. Due to the very high tensile strength of carbon fiber these vessels can be very light, but are much more difficult to manufacture. The composite material may be wound around a metal liner, forming a composite overwrapped pressure vessel. Other very common materials include polymers such as PET in carbonated beverage containers and copper in plumbing. Pressure vessels may be lined with various metals, ceramics, or polymers to prevent leaking and protect the structure of the vessel from the contained medium. This liner may also carry a significant portion of the pressure load. Pressure Vessels may also be constructed from concrete (PCV) or other materials which are weak in tension. Cabling, wrapped around the vessel or within the wall or the vessel itself, provides the necessary tension to resist the internal pressure. A "leak proof steel thin membrane" lines the internal wall of the vessel. Such vessels can be assembled from modular pieces and so have "no inherent size limitations". There is also a high order of redundancy thanks to the large number of individual cables resisting the internal pressure.

Table 1: **Material Properties**

Description	Material	UTS MPa (Min)	YS MPa (Min)
Vessel	SA 515 GR 70	492.9	267.6
Dished Ends	SA 515 GR 70	492.9	267.6

DESIGN AND ANALYSIS

In the present work finite element analysis is performed on pressure vessel by using ANSYS software. The model of pressure vessel is prepared in CATIA software and it is imported in ANSYS software to perform analysis. The finite element is a mathematical method for solving ordinary and partial differential equations. Because it is a numerical method, it has the ability to solve complex problems that can be represented in differential equation form. As these types of equations occur naturally. In virtually all fields of the physical sciences, the applications of the Finite element method are limitless as regards the solution of practical Design problems.

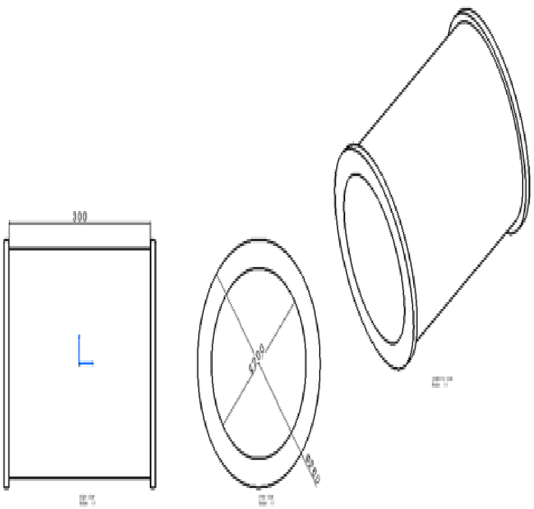

Fig 1: Drawing of solid wall pressure vessel

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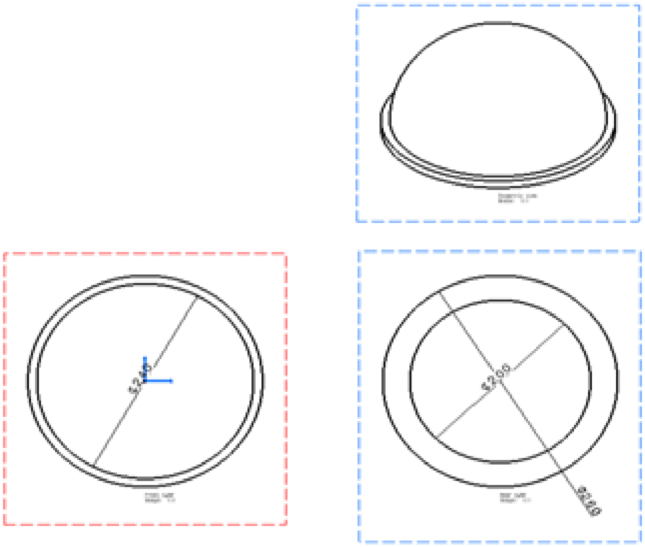

Fig 2: Drawing of hemisphere

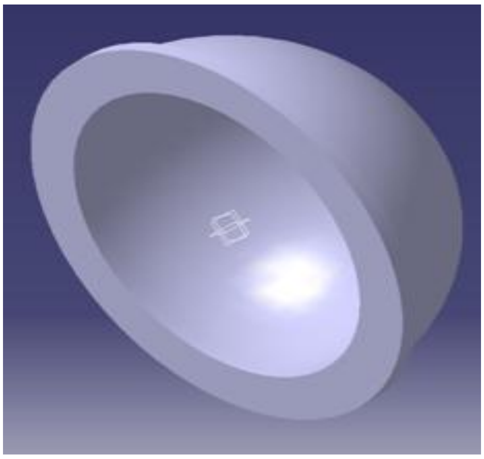

Fig 3: 3D model of cylinder vessel

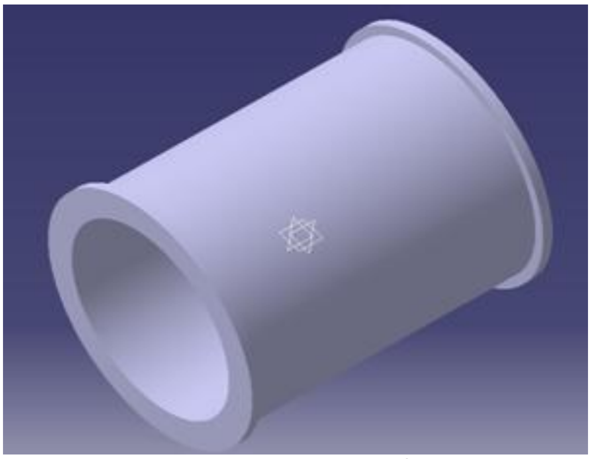

***Fig 4: 3D model of** hemi spherical vessel*

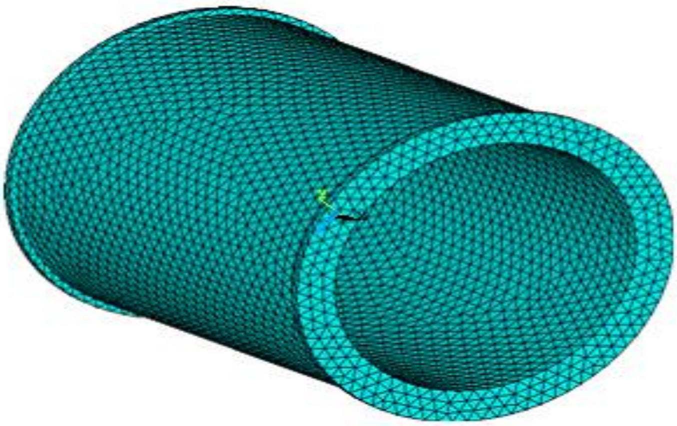

Fig 5:Drawing of solid hemisphere pressure vessel.

RESULTS AND ANALYSIS

Simulation results from testing Pressure vessels under static pressure containing the stress and deflection are listed in following tables for Pressure vessel cylinder and Hemi sphere dish end. These results are obtained from

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FEA.considering three pressure vessels of diameters 20cm, 25cm & 30cm and finding the optimum hole size and location of opening on cylinder and hemi sphere

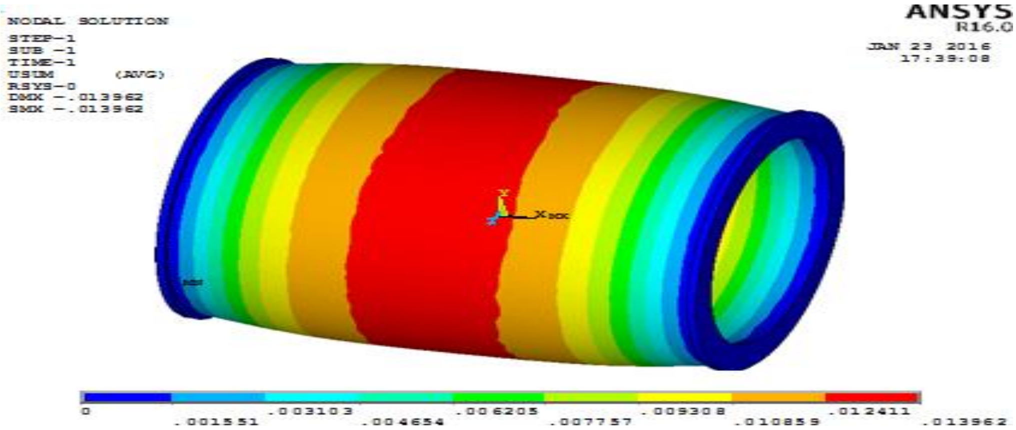

Fig 6: ***Displacement Vector sum of pressure vessel cylinder without hole***

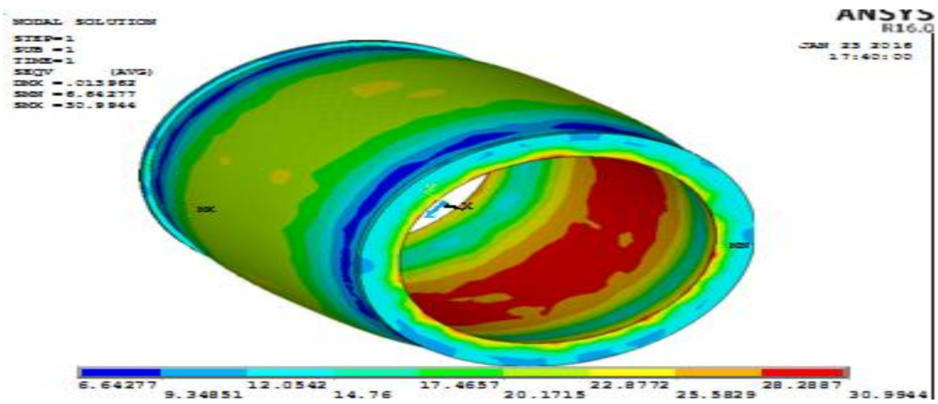

Fig 7: ***Von-Mises stress of pressure vessel cylinder without hole***

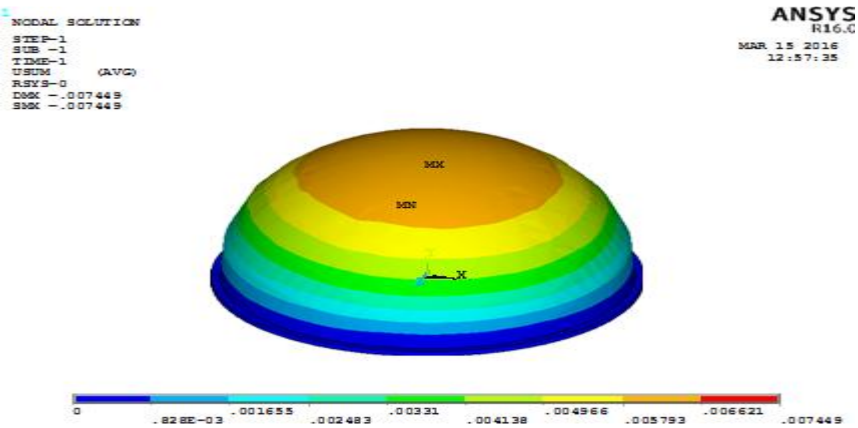

Fig 8: ***Displacement vector sum of hemi sphere without hole***

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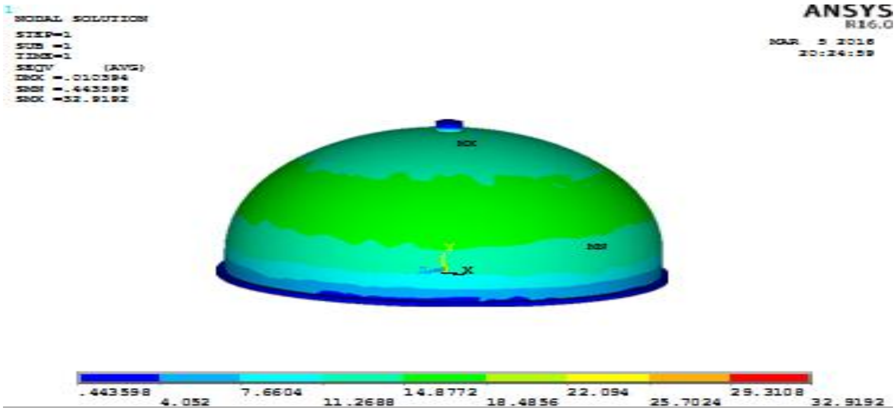

Fig 9: Von-Mises stress on Hemi sphere, the hole location at 90 degrees

Table 2: 20cm diameter of cylinder having stress of different hole size

Hole size	Deformation (m)	Tangential stress (Mpa)	Longitudinal stress (Mpa)	Radial stress (Mpa)	Equivalent stress (MPa)
4	0.014	61.45	16.65	10.53	53.88
8	0.014	74.54	16.93	11.71	65.2
10	0.0139	76.34	16.32	10.85	67.54
12	0.014	77.17	16.03	10.87	69.6
14	0.0142	72.3	16.05	9.81	67.11
16	0.0141	74.45	16.47	9.5	72.97
20	0.0145	85.28	15.97	10.22	79.79

Table 3: Equivalent stress of different hole sizes cylinder having 20, 25 &30 diameters

	Equivalent stress (MPa)		
Hole size	Cylinder-A (20cm)	Cylinder-B (25cm)	Cylinder-C (30)
4	53.88	66.04	78.7
8	65.2	81.44	93.22
10	67.54	83.82	100.2
12	69.6	87.26	102.58
14	67.11	86.58	102.32
16	72.97	94.12	109.63
20	79.79	96.02	114.48

Table 4:Optimum location of hole on pressure vessel cylinder

	Equivalent stress (MPa)		
HOLE POSITION	Cylinder-A (20cm)	Cylinder-B (25cm)	Cylinder-C (30)
1/16	34.56	47.11	52.79
1/8	40	40.54	48.45
2/8	63.29	73.63	78.37
3/8	71.2	88.28	103.97
4/8	71.3	89.7	99.77

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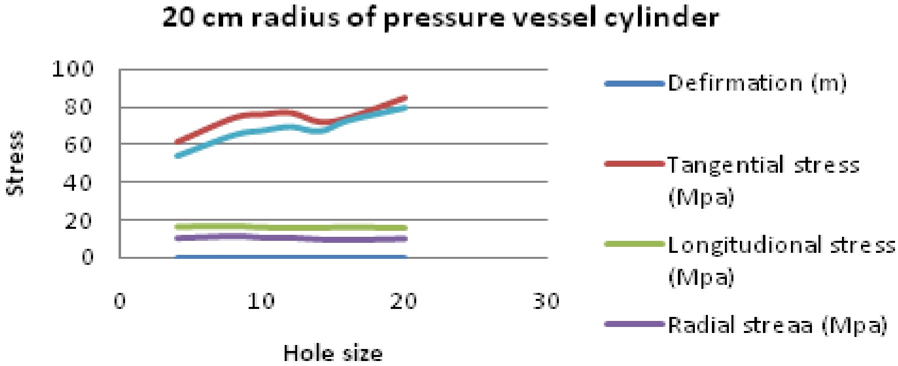
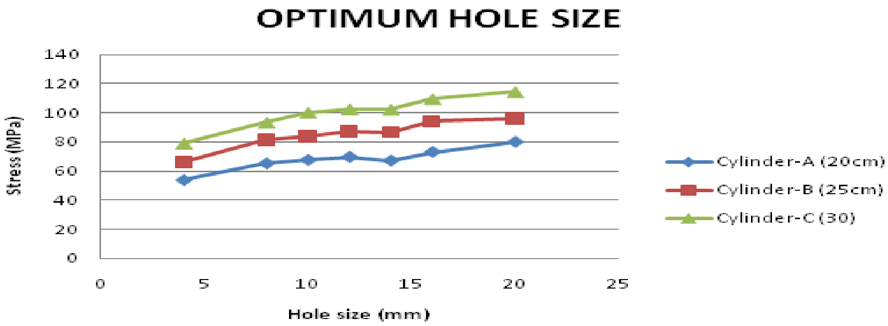


Graph1: Graph between Hole size and stress for 20cm diameter of cylinder



Graph 2: Graph between hole size and stress for cylinders 20, 25 and 30

Table 5: 20cm diameter of hemi sphere dish and stress of different hole sizes

Hole size	Deformation (m)	Tangential stress (Mpa)	Longitudinal stress (Mpa)	Radial stress (Mpa)	Equivalent stress (MPa)
4	0.007128	31.44	17.48	9.406	25.17
8	0.007105	30.47	17.47	9.58	26.75
10	0.007082	30.92	16	9.42	27.47
12	0.007059	30.82	14.46	9.39	28.14
14	0.007021	31.25	14.56	9.77	29.65
16	0.006995	31.47	14.58	9.81	27.35
20	0.006961	30.73	12.47	9.389	27.78

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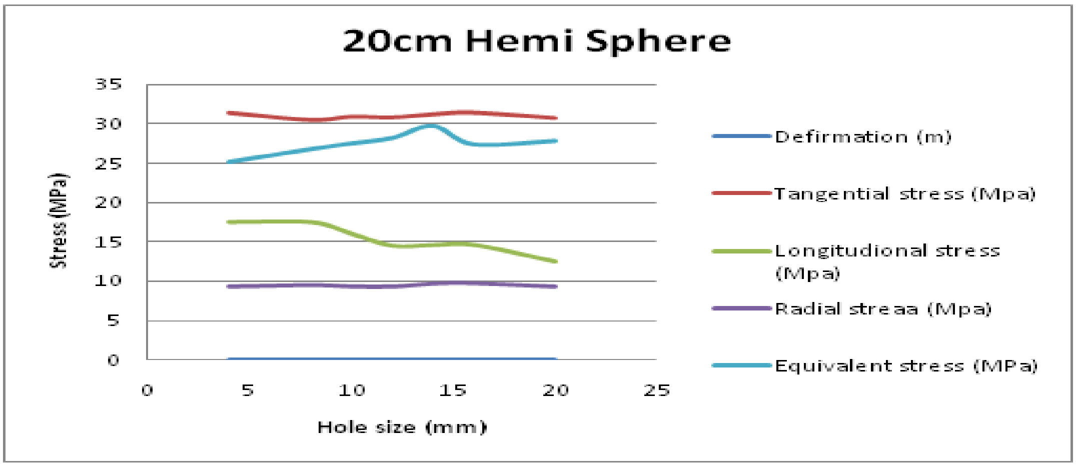
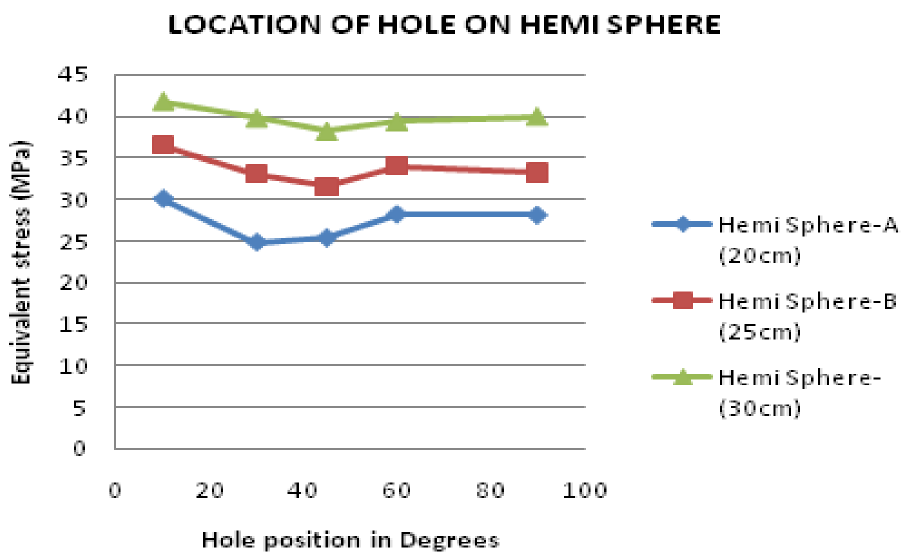


Graph3:graph between hole size and stress for hemi sphere dish having 20cm diameter

Table 5: Equivalent stress of different hole location of hemi sphere having 20, 25 &30 diameters

	Equivalent stress (MPa)		
POSITION OF HOLE in Degrees	Hemi Sphere-A (20cm)	Hemi Sphere-B (25cm)	Hemi Sphere- (30cm)
10	30.1	36.56	41.81
30	24.82	33.1	39.8
45	25.33	31.6	38.2
60	28.2	33.99	39.36
90	28.09	33.24	40.01



Graph4: Graph between hole position and equivalent stress for hemi sphere dish

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Optimization of hole size is carried out by making holes having diameter of 4, 8, 10, 12, 14, 16 and 20 mm located at center in each of the three cylinders, and it is observed that initially Von Misses stress decreases and then become constant with hole size. The optimum size of hole is found to be 14 mm for cylinder having internal diameter of 20, 25 &30 cm. Lastly, optimization of location of hole is carried out by making a 14 mm hole located at 1/16, 1/8, 2/8, 3/8 and 4/8 of cylinder height from top in all the three cylinders and different angles like 10^0, 30^0 45^0 , 60^0 & 90^0 on Hemisphere dish end. The Von Misses stress is maximum at the center i.e., 4/8 location and decreases in the direction away from center and then stress increases as the location is changed from 1/8 to 1/16 from cylinder top due to the end effects. The optimum location of the hole have to found at 1/16 position for cylinder having 20cm, where as 1/8 position for 25&30cm cylinder. And the Von misses stress is maximum at the centre i.e., 90^0 of hemi sphere and decreases in the direction away from center and then stress increases as the location is changed from 90^0 to$10^0$from top due to end effects. . The optimum location of the hole have to found at 10^0 position for Hemisphere dish having 20cm, where as 30^0 position for 25&30cm Hemisphere dish.

CONCLUSIONS

1. It is concluded that the location and size of the hole depends on the size of the cylinder and hemi sphere end.
2. For a specific application and size of the cylinder the location and size of the opening should be decided by caring out the finite element analysis (like ANSYS in this case) considering the end effects introduced by the flanges.
3. The optimum location is where the Von Mises stress is minimum and also the hole size should be such that the Von Mises stresses are minimum around the vicinity of the hole.
4. The optimum size of hole is found to be 14 mm for cylinder having internal diameter of 20, 25 &30 cm.
5. The optimum location of the hole have to found at 1/16 position for cylinder having 20cm, where as 1/8 position for 25&30cm cylinder.
6. The optimum location of the hole has been to found at 10^0 position for Hemisphere dish having 20cm, where as 30^0 position for 25&30cm Hemisphere dish.
1. Finally Hemisphere dish having minimum stress concentration as compared to cylinder. Final optimum location has found as 30^0 of hemi sphere dish end and diameter of hole should be 14mm, finally life of pressure vessel increased with using above parameters.

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