IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

DESIGN, ANALYSIS AND MANUFACTURING OF PRESSURE VESSELS

Y.VASUDHAR[1] , L B BHARATH RAJU[2]

PG SCHOLAR[1], ASSISTANT PROFESSOR[2]

DEPARTMENT OF MECHANICAL ENGINEERING, HYDERABAD INSTITUTE OF TECHNOLOGY

ABSTRACT

The present study explains the effect of holes on pressure vessels which helps to attach pressure vessels together. At first the effect of outer hole on the pressure vessel was known and later the effect of inner hole on the pressure vessel is to be determined. The holes with diameters are analyzed to know the effect of holes on the pressure vessels. The holes of diameter from 50mm to 100mm are analyzed in this project. The pressure vessels considered in this project are made up of composite materials. To determine the effect of hole on pressure vessel, analysis is done on the pressure vessel. The analysis is done using ANSYS software. Later, pressure vessel is also undergoes manufacturing process.

Pressure vessels are manufactured all over the world under various international standards. These standards will specify the requirements to be met during the manufacture of pressure vessels; however, the means used to meet these requirements are not specified in any of the standards. Pressure vessels manufacture is very complicated process. Here by there are many steps to be followed in order to ensure safe working pressure vessels. This can be achieved by following standards in each and every stage of manufacture process. Here in this paper all the processes involved in the manufacture of pressure vessels is detailed and followed to produce a prototype pressure vessel.

METHODOLOGY

- Pressure vessel was modelled by using NX-CAD software.
- The ANSYS software is used for analysis of pressure vessel by importing parasolid file of pressure vessel.
- Static analysis is performed on Toroidal pressure vessel for Eglass/Epoxy material.
- Analysis is done on Toroidal pressure vessel with hole on outer shell and inner shell for different hole diameters.
- Results and graphs are plotted for Eglass/Epoxy material.
- Static analysis is performed on Toroidal pressure vessel for Carbon/Epoxy material.
- Analysis is done on Toroidal pressure vessel with hole on outer shell and inner shell for different hole diameters.
- Results and graphs are plotted for Carbon/Epoxy material.
- Design data for pressure vessels formulated.
- Raw material procured and required machining operations performed.
- Once machining done, all the parts of pressure vessels are assembled.
- Inspections and testing operations performed on the assemblies.
- Finally surface finishing process carried out.

3D MODELLING OF PRESSURE VESSEL

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

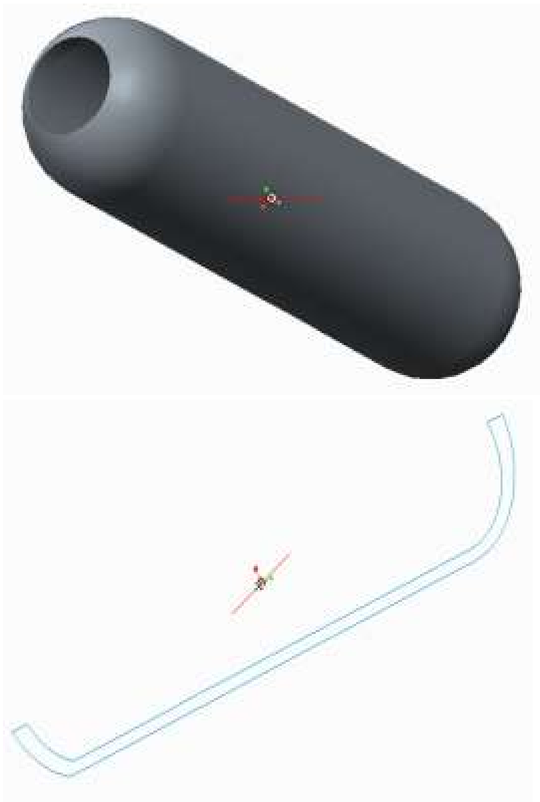


Fig shows Isometric view of pressure vessel

STATIC ANALYSIS OF TOROIDAL PRESSURE VESSEL WITH EGLASS/EPOXY MATERIAL

Case-1: HOLE ON OUTER SIDE OF SHELL

Results:

CASE-1: Toroidal pressure vessel with 50mm hole diameter:

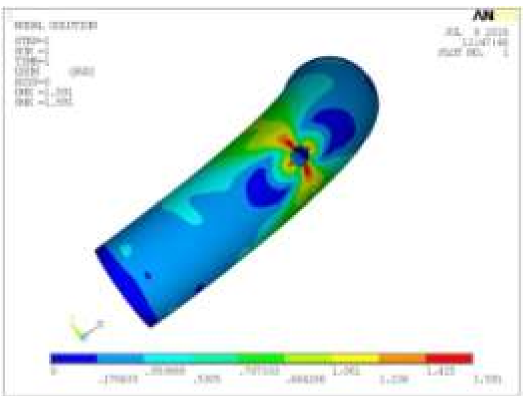


Fig shows displacement of Toroidal pressure vessel

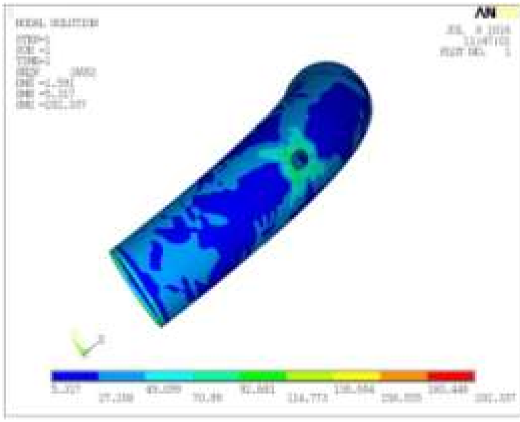


Fig shows von misses stress of Toroidal pressure vessel

From results, the von misses stress of Toroidal pressure vessel is 202.3 MPa**.** The yield strength of Eglass/Epoxy material is 800 MPa. The von misses stress of Toroidal pressure vessel is less than the yield strength of material. Hence, the Toroidal pressure vessel is safe for pressure load.

Similarly the analysis carried for Toroidal pressure vessel with 60mm, 70 mm, 80mm, 90mm and 100 mm hole diameter and observations tabulated.

CASE-2: HOLE ON INNER SIDE OF SHELL

Toroidal pressure vessel with 50mm hole diameter:

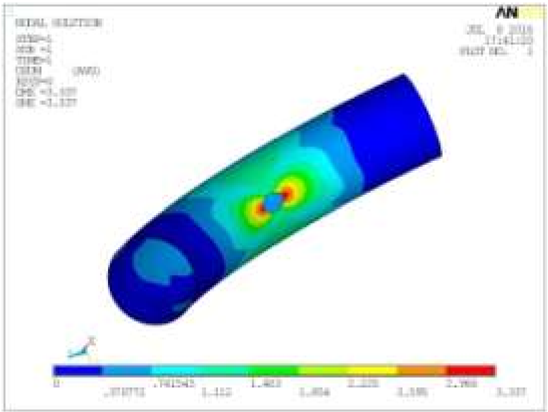


Fig shows displacement of Toroidal pressure vessel

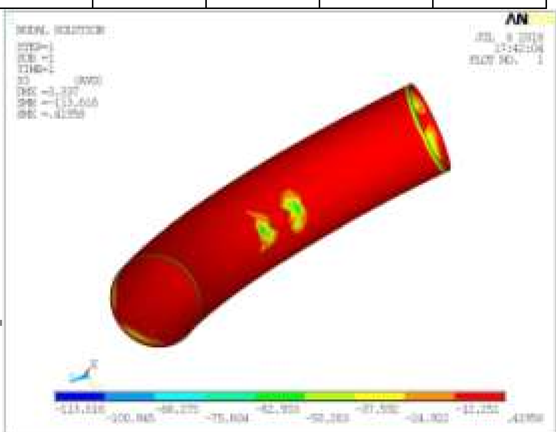
Fig8.8 shows 1st principal stress of

Fig8.9 shows 2nd principal stress of

Toroidal pressure vessel

Toroidal pressure vessel

Hole diameter (mm)	Hole on outer shell		Hole on inner shell	
	Displacement (mm)	Von misses stress (MPa)	Displacement (mm)	Von misses stress (MPa)
50	1.59	202.3	3.33	169.9
60	3.04	270.1	4.24	189.5
70	5.26	287.2	5.37	327.6
80	7.93	335.1	6.24	230.2
90	11	563.6	7.31	245.8
100	14.8	530.8	8.16	316.8



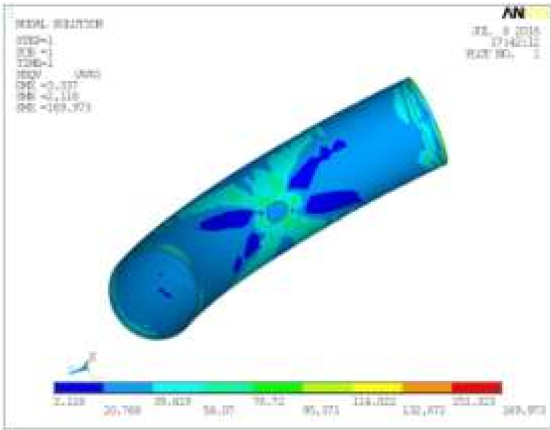


Fig shows von misses stress of Toroidal pressure vessel

From results, the von misses stress of Toroidal pressure vessel is 169.97 MPa**.** The yield strength of Eglass/Epoxy material is 800 MPa. The von misses stress of Toroidal pressure vessel is less than the yield strength of material. Hence, the Toroidal pressure vessel is safe for pressure load.

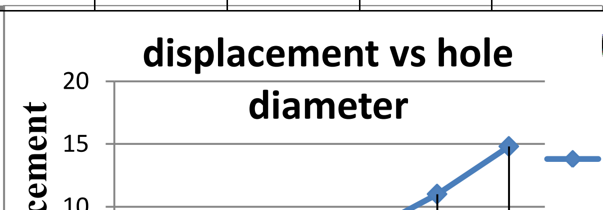
Similarly the analysis carried for Toroidal pressure vessel with 60mm, 70 mm, 80mm, 90mm and 100 mm hole diameter and observations tabulated.

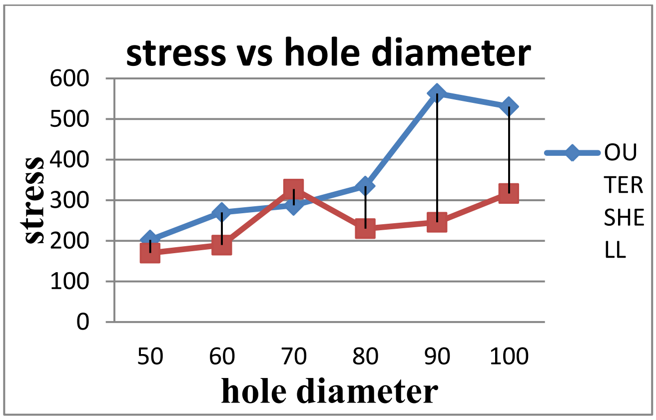
Comparison of toroidal pressure vessel for different hole diameters and different type of hole

Comparisons of displacement for outer shell and inner shell of toroidal pressure vessel:

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017 ISSN: 2320-1363

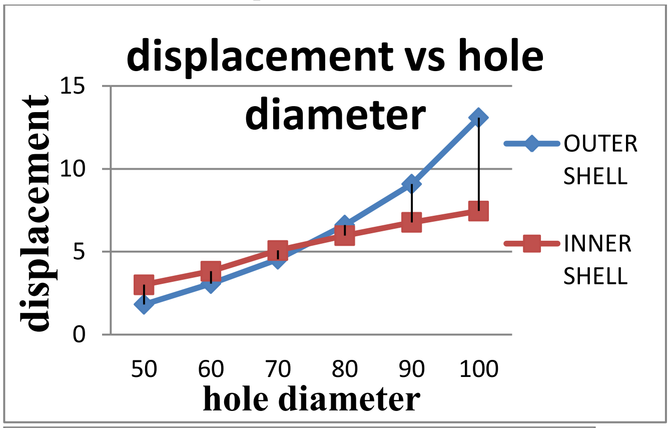
Hole diameter (mm)	Hole on outer shell		Hole on inner shell	
	Displacement (mm)	Von misses stress (MPa)	Displacement (mm)	Von misses stress (MPa)
50	1.82	272.3	3.00	298.6
60	3.07	331.6	3.82	334.1
70	4.54	515.7	5.07	409.4
80	6.61	534.7	5.97	460.5
90	9.08	738.3	6.77	515.6
100	13.09	939.06	7.45	519.26

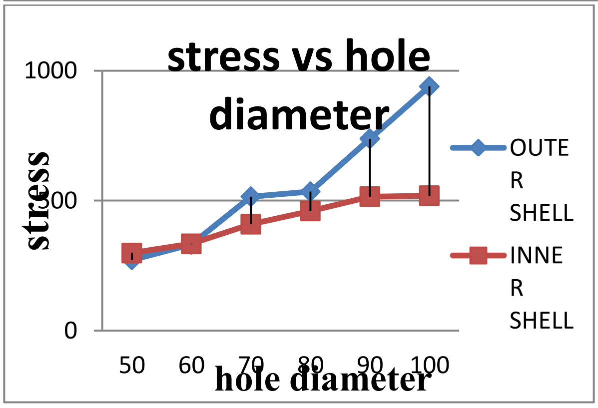




FINITE ELEMENT ANALYSIS OF TOROIDAL PRESSURE VESSEL FOR CARBON/EPOXY MATERIAL

Comparisons of displacement for outer shell and inner shell of toroidal pressure vessel:





Comparison of toroidal pressure vessel for different hole diameters and different type of hole

CASE STUDY ON PRESSURE VESSEL

This case study we are going to study the working and manufacture principles an

Accumulator, a pressure vessel used in hydraulic equipments.

BASIC STEPS IN MANUFACTURING PROCESSES:

There are basic steps in manufacturing processes, these includes the following;

- Creating the design for the products,
- Sourcing raw materials,
- Processing the raw materials,
- Production
- Quality control and Marketing.

MANUFACTURING OF PRESSURE VESSELS

Steps involved in production of pressure vessels are as follows.

- Design of pressure vessels.
- Selection and procurement of raw materials.
- Inspections and testing of raw materials.
- Machining of raw materials.
- Inspections on machined parts.
- Assembly of machined parts.
- Inspections on assemblies.
- Testing of assemblies.
- Surface finishing.
- Final or Third Party Inspections.

DESIGN OF PRESSURE VESSELS:

Spherical vessel:

$$M = \frac{3}{2} PV \frac{\rho}{\sigma},$$

Where,

- m is mass, (kg)
- p is the pressure difference from ambient (the gauge pressure), (pa)
- v is volume,
- ρ is the density of the pressure vessel material, (kg/m^3)
- σ is the maximum working stress that material can tolerate.

Cylindrical vessel with hemispherical ends:

This is sometimes called a "bullet" for its shape, although in geometric terms it is a capsule. For a cylinder with hemispherical ends is

$$M = 2\pi R^2 (R + W) P \frac{\rho}{\sigma},$$

Where,

- r is the radius (m)
- w is the middle cylinder width only, and the overall width is w + 2r (m)

Cylindrical vessel with semi-elliptical ends:

In a vessel with an aspect ratio of middle cylinder width to radius of 2:1,

$$M = 6\pi R^3 P \frac{\rho}{\sigma}.$$

Gas storage:

$$M = \frac{3}{2} nRT \frac{\rho}{\sigma}.$$

Stress in thin-walled pressure vessels:

Stress in a shallow-walled pressure vessel in the shape of a sphere is

$$\sigma_\theta = \sigma_{\rm long} = \frac{pr}{2t},$$

Stress in a shallow-walled pressure vessel in the shape of a cylinder is

$$\sigma_\theta = \frac{pr}{t}$$

$$\sigma_{\rm long} = \frac{pr}{0.2t}$$

Where σ_θ is hoop stress, or stress in the circumferential direction, $\sigma_{\rm long}$ is stress in the longitudinal direction, *p* is internal gauge pressure, *r* is the inner radius of the sphere, and *t* is thickness of the sphere wall. a vessel can be considered "shallow-walled" if the diameter is at least 10 times (sometimes cited as 20 times) greater than the wall depth.

where,

- σ_θ is hoop stress, or stress in the circumferential direction
- $\sigma_{\rm long}$ is stress in the longitudinal direction
- p is internal gauge pressure
- r is the inner radius of the cylinder

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

- t is thickness of the cylinder wall.

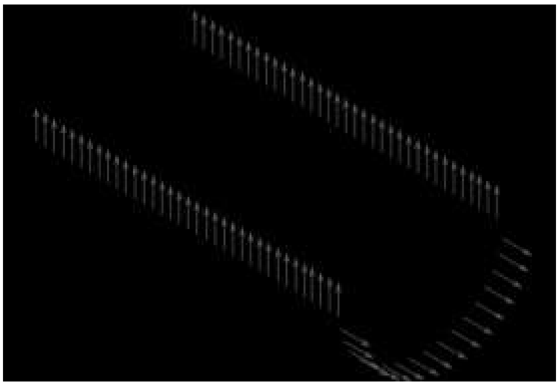


fig shows the forces acting on the walls of the pressure vessel

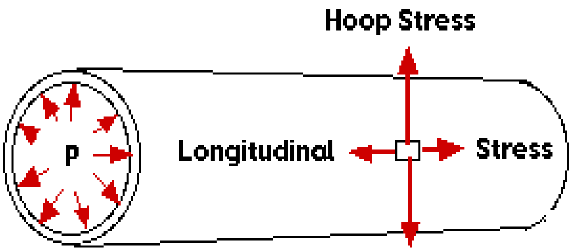


Fig shows the direction of the forces acting on the pressure vessel

Design for inner dimensions of the pressure vessels:

Design of pressure vessel cylindrical shell:

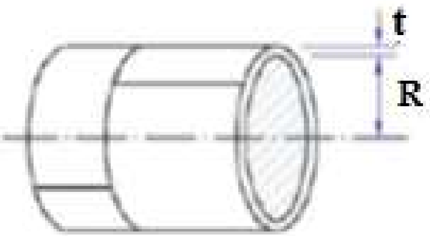


Fig shows the pressure vessel cylinder shell

$$t = \frac{PR}{SE - 0.6P}$$

$$P = \frac{SEt}{R + 0.6t}$$

Design of pressure vessel hemispherical dome:

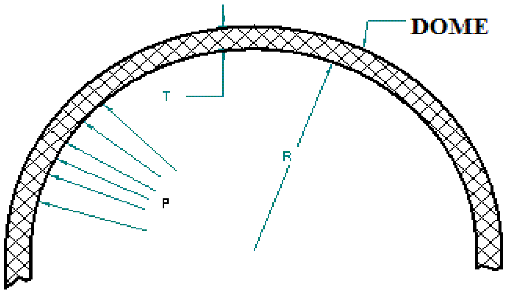


fig shows the pressure vessel hemispherical dome

$$t = \frac{PR}{2SE - 0.2P}$$

$$P = \frac{2SEt}{R + 0.2t}$$

Design for outer dimensions of the pressure vessels:

Design of pressure vessel cylindrical shell:

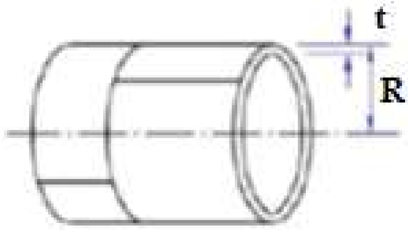


fig shows the pressure vessel cylinder shell

$$t = \frac{PR}{SE + 0.4P}$$

$$P = \frac{SEt}{R - 0.4t}$$

Design of pressure vessel hemispherical dome:

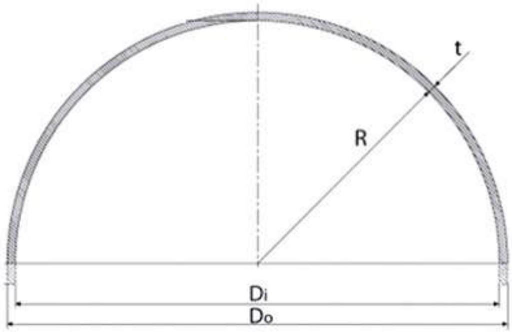


Fig shows the pressure vessel hemispherical dome

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017 ISSN: 2320-1363

$$t = \frac{PR}{2SE + 0.8P}$$

$$P = \frac{2SEt}{R - 0.8t}$$

Where,
p= design pressure or maximum allowable working pressure
s= stress value of material
e= joint efficiency
r= inside\ outside radius
d= inside\ outside diameter
r= inside knuckle radius
t= wall thickness

DESIGN CALCULATIONS FOR ACCUMULATOR SHELL

(Reference: Hand Book Dennis Moss Third Edition)

<u>SHELL 0.75 LTRS</u>

Design Pressure (P) 360 BAR 5220 PSI
Max. Design Temperature (T) 85 C(Deg) 185 (F^0)
Test Pressure (Hydro) 5 X (Design Pressure)
Corrosion Allowance 1

Description	Value	Units

Material of Shell 34 CRMO4
Outside dia. of Shell D 90 mm 3.54 in
Inside dia. of shell D_i 77.6 mm 3.05 in
Inside radius of curvature R 38.8 mm 1.52 in
Design Pressure P 360 BAR 5220 psi
Maximum allowable stress
(YIELD=755 MPA) =2/3xYIELD S
503.3 MPA 72997.5 psi
Joint Factor E 1

As per UG-27

Calculated required thickness of shell t_c
= PxR / (SxE-0.6P) = 2.89 mm

Corrosion Allowance c 1mm

Min. Required thickness of shell t_r = t_c + c = 3.89 mm

Provided Thickness of shell (min.) T_p = 6.2 mm

<u>DISH</u>

Description	Value	Units

Type of Dished end Hemispherical
Inside radius of curvature R 38.8 mm 1.52 inch
Maximum allowable stress
(YIELD=755 MPA) =2/3xYIELD S
=503.3 MPA = 72997.5 psi
Joint Factor E 0.85

As per UG-32 (f) Hemispherical Heads

Calculated required thickness of Dished end t_c =
= PxR / (2SxE-0.2P) = 1.6 mm

Provided Thickness of Dished end (min.)
T_p = 6.2 mm

CONCLUSION

Toroidal pressure vessel was developed in NX-CAD SOFTWARE. Static analysis was performed on toroidal pressure vessel for two different locations of hole on shell. Toroidal pressure vessel was also studied for two composite materials (i.e. Eglass/Epoxy and Carbon/Epoxy materials). Based on results, Eglass/Epoxy material for different locations has less displacement values than Carbon/Epoxy material. The von misses stresses of Eglass/Epoxy material at different locations for different hole diameters were less comparative to Carbon/Epoxy material. Hence, Eglass/Epoxy material was best suitable for Toroidal pressure vessel.

Also the manufacturing techniques of the pressure vessels had been studied and the prototype pressure vessel had been produced. All the steps and standards in the manufacture of pressure vessels is studied and implemented in manufacturing the pressure vessel.

This project has provided an excellent opportunity and experience, to use my limited knowledge. I gained a lot of practical knowledge regarding, planning, purchasing, assembling and machining while doing this project work. I feel that the project work is a good solution to bridge the gates between institution and industries. now I am able to understand the difficulties in maintain the tolerances and also quality and have done to our ability and skill making maximum use of available facilities.

REFERENCES

1. Finite Element Analysis of Toroidal Pressure Vessel Using FEASTSMT/PreWin by Rakendu R, MK Sundaresan and Pinky Merin Philip

IJMTARC – VOLUME – V – ISSUE - 18 – JUNE , 2017

ISSN: 2320-1363

2. Stability analysis of a toroidal pipe-reducer under uniform external pressure by Prashanta Dutta, Md. Raisuddin Khan, Md. Abdus Salam Akanda and Md. Wahhaj Uddin
3. Simplified theoretical solution of circular toroidal shell with ribs under uniform external pressure by Qinghai Du , Guang Zou , Bowen Zhang, Zhengquan Wan.
4. Design and Analysis of Filament Wound Composite Pressure Vessel with Integrated-end Domes by M. Madhavi, K.V.J.Rao and K.Narayana Rao.
5. Application of isotensoid-based cross sections to filament-wound toroidal pressure vessels by L. Zu, S. Koussios and A. Beukers.
6. Pattern design for non-geodesic winding toroidal pressure vessels by Lei Zu, Qin-Xiang He, Qing-Qing Ni.
7. Pressure vessel design manual by Dennis Moss, illustrated procedures for solving major pressure vessel design problems.
8. Practical guide to pressure vessel manufacturing by Sunil Pullarcot.