International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 10, October 2016)

Fabrication and FE Analysis of Hemispherical Closed Ends Composite Cylinder

Mohd Rafeeq Ur Rahman[1], B.T. Naik[2], P. Seema Rani[3]

[1]Research Scholar, Mechanical Engg. Dept., Abhinav Hitech College of Engineering, Hyderabad, India
[2]Associate Professor & Head, Mechanical Engg. Dept., Abhinav Hitech College of Engineering, Hyderabad, India
[3]Assistant Professor, Mechanical Engg. Dept., JBIET, Hyderabad, India

***Abstract* - The focus on light weight material, high strength and stiffed fiber reinforcement for automobile application is associated with composite materials. A composite material are made from two or additional constituent material with considerably different chemical, physical and mechanical properties that when merge produce a material with characteristics dissimilar from the individual. The present work is aimed to determine the optimum helix angle of the hemispherical closed ends composite cylinder made of glass fiber with respect to deformation and strain, when fabricated using filament winding methods. And also calculate the bursting pressure of the cylinder. The whole work is carried out by using FEA tool Ansys 15.0.**

***Keywords*- Filament winding, finite element analysis, Composite materials, Bursting pressure, Pressure Vessel (PV).**

I. INTRODUCTION

A pressure vessel is a closed container intended to seize gases or liquids at a pressure dissimilar from the room pressure. The cap fixed to the cylinder body is called heads. PV is used in many industrial applications like Automobile sectors to carry liquefied gases such as LPG, CNG etc, in Cars, Buses, Rails and Aircrafts.

In the industrial sector, PV are premeditated to operate securely at a precise pressure and temperature precisely.

A PV that is improperly designed to knob a high pressure comprises a very important safety hazard. With these purpose, the design and certification of pressure vessels is directed by design codes such as the ASME Boiler and Pressure Vessel Code in North America, the Pressure Equipment Directive of the EU (PED), Japanese Industrial Standard (JIS), CSA B51 in Canada, AS1210 in Australia and other international standards like Lloyd's, Germanischer Lloyd, Det Norske Veritas, Stoomwezen etc [1]

Composite material are well known to be arrangement of materials differing in composition or form on a large-scale. The element preserve their identities in the composite i.e. they do not dissolve each other. The first glass fiber reinforced polymer was developed in 1940.

The origin of distinct discipline of composite materials started in 1960‟s.Extensive research has been done on composite material since 1965[2].

Dissimilarity between laminated composites and conventional engineering materials is that a composites retort to loads is direction dependent. Metals and metal alloys cannot meet the demands of today's superior technologies. The composite materials show high specific stiffness and strength modulus resulting in considerable weight reduction of the component by improving the efficiency. The main advantage of composite materials is the flexibility involved in getting the desired strength and stiffness in the direction required. Carbon fibers are very common in high-modulus and high-strength applications [2].

II. LITERATURE REVIEW

Authors in this research paper analyzed the pressure vessels by considering stresses induced in the materials of different standards. Accordingly they evaluate for better material for a marine substation by different consideration. Further they have compared the result obtained from analytical calculation and by using MATLAB programming. [3]

Authors in this literature performed design and analysis of 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 accordingly as specified in American Society of Mechanical Engineers (A.S.M.E) Sec VIII Division 1 [4].

The key feature discussed by authors in this paper is to check the performance of pressure vessel in case of fluctuating loads. The technical step includes various aspects such as selecting the material based on American Society of Mechanical Engineers (ASME) codes, and then designing on the standards procedures with referring standard manuals based on ASME. Further, they include the different methods of manufacturing practice by the industrial aspects. [5]

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 10, October 2016)

In this paper author discussed about how to calculate induced stresses using ANSYS coupled field analysis for thermo-mechanical loading. The results obtained from ansys are then compared with analytical results. Analytical solutions such as ASME and Japanese Code give empirical relationships to calculate thermal stress [6].

Technical paper presented by authors discussed about design, and analysis of pressure vessel. In the design of pressure vessel safety is the primary consideration, due to the impact of probable accident. Allowable working pressures are calculated by using Pressure Vessel Design Manual by Dennis Moss, third edition. The corruption of the vessel are probability occur at maximum pressure which is the element that only can sustain that pressure. Efforts are made in this paper to design the pressure vessel using ASME codes & standards to legalize the design. [7].

III. OBJECTIVE

The main objective of the work is to determine the optimum stacking sequence of hemispherical closed end cylinder made of glass / epoxy using fibers angles of 0^o, $\pm 15^o$, $\pm 30^o$, $\pm 45^o$, $\pm 60^o$, $\pm 75^o$, 90^o. and determine the bursting pressure of the cylinder.

IV. MATERIAL SELECTION

The selection of materials for ASME pressure vessels must be code approved. A metallurgical engineer generally specified the most cost-effective materials at the lowest cost and lowest maintenance cost that will be suitable under operating conditions [8].

Presently there are many factors experience in considering the selection of suitable materials. They embrace the following:

- Cost
- Corrosion Resistance
- Strength Requirements
- Cost of future maintanance
- Ease of Fabrication

V. FE ANALYSIS OF CYLINDER

Finite element Analysis is a authoritative numerical technique for analysis of many complex problems. FEA is used to determine the strength and analysis in that area of solid mechanics.

The basic concept of finite element method is that a structure is divided in considerable smaller elements called finite elements. The properties of the element are originated and shared to obtain the solution for the entire structure.

FE Analysis of helical wound Cylinder:

The design of the pressure vessel consists of hemispherical dishes with cylindrical shell. In the current work the projected cylinder of composite is considered with the same internal pressure as that of structural steel cylinder, the material used for the designing of the cylinder is glass fiber and epoxy resin the simulation results are shown in fig. 1 to fig.14.

Dimension of Cylinder

Diameter: 350mm (Hemispherical Domes two ends = 175 + 175)

Length of cylinder: 700mm, Total number of layers: 6

Total thickness: 12mm

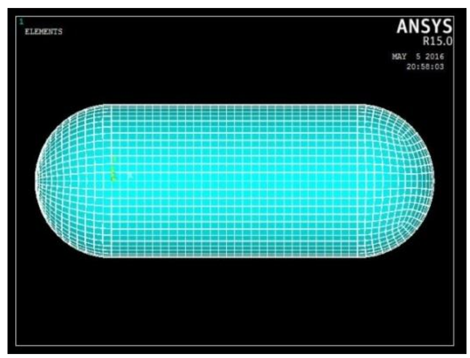

Fig.1: Geometry and Meshed Modal of cylinder

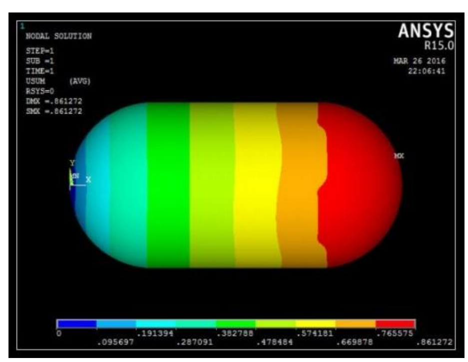

Fig.2: Deformation at 0^o fiber angle of Glass / Epoxy PV at Pressure $1.3 N/mm^2$

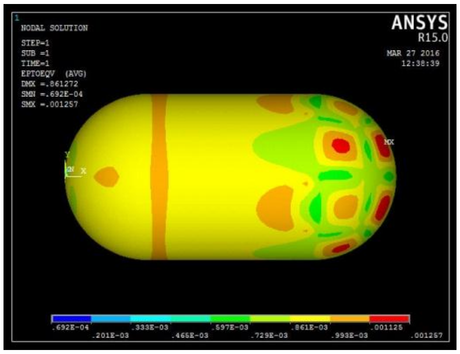

Fig.3: Von Mises Strain at 0° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

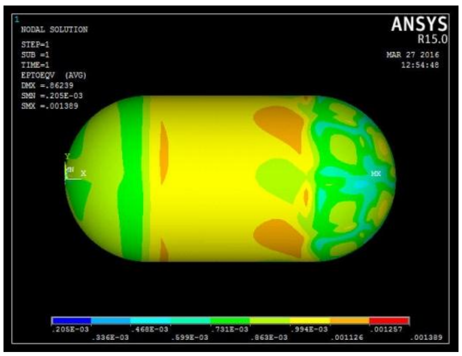

Fig.4: Von Mises Strain at 15° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

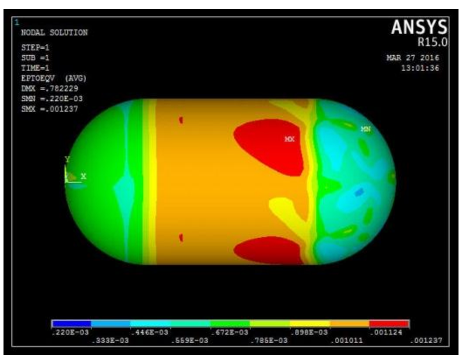

Fig.5: Von Mises Strain at 30° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

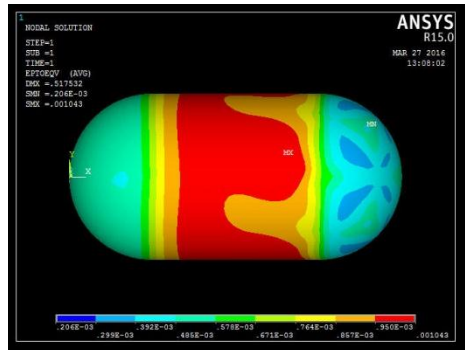

Fig.6: Von Mises Strain at 45° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

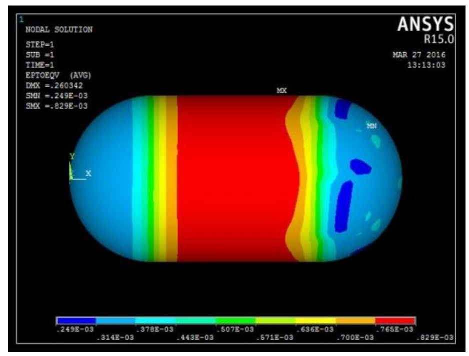

Fig.7: Von Mises Strain at 60° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

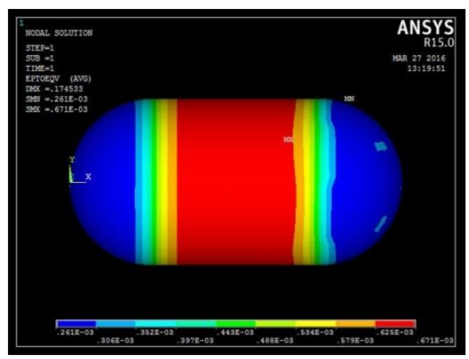

Fig.8: Von Mises Strain at 75° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

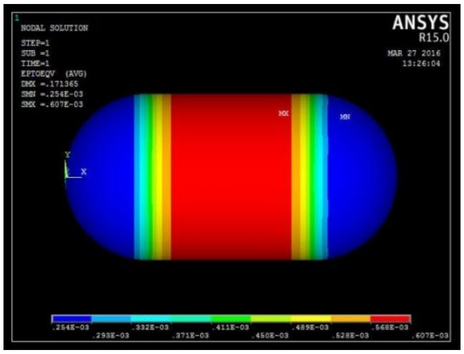

Fig.9: Von Mises Strain at 90° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

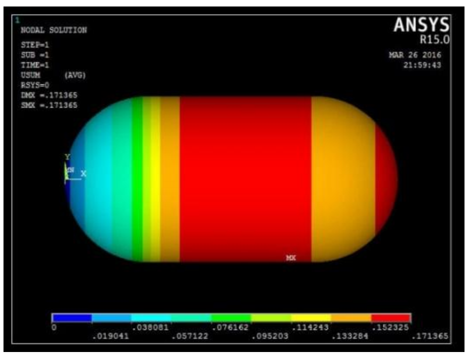

Fig.10: Deformation at 90° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

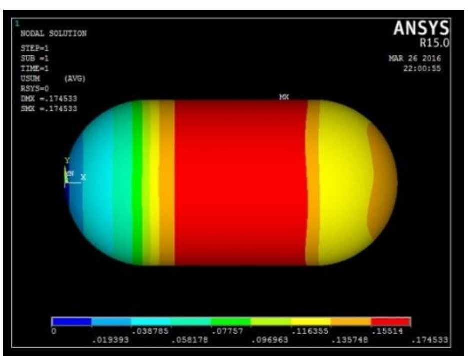

Fig.11: Deformation at 75° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

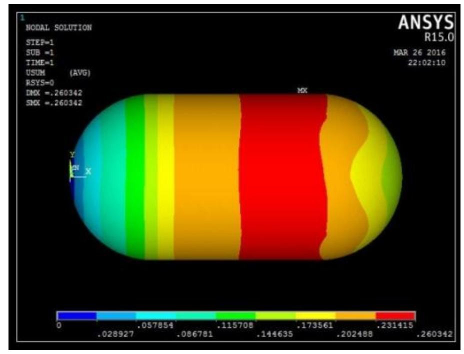

Fig.12: Deformation at 60° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

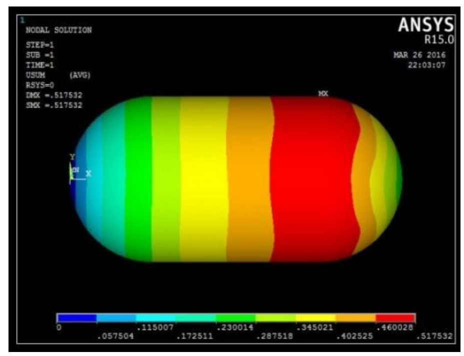

Fig.13: Deformation at 45° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

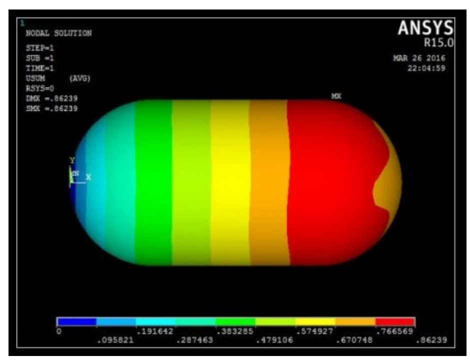

Fig.14: Deformation at 15° fiber angle of Glass / Epoxy PV at Pressure 1.3N/mm^2

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 10, October 2016)

VI. FABRICATION OF CYLINDER AND ITS PROCEDURE

Cylindrical pattern

Polypropylene pipe of required diameter is taken and waxpol is applied on outer surface for easy removal of pattern. Surface mat is rolled on the pipe and resin is applied. Chopped mat is taken and rolled on the pipe then prepared resin solution is applied with the help of brush. After curing the mould is removed from the pipe. Thus the pattern is obtained.

Dome pattern

Circular dome as shown in fig.15 of required diameter is taken and waxpol is applied on it and Surface mat is wrapped around and resin is applied. Then chopped mat is placed and resin is applied and left for curing. One of the dome consists of valve which is placed while wrapping the mat on it.

Fig.15: Preparation of Dome and Cylindrical Patterns

Attaching of domes to cylindrical portion

Dome is kept on the cylinder end as shown in fig. 16, at the interface chopped matrix is placed and resin, promoter (which promotes the quick curing) are applied and left for curing.

Fig.16: Dome being attached to the cylindrical portion

Pattern is ready, now two layers of woven matrix are wrapped at an angle of 45^0, one after the other resin is applied. After curing, grinding is done to obtain good surface finish as shown in fig.17.

Fig.17: Mat being laid with fiber orientation angle 45^0

VII. PRESSURE TEST

The pressure in the vessel shall be gradually increased to not more than one-half of the test pressure. Thereafter, the test pressure shall be increased in steps of approximately one-tenth of the test pressure until the required test pressure has been reached. Then the pressure shall be reduced to a value equal to the test pressure divided by 1.1 and held for a sufficient time to permit inspection of the vessel. Inspection at the test pressure will be performed visually.

Table 1:
Pressure test loading

Step	Hold time	Comments
17 bar	3minutes	No leakage
30 bar	3 minutes	No leakage
36 bar	3 minutes	No leakage
42 bar	3 minutes	No leakage
48.8 bar	3 minutes	Leakage at the interface of valve and composite vessel
54 bar	3 minutes	Leakage due to crack at interface of dome and cylinder

VIII. RESULTS AND DISCUSSION

Composite pressure vessel of E- Glass fiber having dimensions of 175 mm diameter, 350 mm length and 12mm thick is analyzed and fabricated with operating pressure of 1.3 N/mm^2. The graphs show the comparison of deformation, Von misses stress and strain for different fiber angle. The graph is shown in fig 18 to fig 20.

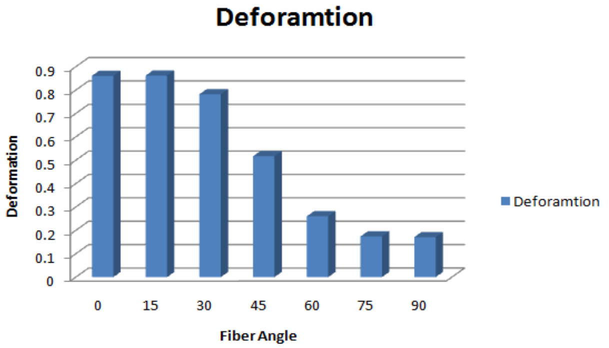

Fig.18: Deformation of PV Glass / Epoxy for different fiber angles at Pressure 1.3N/mm^2

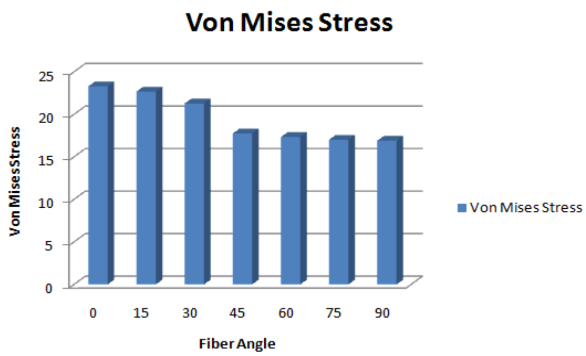

Fig.19: Von Mises Stress of PV Glass / Epoxy for different fiber angles at Pressure 1.3N/mm^2

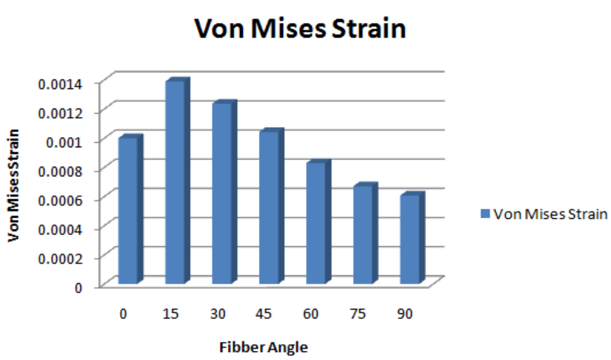

Fig.20: Von Mises Strain of PV Glass / Epoxy for different fiber angles at Pressure 1.3N/mm^2

Table 2:
Experimental Test Results

Pressure	Remark
48.8 bar	Leakage at the interface of valve and composite vessel
54 bar	Leakage due to crack at interface of dome and cylinder

IX. CONCLUSION

Composite hemispherical closed ends pressure vessel of E- Glass fiber having dimensions of 175 mm diameter, 350 mm length and 12mm thick is analyzed and fabricated with operating pressure of 1.3 N/mm^2. The following are the conclusion

- Fiber angle 90^o is found to be the optimum fiber angle compared to other fiber angles because the deformation & Strain values at this angle are low compared to other fiber angles. Its value is 0.171mm (deformation) & 0.607E^{-3} (Strain) as shown in graph 18 and 20.
- The stress at fiber angle 0^o has maximum compare to other angles. Its value is 23.297N/mm^2.
- Bursting Pressure for this cylinder is 48.8 Bars (4.88N/mm^2)

REFERENCES

[1] Prof. Vishal, Prof. Arun, "Design & Weight Optimization of Pressure Vessel Due to Thickness Using Finite Element Analysis", International Journal of Emerging Engineering Research and Technology (IJEERT), ISSN 2349-4395, Volume 2, Issue 3, June 2014, PP: 1-8.

[2] Rao Yarrapragada K.S.S, R. Krishna Mohan, B. Vijay Kiran, "Composite Pressure Vessel", International Journal of Research in Engineering & Technology, ISSN: 2319—1163, Volume – 1, Issue – 4, Dec- 2012, PP: 597 – 618.

[3] Prof. Nitinchandra, " Design Analysis of Pressure Vessel Amalgamating With Selection of Material Used In Marine Application", International Journal of Innovative Research In Science, Engineering and Technology (IJIRSET), ISSN 2319_8753, Volume 2, Issue 6, June 2016, PP: 1-8.

[4] Siva Krishna, T.Seshaiah, "Design and Analysis of Multilayer High Pressure Vessels", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Volume 2, Issue 1, Jan-Feb 2012, PP: 355-361

[5] Prof. M. V. Mallikarjuna, A. Dhanaraj, "Design & Stress Analysis of a Cylinder with Closed ends using ANSYS", A. Dhanaraj Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 5, Issue 4, (Part -6) April 2015, PP. 32-38.

[6] Prof. Mulla Niyama, K.Bicha, "Design and Stress Analysis of Pressure Vessel by Using Ansys", International Journal of Engineering Sciences & Research Technology, (IJESRT), ISSN 2277-9655.

[7] Rajkumar Patil, Nitin Deshmukh, Apurva R. Pendbhaje, "Design and Analysis of Pressure Vessel" International Journal of Innovative Research in Technology & Science (IJIRTS), ISSN:2321-1156, VOLUME 2, NUMBER 3.

[8] http://hollowayamerica.com/products/stainless-steel-pressure-vessels/asme-materials/

[9] B.S. Thakkar, S.A. Thakkar, "Design of Pressure Vessel Using ASME CODE section VIII, Division 1, International Journal of Advanced Engineering Research and Studies, (IJAERS), E-ISSN 2249-8974, Vol. 1 Issue II, Jan – March 2012 / 228-234.

[10] Subhas N. Khetre, P.T. Nitnaware, Arun Meshram, "Design and Analysis of Composite High Pressure Vessel with Different Layers Using FEA", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol . 3, Issue 11, Nov – 2014, PP: 1460-1464

[11] Prof. V.V. Wadkar, S.S. Malgave, "Design and Analysis of Pressure Vessel using Ansys", Journal of Mechanical Engineering and Technology (JMET), ISSN Print: 2347-3924, Volume 3, Issue 2, July-Dec 2015, PP: 01-13.

[12] Ahmed Ibrahim, Yeong Ryu, "Stress Analysis of Thin-Walled Pressure Vessels", Scientific Research Publishing, Modern Mechanical Engineering, 2015.

[13] Andrade, Tatiana Lima, Paula, Wagner Andrade de, "Analysis of Stress in Nozzle/Shell of Cylindrical Pressure Vessel under Internal Pressure and External Loads in Nozzle", Andrade, Tatiana Lima et al. Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 5, Issue 9, (Part - 1) September 2015, pp.84-91.

[14] https://en.wikipedia.org/wiki/Pressure_vessel