Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 3; April-June, 2015 pp. 203-207

http://www.krishisanskriti.org/jmsme.html

Comparative Study of Pressure Vessels Made from Laminated Composite Material (COPV) with the Pressure Vessels Made with Sandwich Core Composite Material

Rakesh Potluri

M.Tech Student in PVPSIT Kanuru, Vijayawada – 07
E-mail: y09me042@gmail.com

Abstract—*Pressure Vessels are widely used as tanks in automobiles, heavy trucking, and transportation, aerospace…etc. At present the outer shells of the pressure vessels are made up of conventional metals like steels aluminum, and titanium alloys. The payload performance/ speed/ operating range depends upon the weight. The lower the weight the better the performance, one way of reducing the weight is by reducing the weight of the shell structure. The use of composite materials improves the performance of the vessel and offers a significant amount of material savings.*

Composite pressure vessels are increasingly used in aerospace applications because of their superiority in strength, weight advantage, and lower production costs. Usually composite pressure vessels are designed for minimum weight under the given strength requirements which is generally the internal pressure for these vessels. The sandwich structures are a special type of composite materials which consists of a very thick core with thin skins on it. Here in this work a comparative study was made on the design of the composite pressure vessel that has been made from composite laminate (COPV) and a pressure vessel which is made from sandwich structured composites. The design and analysis of the pressure vessel was performed with Ansys Workbench 15.0.

1. INTRODUCTION

Composite materials are different materials which have interesting properties such as high strength to weight ratios when compared to metals, which make them very attractive for replacing many advance systems. Attempts are being made to replace metal pressure vessels by composite ones which are used for several purposes.

1.1 Composite Material

A material composed of 2 or more constituents is called composite material. Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and or not soluble in each other. The main difference between composite and an alloy are constituent materials which are insoluble in each other and the individual constituents retain those properties in the case of composites, whereas in alloys, constituent materials are soluble in each other and forms a new material which has different properties from their constituents. Classification of Composites Polymer matrix composites Metal matrix composites Ceramic Matrix.

Here we also have a special type of composites called Sandwich structures. As the name suggests the structure is made by sandwiching two thin skins with a very thick core which provides the necessary stiffness.

B) Advantages of Composites

The advantages of composites over the conventional materials are: High strength to weight ratio, high stiffness to weight ratio, high impact resistance, better fatigue resistance, Improved corrosion resistance, Good thermal conductivity, Low Coefficient of thermal expansion. As a result, composite structures may exhibit a better dimensional stability over a wide temperature range, high damping capacity.

C) Limitations of Composites

The limitations of composites are: Mechanical characterization of a composite structure is more complex than that of a metallic structure, the design of fiber reinforced structure is difficult compared to a metallic structure, mainly due to the difference in properties in directions, the fabrication cost of composites is high, rework and repairing are difficult, they do not have a high combination of strength and fracture toughness as compared to metals and they do not necessarily give higher performance in all properties used for material selection.

D) Applications of Composites

The common applications of composites are extending day by day. Now a day they are used in medical applications too. The other fields of applications are:

Automotive: Drive shafts, clutch plates, engine blocks, push rods, frames, valve guides, automotive racing brakes, filament–wound fuel tanks, fiber Glass/Epoxy leaf springs for heavy trucks and trailers, rocker arm covers, suspension arms and bearings for steering system, bumpers, body panels and doors.

Space: payload bay doors, remote manipulator arm, high gain antenna, antenna ribs and struts etc.

Marine: Propeller vanes, fans & blowers, gear cases, valves & strainers, condenser shells.

Chemical Industries: Composite vessels for liquid natural gas for alternative fuel vehicle, racked bottles for fire service, mountain climbing, underground storage tanks, ducts and stacks etc.

Aircraft: Drive shafts, rudders, elevators, bearings, landing gear doors, panels and floorings of airplanes etc.

Electrical & Electronics: Structures for overhead transmission lines for railways, Power line insulators, Lighting poles, Fiber optics tensile members etc.

Sports Goods: Tennis rackets, Golf club shafts, Fishing rods, Bicycle framework, etc.

E) Sandwich structures

A **sandwich-structured composite** is a special class of composite materials that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density.

Open- and closed-cell-structured foams like polyvinylchloride, polyurethane, polyethylene or polystyrene foams, balsa wood, syntactic foams, and honeycombs are commonly used core materials. Open- and closed-cell metal foam can also be used as core materials.

Laminates of glass or carbon fiber reinforced thermoplastics or mainly thermoset polymers (unsaturated polyesters, epoxies...) are widely used as skin materials. Sheet metal is also used as skin material in some cases the core is bonded to the skins with an adhesive or with metal components by brazing together.

Sandwich panels are used in those applications where high structural rigidity and low weight is required. An evident example of use of sandwich panels is aircraft where mechanical performance and weight saving is essential. Other applications include packaging (e.g. fluted polypropylene boards of polypropylene honeycomb boards), transportation and automotive as well as building & construction

(G) Pressure Vessels

A **pressure vessel** is a closed 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.

2. METHODOLOGY

In this paper the a pressure vessel has been taken and constructed for the prescribed thickness and conditions which have been taken from the reference paper [6] .then the model of the pressure vessel was created and the first case was to analyze the pressure vessel with ordinary Composite Layup and then for the same design conditions again the pressure vessel with sandwich construction embedded into it was analyzed and the terms like stress, strains, frequencies were compared.

An internal pressure of 21 Mpa was applied as the load for the pressure vessel.

The pressure vessel consist of steel liner of thickness 15 mm and over it the layers of e-glass epoxy were laid until the total thickness was about 64 mm. Then for the next case the same steel liner was taken and on that a sandwich structure consisting of two E-glass Epoxy skins and San foam core.

Static analysis was performed over on the two pressure vessels.

3. EXPERIMENTATION

First as stated the pressure vessel model was design according to dimensions that are taken from the stated reference paper and as the first case modeled the composite layup for the composite overwrapped pressure vessel with the layup that has been given below which can be referred to as Composite Layup Configuration.

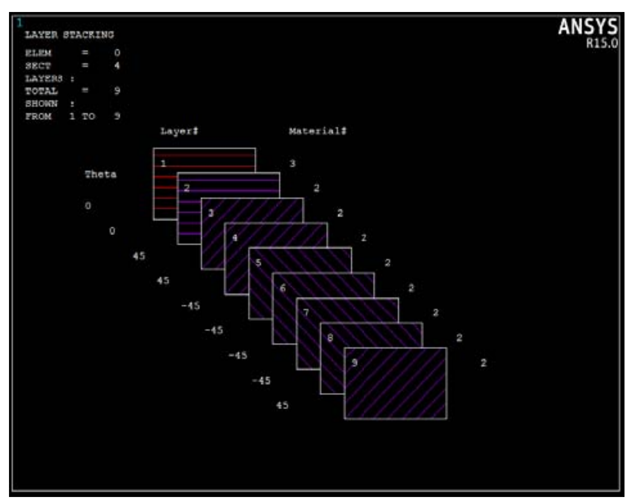

Fig. 1: Layup plot of Composite Layup Configuration

In the second case the same dimension were modeled with the sandwich structure construction and the layup is shown below which may be referred to as Sandwich Layup Configuration.

Fig. 2: Layup plot of Sandwich Layup Configuration

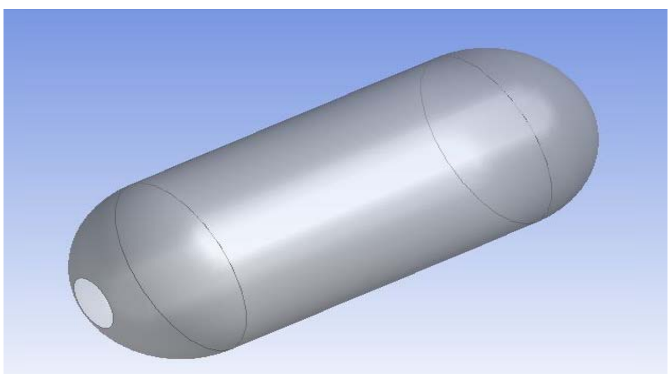

Fig. 3: Surface model of the pressure vessel

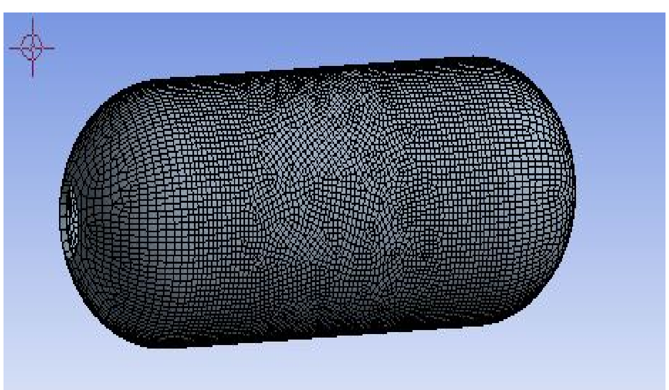

Fig. 4: Meshed model of the pressure vessel

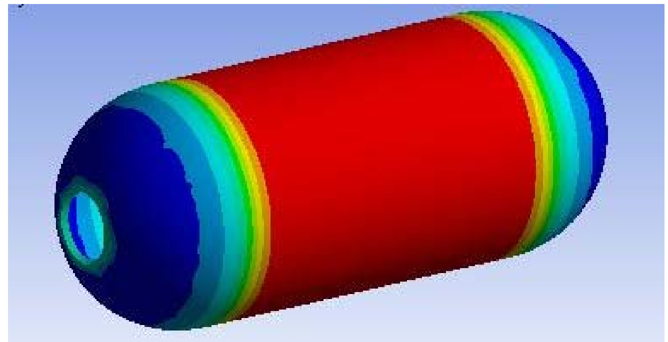

Fig. 5: Stress distribution on pressure vessel

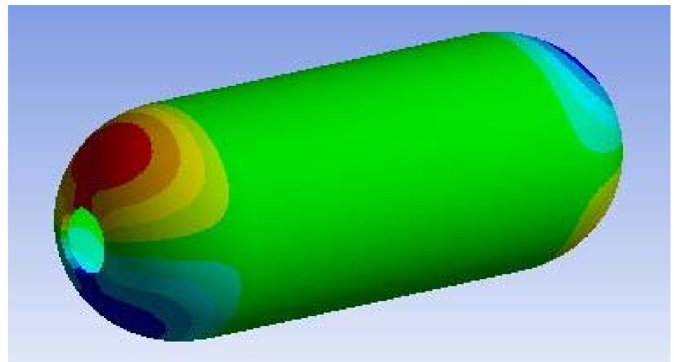

Fig. 6: Shear Stress distribution on pressure vessel

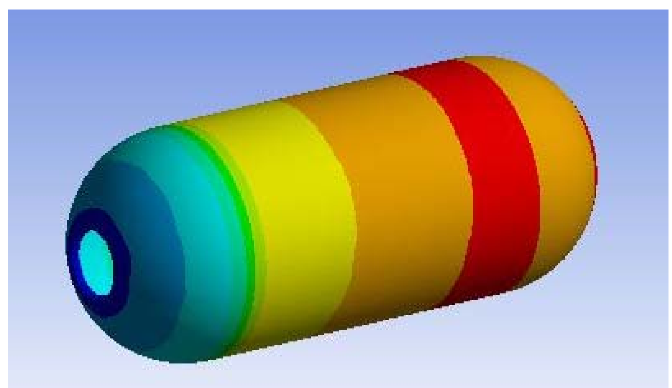

Fig. 7 Deformation distribution on pressure vessel

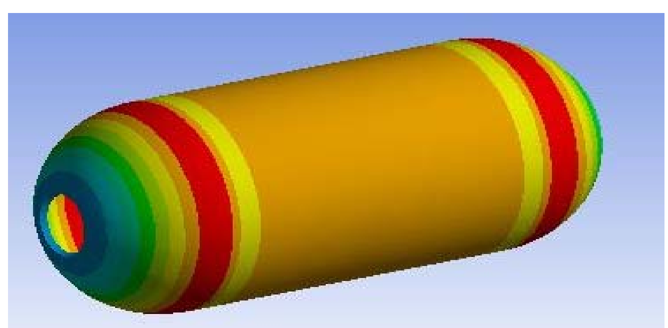

Fig. 8:Longitudinal Stress distribution on pressure vessel

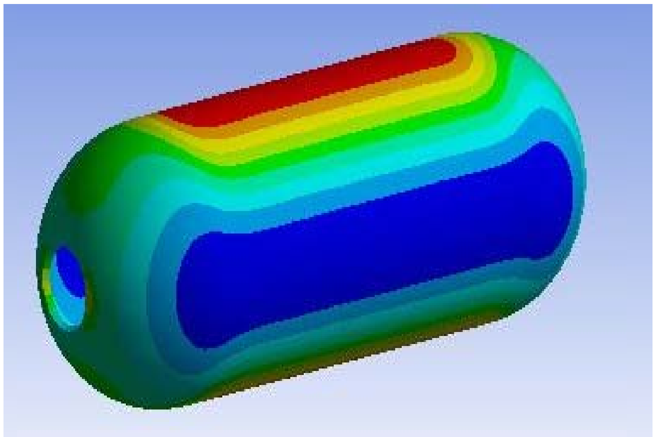

Fig. 9: Radial distribution on pressure vessel

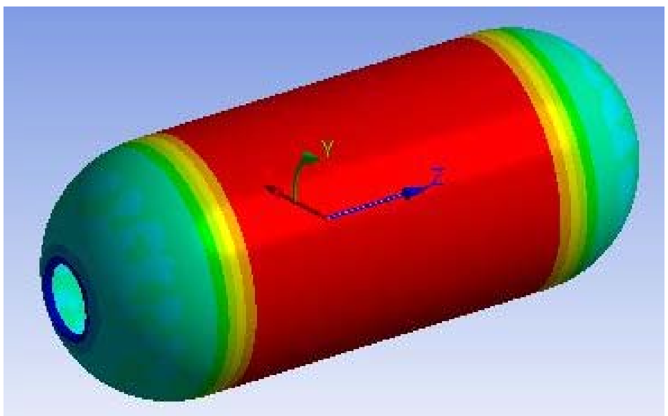

Fig. 10: Hoop Stress distribution on pressure vessel

The Static structural analysis was performed for the two configurations and the values of von-misses, shear, longitudinal stresses …etc were found out which were represented in the form of a table below.

Table 1: All the calculated values for the two different layup's.

	Case	Composite Layup configuration	Sandwich Layup Configuration
1	Equivalent stresses (Mpa)	890.36	1236.1
2	Shear stress(Mpa)	258.81	385.36
3	Total Deformation(mm)	6.9172	8.9035
4	Longitudinal Stress (Mpa)	572.68	751.09
5	Radial stress (Mpa)	1021.9	1346.3
6	Circumferential stress(Mpa)	1027.6	1428.1
7	Mass (Kg)	7392.221	4531.366

And after getting all those values from the structural analysis the I tried to study future in depth the failure of individual plies which was tested for failure against Tsai-Wu failure criteria for composite materials and the second configuration was tested for the core shear failure and the "Tsai-Wu" inverse failure index was obtained and that value was plotted individually for every layer in the composite or the sandwich layup configuration and the plots were provided below.

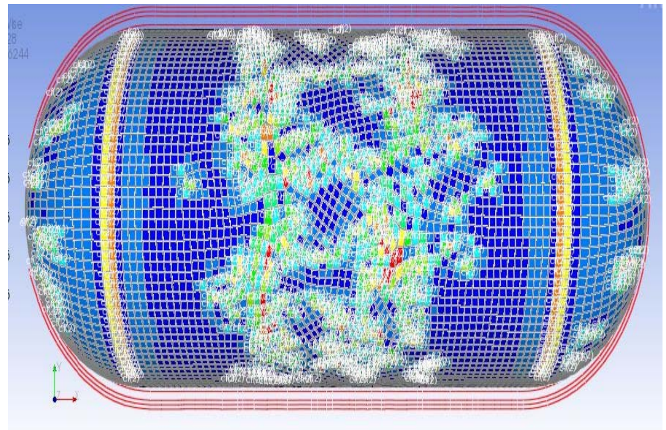

Fig. 11: Tsai-Wu Inverse Failure Factor for core material in Sandwich Layup Configuration

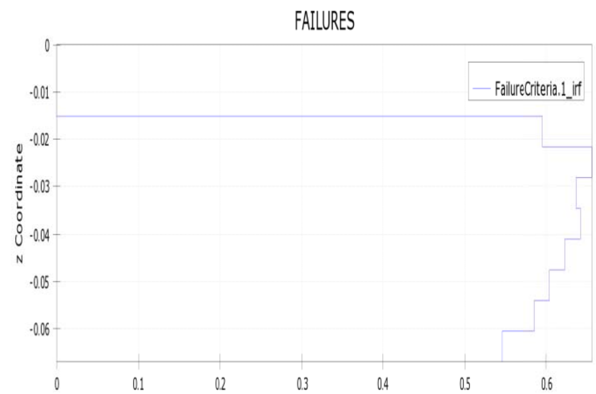

Fig. 12: Tsai-Wu Inverse Failure Factor for Composite Layup Configuration

Fig. 13: Tsai-Wu Inverse Failure Factor for Sandwich Layup Configuration

Here the in the Fig. No: 13 the plot depicts two types of failure one which is the failure of the composite skin and one which is denoted by the blue color denotes the core failure in the sandwich configuration. From fig no: 11 we can see that if not the total core has failed but there are very critical points here the core fails. So we should take as it as if the total core has failed.

4. CONCLUSION

1.) Modeling and analysis of pressure vessels was done in two configurations: they are one with Composite Layup Configuration and another one is of Sandwich Layup Configuration.
2.) Comparisons between the different types of stresses that are present were made between the two configurations.
3.) An extensive layer wise failure which is common in composite materials was also studied and compared for both the cases.
4.) If you see the masses of both the cases the there very drastic difference in the weight which shows if we could develop better core materials we can a very significant weight reductions even when we compared to normal composite materials.
5.) After all of this one can conclude that it is best to go for normal composite layup configuration but there is also a possibility of taking into account more dense cores in order to increase the strength, for which there should be a very careful research.
6.) There is a lot of scope or requirement for the future research in this area of makes composites lighter and stronger like by using aluminum cores…etc

REFERENCES

[1] A Computational Study of Buckling Analysis of Filament Wound Composite Pressure Vessel Subjected to Hydrostatic Pressure By Abhijit Dey et.al., Global Journal of Researches in Engineering: A Mechanical and Mechanics Engineering, Volume 14 Issue 2 Version 1.0 Year 2014
[2] A comparison study of filament wound composite cylindrical shell used in under water vehicle application by Finite Element Method by Abhijit Dey .et. al., 5th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014) December 12th–14th, 2014, IIT Guwahati, Assam, India
[3] Composite tubing collapse under uniform external hydrostatic pressure by Paul.T.Smith et.al. Proceedings of ICCCBE, Nottingham university2010
[4] Design and Analysis of Composite High Pressure Vessel with Different Layers using FEA by Subhash N. Khetre et.al. International Journal of Engineering Research & Technology (IJERT),ISSN: 2278-0181,Vol. 3 Issue 11, November-2014
[5] Stress Analysis of a Composite Cylinder for the
[6] Storage of Liquefied Gases -International Journal of Engineering Trends and Technology (IJETT) – Volume 13 Number 8 – Jul 2014
[7] Design And Analysis of Cfrp Composite Multilayer High Pressurevessels and Burst Pressure Analysis for Various Fiber Orientation Angles by Rayapuri Ashok et.al. International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.1, Pages : 602 - 607 (2013), Special Issue of ICACSE 2013
[8] Term paper on sandwich composites authored by Rakesh.P, M.tech student, PVPSIT, Vijayawada.
[9] Experimental strength of composite sandwich panels with cores made of aluminum honeycomb and foam – cheol-won kong et.al.
[10] Advanced probabilistic design and reliability-based design optimization for composite sandwich structure -- seokje lee et.al.
[11] Design of sandwich structures – a dissertation submitted for ph.d. By petras (cambridge university)