International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol. 3, Issue. 5, Sep - Oct. 2013 pp-2717-2725 ISSN: 2249-6645

Finite Element Analysis of Obround Pressure Vessels

Manish M. Utagikar[1], Prof. S.B. Naik[2]
[1]*M.E. Student, Dept. of Mechanical Engg, Walchand Institute of Technology, Solapur, India*
[2]*Professor, Dept. of Mechanical Engg, Walchand Institute of Technology, Solapur, India*

ABSTRACT: *This paper presents the work carried out for determination of stresses in an open ended pressure vessel of obround shape. In some situations, due to the limited space available, exit pipes are made of elliptical or obround shape. In this study, the stresses in the obround pressure vessel are determined using finite element method. The material of the vessel is aluminum alloy. Internal pressure is applied to the vessel. Software 'ANSYS' is used for modeling & analysis purpose. Considering the symmetry about both axes, only quarter model is prepared. Firstly analysis of circular pressure vessel is done. The results of the circular vessel are validated by analytical solution. Then using the same type of element & mesh density, analysis of obround pressure vessel is done. During the study, different parameters were varied & their effect on the stresses was observed.*

Keywords: *Obround Pressure Vessel, Finite element analysis, ANSYS*

I. INTRODUCTION TO PRESSURE VESSELS

Pressure vessels are a commonly used device in engineering. Cylindrical or spherical pressure vessels (e.g., hydraulic cylinders, gun barrels, pipes, boilers and tanks) are commonly used in industry to carry both liquids and gases under pressure. When the pressure vessel is exposed to this pressure, the material comprising the vessel is subjected to pressure loading, and hence stresses, from all directions. The normal stresses resulting from this pressure are functions of the radius of the element under consideration, the shape of the pressure vessel (i.e., circular, obround or elliptical) as well as the applied pressure.

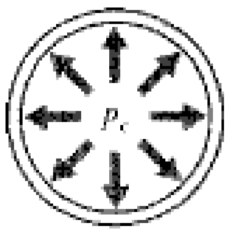	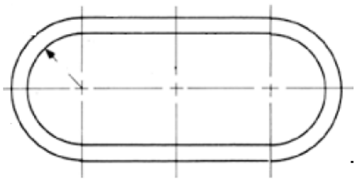	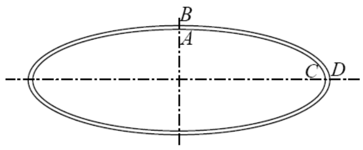
Circular Pressure Vessel	Obround Pressure Vessel	Elliptical Pressure Vessel

Figure.1 Types of Pressure Vessels

II. PROBLEM DEFINITION:

Analysis of a circular pressure vessel will be done for a certain pressure. Hoop stresses will be determined for this geometry. Analytical solution of the same will be determined. Comparison of the results will be done. To maintain the flow rate, the area of flow is kept same & shape is changed to obround & the stress analysis is done for this vessel. Following data will be used for the analysis work.

Inner Diameter (D) = 200 mm, Thickness of vessel (t) = 2.5 mm
Pressure applied (P) = 0.1 MPa
Material Properties: Material selected is Aluminum alloy used in aircraft.

Table.1 Material Properties

Young's Modulus	1.03458 e5 MPa
Poisson's Ratio	0.33

III. ANALYTICAL SOLUTION

Analytical solution is determined for circular pressure vessel using Formula,
Hoop Stress = (P x R) / t = (0.1 x 100) / 2.5 = 4 MPa

IV. FINITE ELEMENT ANALYSIS

Circular Pressure Vessel: Taking the advantage of symmetry about both the axes, a quarter model is prepared & the analysis is done using Finite Element Method based software ANSYS.

Meshing: For meshing quadrilateral elements with midside nodes are used. The details of this element are as below.

PLANE82: It is a higher order version of the 2-D, four-node element PLANE42. It provides more accurate results for mixed (quadrilateral-triangular) automatic meshes and can tolerate irregular shapes without as much loss of accuracy. The 8-node elements have compatible displacement shapes and are well suited to model curved boundaries.

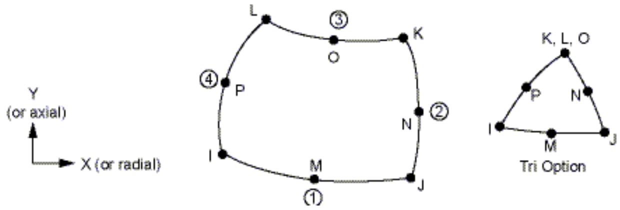

Figure.2 Structure of PLANE82 element

The 8-node element is defined by eight nodes having two degrees of freedom at each node: translations in the nodal x and y directions. The element may be used as a plane element or as an axi-symmetric element. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

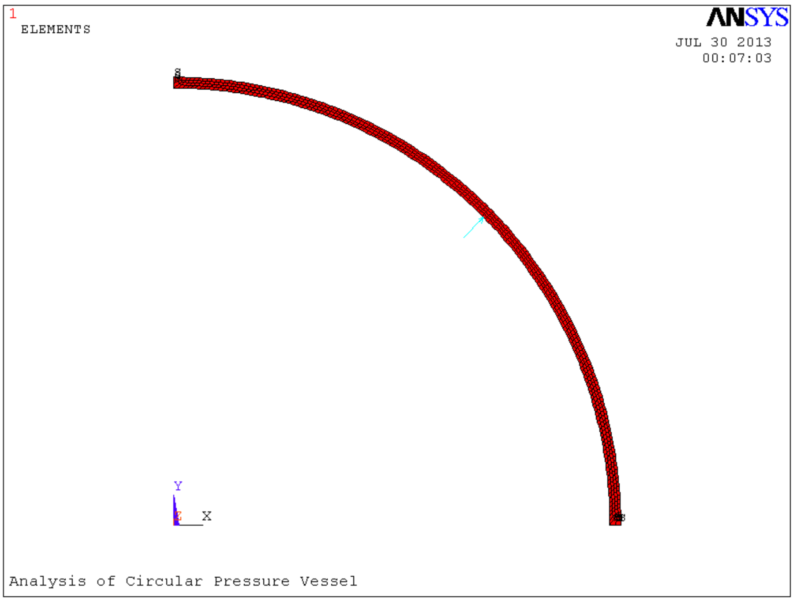

Figure.3 Circular Pressure vessel with load condition & boundary condition

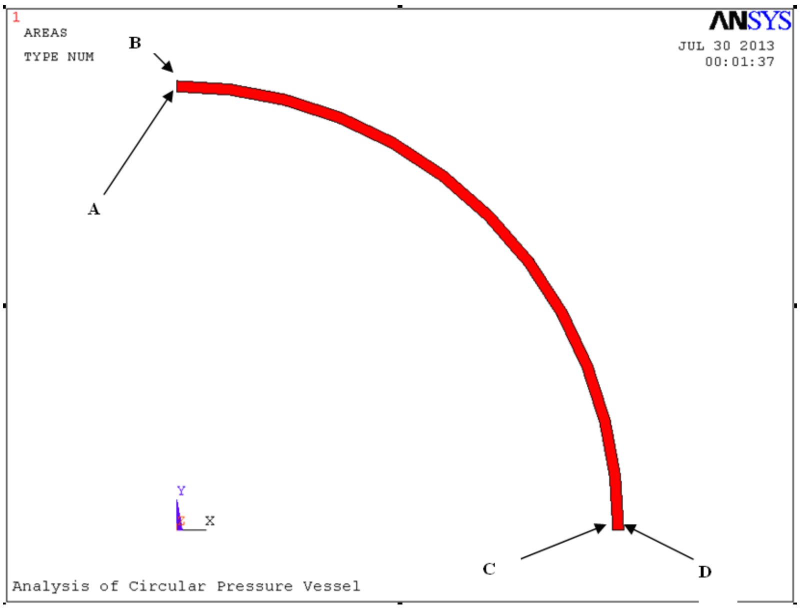

Figure.4 Location of Points A, B, C & D

The various points of interest are as shown in the above figure.

Obround Pressure Vessel: For the obround vessel radius of curved part is taken equal to 50mm.

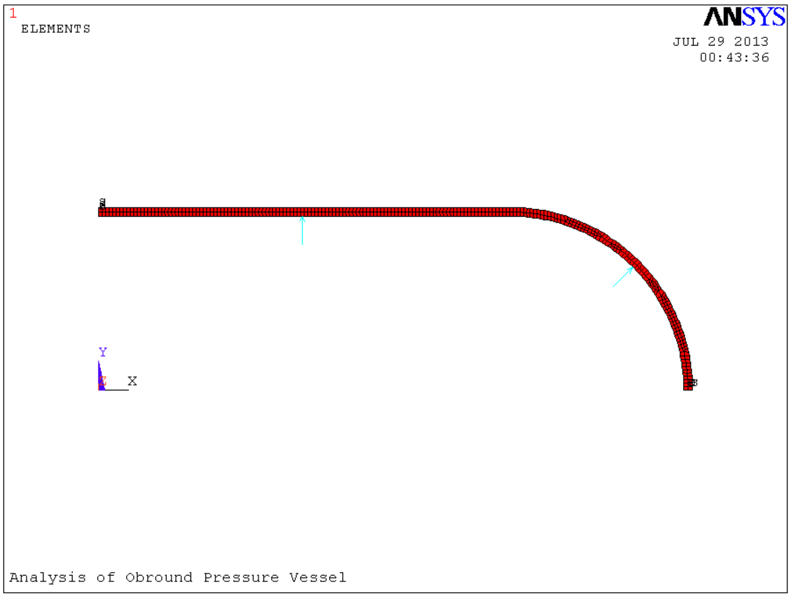

Figure.5 Meshed model of obround pressure vessel with boundary condition & Load Conditions

V. RESULTS & DISCUSSIONS

Circular Pressure Vessel:

Initially for circular pressure vessel, trials are taken to see the effect of mesh density. It is seen that using edge length of 1.25 mm for small edges & edge length of 1 mm for curved edges, we get more accuracy. Hence the same is finalized for further analysis. Following table gives the details of the results obtained with the above mesh density.

Table.2 Values of Principal Stresses

Stress at A (MPa)	Stress at B (MPa)	Stress at C (MPa)	Stress at D (MPa)
4.0504	3.9506	4.0504	3.9506

Fig.6 indicates the deformed shape along with un-deformed shape of the circular pressure vessel. I can be seen that the maximum deformation is only 0.003947 mm. Fig.7 indicates the values of principal stresses in this circular pressure vessel.

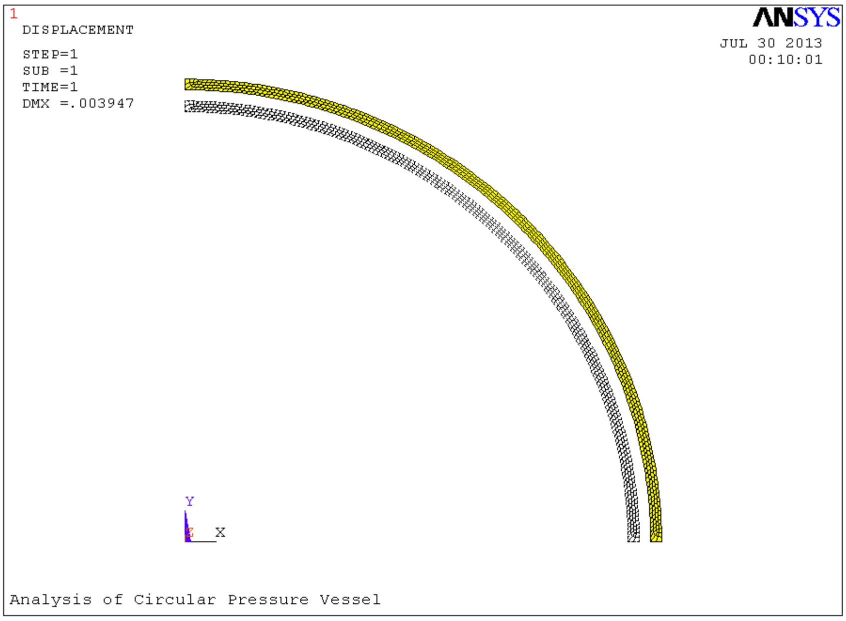

Figure.6 Deformed shape along with undeformed shape (Circular Pressure Vessel)

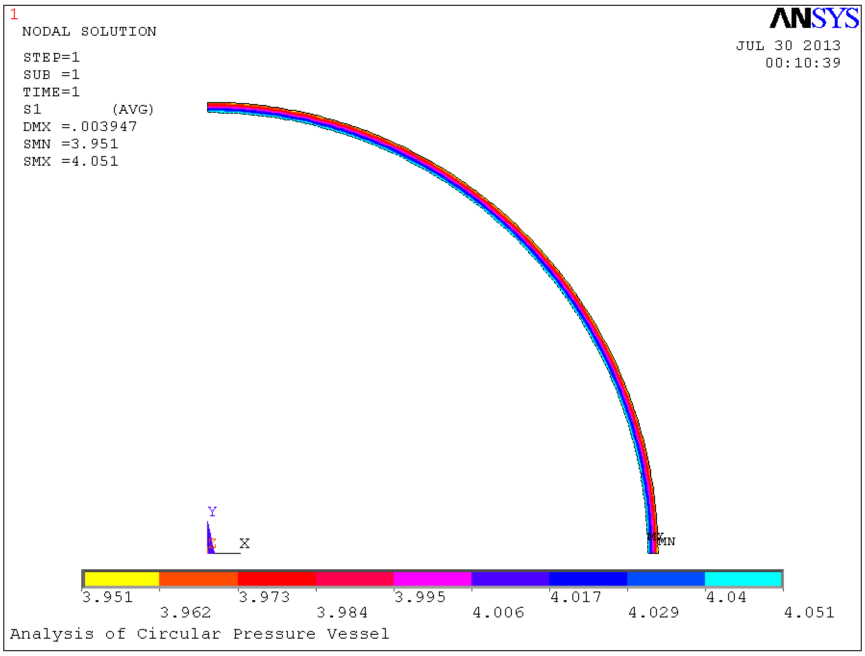

Figure.7 Principal stresses (Circular Pressure Vessel)

Stresses at A, B, C & D points: The output of nodal solution is listed & observation of the stresses at A, B, C & D points is done. The values obtained are as below.

Table.3 Principal Stresses at A, B, C & D for Circular Pressure Vessel

Node Position	Point	Node Number	Stress (ANSYS)	Hoop Stress (Analytical)
			MPa	MPa
Inner - Upper Side	A	326	4.0506	4
Outer - Upper Side	B	2	3.9506	
Inner - Lower Side	C	330	4.0506	
Outer - Lower Side	D	1	3.9506	

Obround Pressure Vessel:

Following figure indicates the deformed & un-deformed shape of the obround pressure vessel with radius of curved portion as 50 mm.

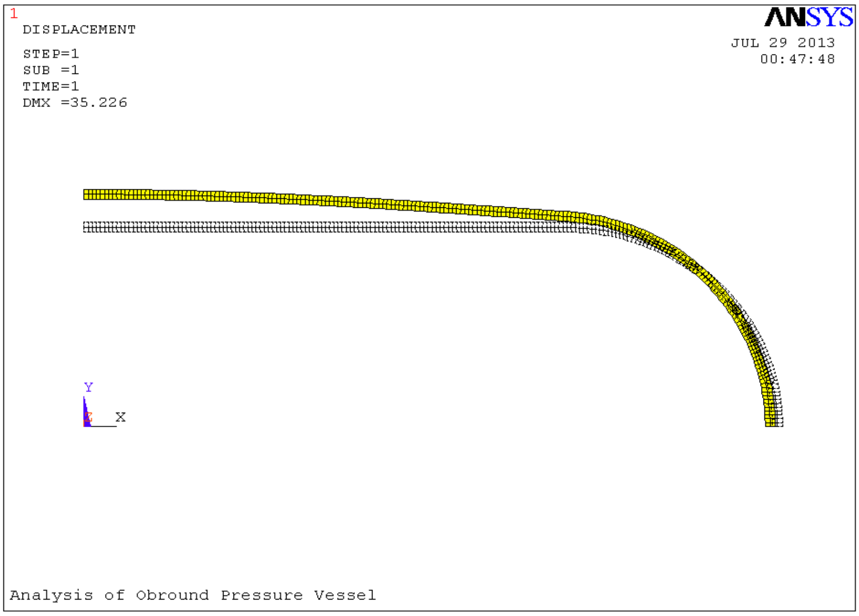

Figure.8 Deformed shape & Un-deformed shape of obround pressure vessel

Fig.9 shows the first principal stresses & fig.11 gives Third Principal Stress. Fig.10 & fig.12 shows the exaggerated views of the areas of high stresses.

The maximum stress values are given in Table.4.

Table.4 Principal Stresses at A, B, C & D for Obround Pressure Vessel

Stress at A (in MPa)	Stress at B (in MPa)	Stress at C (in MPa)	Stress at D (in MPa)
-550	554	708.77	-678.45

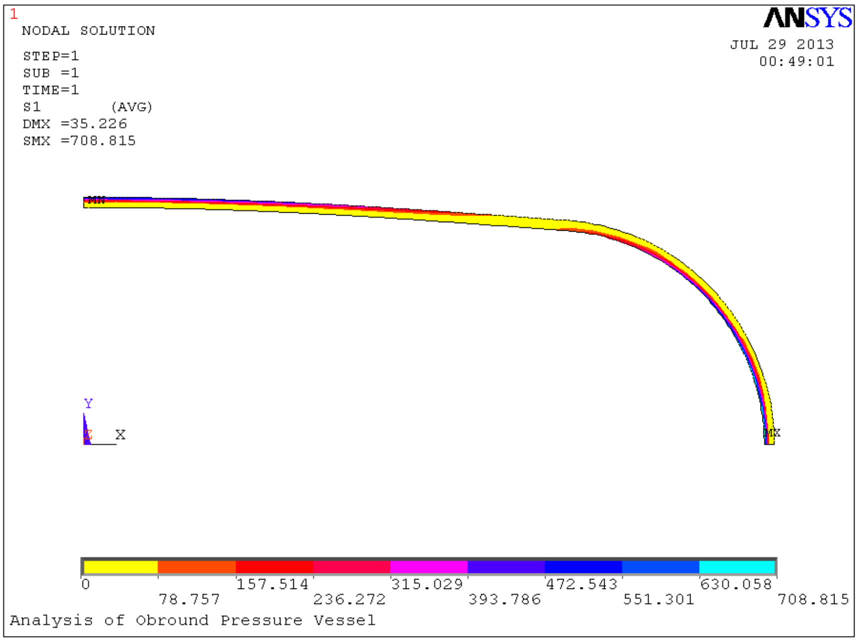

Figure.9 First Principal Stresses (Obround Pressure Vessel)

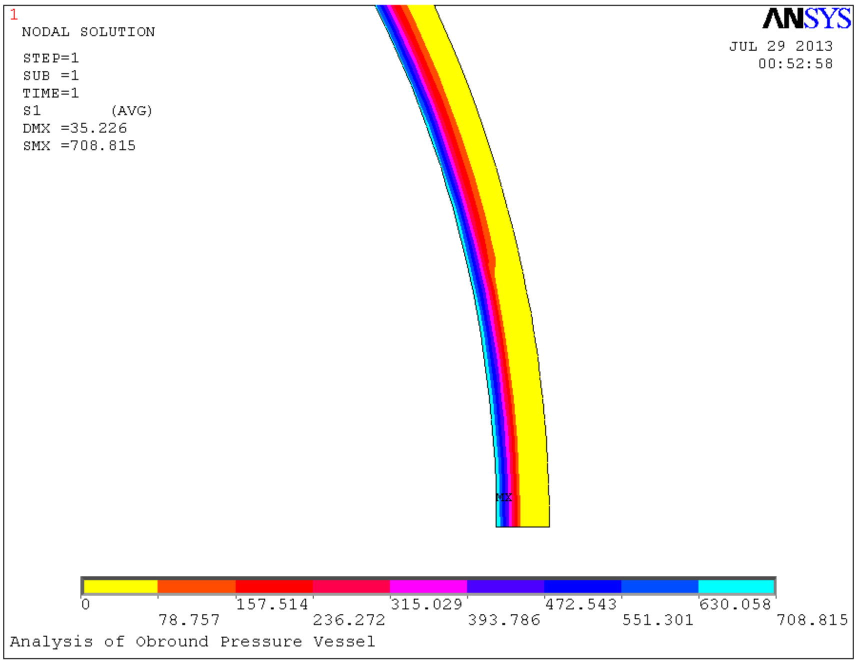

Figure.10 Exaggerated view of area near to point C & D (First Principal Stresses)

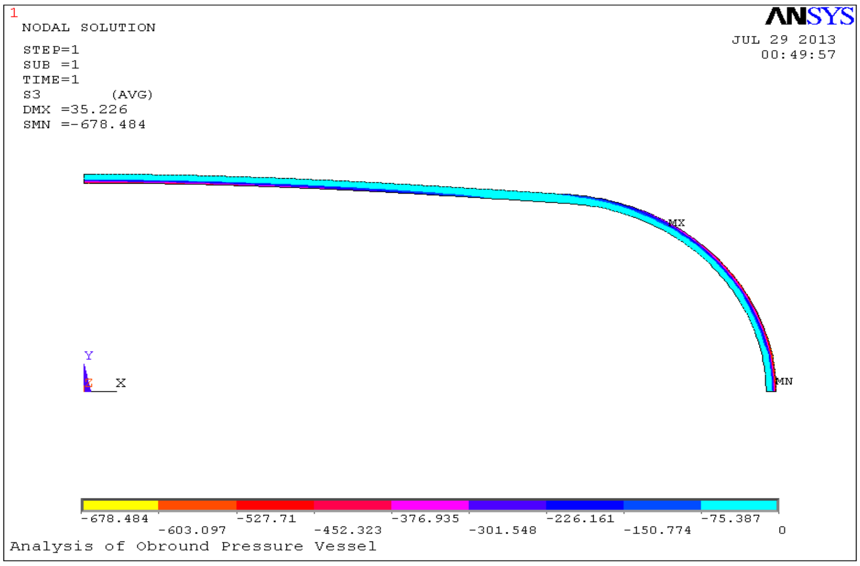

Figure.11 Third Principal Stress (Obround Pressure Vessel)

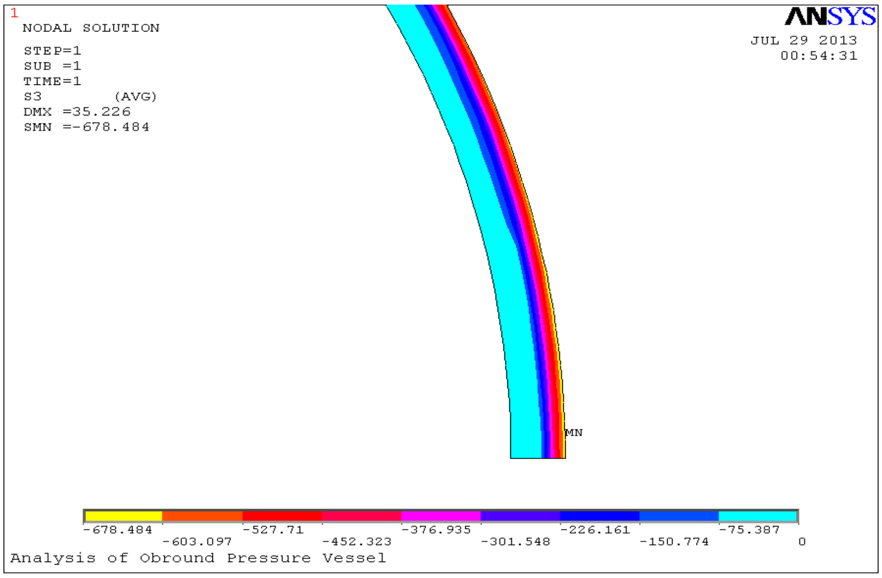

Figure.12 Exaggerated view of area near to point C & D (Third Principal Stress)

From the above study, it is seen that values of hoop stresses are very much higher than that of the circular pressure vessel. Also the maximum deformation is 35.226 mm which also is very much higher than that of circular pressure vessel.

Following table (Table.5) gives the details of the values of stresses at A, B, C & D points for values of radii of curved portion.

Table.5 Results of Hoop Stresses in Obround Pressure Vessel

Sr. No.	R	Stress at A	Stress at B	Stress at C	Stress at D
1	25	-1785.9	1787.9	3207.5	-3033
2	30	-1294.9	1297.3	2197.3	-2090
3	35	-995.07	997.87	1586.1	-1514
4	40	-796.35	799.55	1186.6	-1135
5	45	-655.64	659.24	909.85	-871.04
6	50	-550	554	708.77	-678.45
7	60	-397.46	402.26	439.6	-419.32
8	70	-283.43	289.35	269.28	-254.51
9	80	-185.35	191.8	152.58	-141.09
10	90	-91.346	98.546	67.891	-58.501
11	95	-43.97	51.621	33.812	-25.186

The following graph indicates the variation of stresses with references to the radius of curved portion.

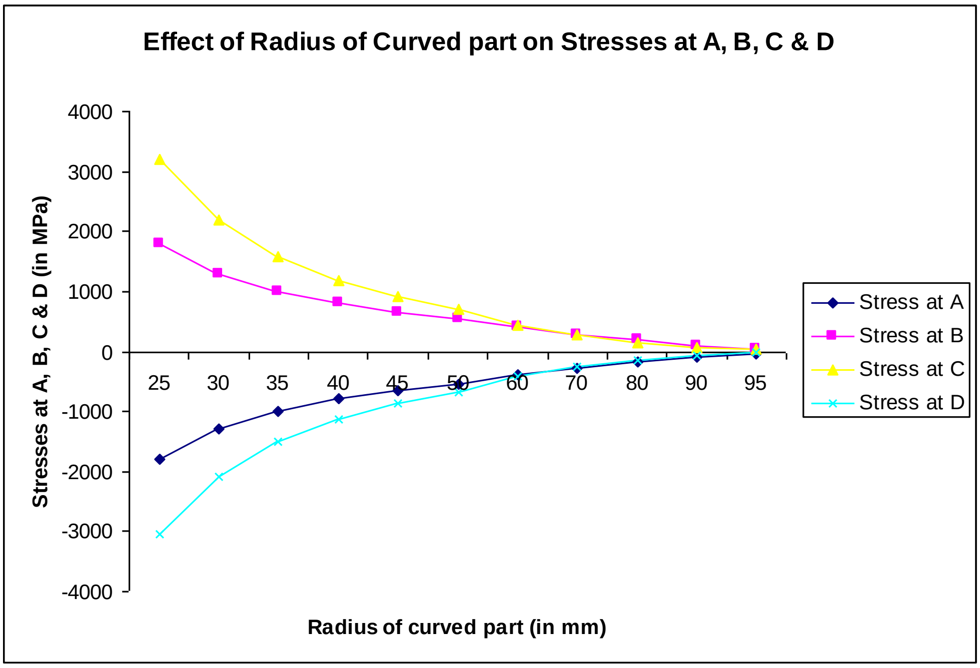

Figure.13 Radius of Curved part Vs Hoop Stresses at A, B, C & D

From all the above figures, it can be said that as radius of curved portion of obround pressure vessel goes on increasing, the hoop stresses go on reducing. The reduction is as per the curves indicated above.

Effect of thickness of Obround Pressure Vessel on the values of the Hoop Stress:

The effect of thickness on the values of the stresses is also observed. Following table indicates the values of the hoop stresses at different thickness of the pressure vessels. The analysis is done for the obround pressure vessel with radius = 50 mm for curved portion.

Table.6 Stresses at different thicknesses of Pressure Vessel

Sr. No.	Thickn ess	Stress at A	Stress at B	Stress at C	Stress at D
	mm	MPa	MPa	MPa	MPa
1	2.5	-550	554	708.77	-678.45
2	3	-382.84	386.17	496.51	-468.69
3	3.5	-281.92	284.78	367.1	-343.28
4	4	-216.34	218.84	283.21	-261.72
5	4.5	-171.33	173.55	225.21	-206.14
6	5	-139.1	141.1	183.58	-166.45
7	5.5	-115.22	117.04	152.82	-137.04
8	6	-97.036	98.706	129.23	-114.79

Following are the graphs showing relation between the thickness of pressure vessel & hoop stresses.

From the graph (fig.14) it is seen that as the thickness of vessel goes on increasing, stresses go on reducing.

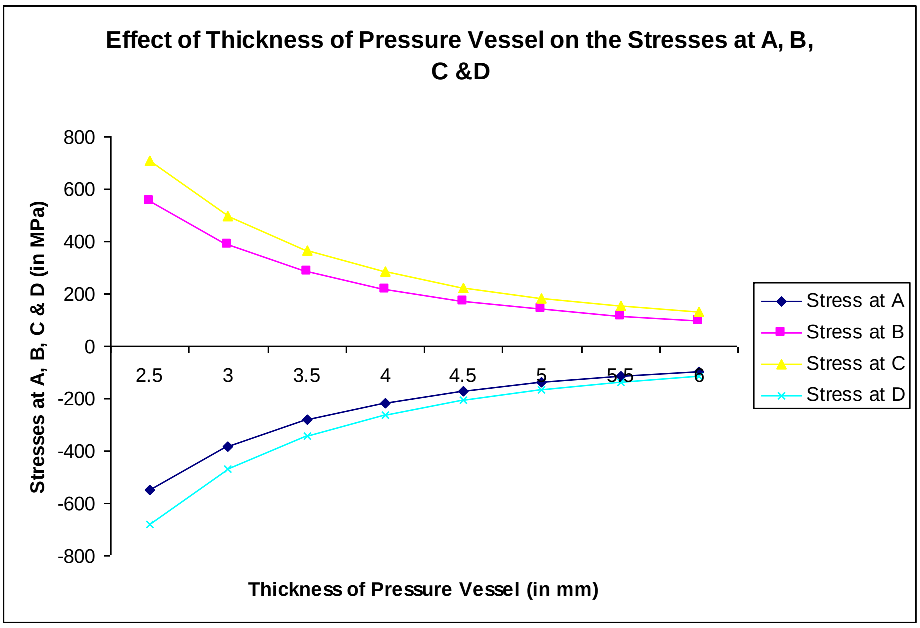

Figure.14 Thickness of Pressure Vessel Vs Stresses at point A, B, C & D

Effect of pressure on the on the values of Hoop Stress Obround Pressure Vessel:
For R= 50 mm & Thickness = 2.5 mm, Pressure variation is done & its effect on the values of the stresses are studied.

Table.7 Stresses at Different Values of Pressure inside the Pressure Vessel

Sr. No.	Pressure	Stress at A	Stress at B	Stress at C	Stress at D
	MPa	MPa	MPa	MPa	MPa
1	0.05	-275	277	354.39	-339.22
2	0.075	-412.5	415.5	531.58	-508.84
3	0.1	-550	554	708.77	-678.45
4	0.125	-687.5	692.5	885.97	-848.06
5	0.150	-825	831	1063.2	-1017.7
6	0.175	-962.5	969.5	1240.4	-1187.3
7	0.2	-1100	1108	1417.5	-1356.9

Following fig.15 indicates the relation between the pressure applied & the hoop stresses at points A, B, C & D.

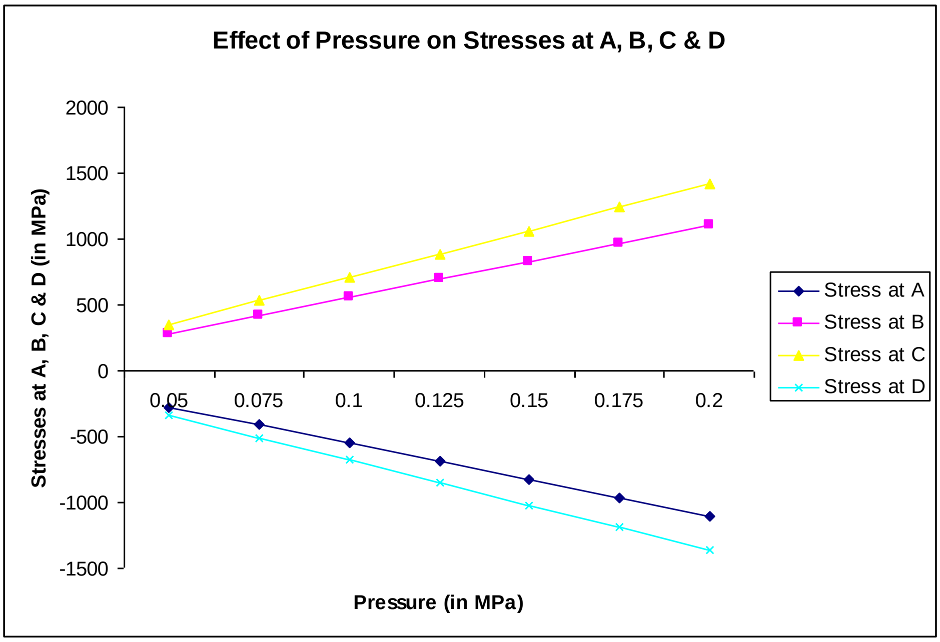

Figure.15 Pressure applied Vs Stress at point A, B, C & D

From the above figures, it is seen that the hoop stress is directly proportional to the pressure applied inside the vessel.

VI. CONCLUSIONS

- The hoop stresses in the obround pressure vessel are very much higher as compared to the stresses in circular pressure vessels.
- Deformation in the obround pressure vessel is also very much higher as compared to the deformation in circular pressure vessels.
- As radius of curved portion of obround pressure vessel goes on increasing, the hoop stresses go on reducing.
- As the thickness of vessel goes on increasing, stresses go on reducing.
- Hoop stress is directly proportional to the pressure applied inside the vessel.

ACKNOWLEDGEMENT

We are thankful to Principal, Management & Head –Mechanical Engg. Walchand Institute of Technology, Solapur, for their support during this work.

REFERENCES

[1] David Heckman, "Finite Element Analysis of Pressure Vessels", *University of California, Davis, Summer 1998*
[2] Jimit Vyas And Mahavir Solanki, "Design And Analysis of Pressure Vessel", Thesis, *U. V. Patel College of Engineering.*
[3] Jonathan C Wang, "Stress Analysis of an Elliptical Pressure Vessel Under Internal Pressure", *M.S. Seminar, Hartford CT, 2005*
[4] David Roylance, "Pressure Vessels", *Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, 2001*
[5] D. Dewayne Howell, "Open End Cylindrical Pressure Vessel Development", *Society for The Advancement of Material And Process Engineering, Colorado. 2004*
[6] Reddy J.N. , *An Introduction to Finite Element Method*, (Tata McGraw-Hill Publication, Fifth Edition)
[7] Tirupati Chandrupatla, Ashok Belegundu, *Introduction to Finite Elements in Engineering*, (Prentice Hall India, 2007)
[8] V.B. Bhandari, *Design of Machine Elements*, (Tata McGraw Hill Publishing Co. Ltd, New Delhi, 2005)
[9] Joseph Edward Shigley, *Mechanical Engineering Design*, (McGraw Hill, 2009)