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MODELLING AND ANALYSIS OF COMPOSITE PRESSURE VESSEL

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Abstract- *In this study, optimal angle-ply orientations of symmetric and anti-symmetric shells constructed for supreme burst pressure were examined. Burst pressure of filament wound complex pressure vessels under alternating pure internal pressure was investigated. The study deals with the winding angle on filament wound complex pressure vessels. Finite element method was employed to verify the positive turning angles. The result was reported and discussed for various orientation angles. Glass reinforced plastic (GRP) was manufactured by E-glass-epoxy fiber. The specimen had ten layers which had various orientation angles. The layers were oriented symmetrically and anti-symmetrically for, [45^o/-45^o/90^o/45^o] orientations. The finite element solution was obtained using commercial software ANSYS 11.0.*

Keywords-*E-Glass, Epoxy, ANALYS.*

I. INTRODUCTION

The CFRP complex pressure vessel has used in aerospace and civil application of its high specific strength and rigidity and has high frictional fatigue load.However,it involvesin complex structural constructed it grab much higher variability than other metal due to unpredictable raw sources and geometric sizes and manufacturing method.The carrying out of complexpressure vessel can be improvised 30% by optimizing various technological factors. Due to changes in technological factors, the geometrical properties and accuracy should be considered in complexgeometricalconstructed. Conventional safety factor constructed, based on the deterministic analysis, neglect the effect of constructed variable distribution and can only present safety factor sensitivity experientially with generally hypotheticalaccuracy. So it should be replaced by the accuracyconstructed combined with the probabilistic constructed variable analysis if highly reliable complexgeometrical are to be constructed.The diameter of the pressure vessel is an essential source in design of pressure vessel and is determined using netting analysis. By using Equation (1) and Equation (2) we determine the thickness of the helical winding and hoops winding of pressure vessel. The pressure vessels are constructed with 0.6 to 0.8 stress ratio.

$$t_{f\alpha} = \frac{PR}{2fk\,(\cos\propto)^2} \text{ ---------------- (1)}$$

$$t_{f\theta} = \frac{PR}{2f}(2 - tan^2 \propto) \text{ -------------- (2)}$$

Where,

P-Applied pressure.

R- Radius of pressure vessel.

f- Fiber stress.

K - Fiber strength factor.

$\propto$-Fiber winding angle.

$$stress\ ratio = \frac{t_{f\theta}}{t_{f\alpha}} \qquad \text{-------------- (3)}$$

The features of the pressure vessel considered for study is as followsInner diameter of the pressure vessel computed from netting analysis is 150 mm, Length of the pressure vessel is 320 mm Thickness of helical winding is 12.64 mm, Thickness of hoop winding is 10.65 mm. The material system of T700-carbon fiber/ E51-epoxy matrix is selected. Seventy-five CFRP lamina specimens were all machined from the same batch of fiber and resin as well as the same winding technology and curing cycle to determine the statistics of random variables.

II. FAILURE ANALYSIS:

Failure analysis is a tool for predicting the strength of a laminated complex, containing numerous plies with diversed orientations, under complex loading conditions using strength data obtained from single axial tests of onedirectional plies and strength theories. As the metal is complex in nature it requires numerous failure types, it observe failure phenomena. These types are only useful if they can be incorporated into a progressive damage analysis, which usually means that they must be compatible with a finite element formulation. The different types of failure types have been used for failure constructed of complex laminates. In general, the failure types is categorized into twotypes:An independent classification, such as supreme stress or supreme strain, is simple to apply and more significantly, tells the mode of failure, but it neglects the effect of stress interactions, as it is quite conservative.An interactive classification, such as Tsai-Wu, Tsai-Hill and Hoffmann includes stress interactions in the failure mechanism and predicts first ply failure but it requires some efforts to determine parameters. The first ply failure analysis of the laminated complex pressure vessel is carried out via the use of a suitable failure classification. Determination of first ply failure pressure loads of laminated pressure vessels based on Tsai-Wu failure types has been used.

Table 1. Experimental result of statistics of constructed random variables of FRP pressure vessel

Random variable	Distribution type	μ	σ	α	β
X_t [MPa]	Weibull	1760.06	147.040	20.96	1800.8
X_c [MPa]	Weibull	1016.63	99.990	18.40	1056.7
Y_t [MPa]	Weibull	24.69	2.436	9.52	25.89
Y_c [MPa]	Weibull	116.69	14.100	32.97	117.98
S [MPa]	Weibull	25.09	2.340	5.96	25.72
E_L [GPa]	Normal	146.23	7.840	—	—
E_T [GPa]	Normal	9.64	0.726	—	—
G_{LT} [GPa]	Normal	5.75	0.450	—	—
V_{LT}	Normal	0.31	0.010	—	—
Θ (^{0})	Normal	21.00	0.330	—	—
$t_{f\alpha}$[mm]	Normal	12.64	0.019	—	—
$t_{f\theta}$[mm]	Normal	10.65	0.045	—	—

III. RESULT AND DISCUSSION

3.1.Experimental

12 CFRP pressure vessels with rubber liner were fabricated by the wet-winding method with FW500 three axis filament-winding machine controlled by computer the cylinder part includes helical layers with 21^0 winding angle and hoops layer.Test Results: The test results are shown in the following tables.The statistics of all constructed variables and burst pressure obtained from experimental testing and hydro-burst tests re shown in Tabular columns respectively.

3.2.ANALYSIS :

The problem is solved at static conditions for both steel and complex materials before conducting an FE analysis, the element type must first be decided upon. In the previous studies, solid and shell elements were often used. A solid element requires that the mesh division in the thickness direction should be equal to the number of material layers (But it will take long calculation time). A shell element does not require thickness- direction mesh division,(so the calculation time will be shortened). Therefore, linear layered geometrical shell element SHELL99 for CFRP and nonlinear layered geometrical shell element SHELL91 for the inner metal are used in our study, respectively.

SHELL99 may be used for layered applications of a structural shell model which allows up to 250 layers. These particles has 6 degrees of freedom at all points in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The element is defined by eight nodes, average or corner layer thicknesses, layer material direction angles, and orthotropic material properties. SHELL91 may be used for layered applications of a structural shell model or for modelling thick sandwich geometrical. Up to 100 different layers are permitted to choose as the sandwich option turned off. The Finite Element model of the geometrical is shown in Figure 1. This model consists of 3,010 nodes, 903SHELL91 elements and 910 SHELL99 elements.The pressure distribution and layup sequences are shown in Figure 2 and Figure 3 respectively. Real constant sets were defined for 4 layers; various orientation angles and each layers thickness are entered.

After material properties are defined, linear orthotropic material is chosen and the mechanical properties of carbon/epoxy complex material was added as EX, EY, EZ, PRXY, PRYZ, PRXZ, GXY, GYZ and GXZ. In order to calculate failure types, ultimate tensile strength, compressive strength and shear strength are entered both in fiber direction and in matrix direction. Then a pressure vessel is modelled and material properties, real constant sets and element type are appointed to the volume. After that the model is meshed and the boundary condition is defined to the bottom of the pressure 50vessel as shown in the Figure5. Then analysis was run and the solutions were observed with plot results nodal solutions failure types Inversion of T-Saiwu strength ratio failure index. Failure type value was made equal to 1 by changing the pressure value. Then this pressure values is substituted as a stresses in Equation to calculate burst pressure of the complex pressure vessel.

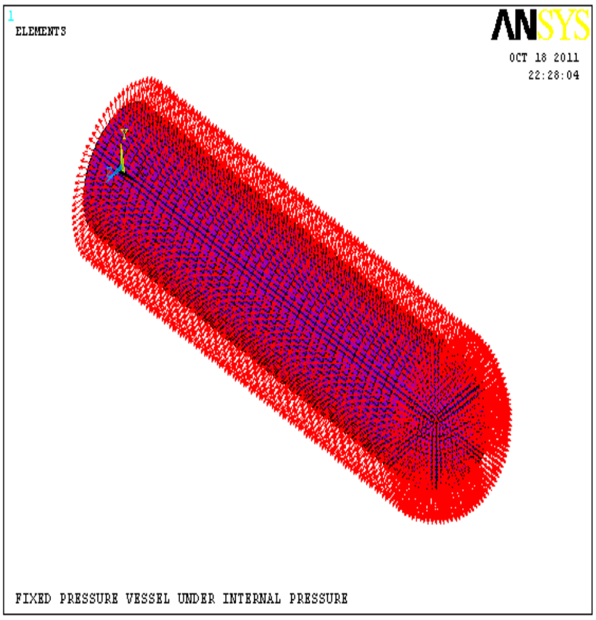

Figure 1. Pressure distribution of the pressure vessel

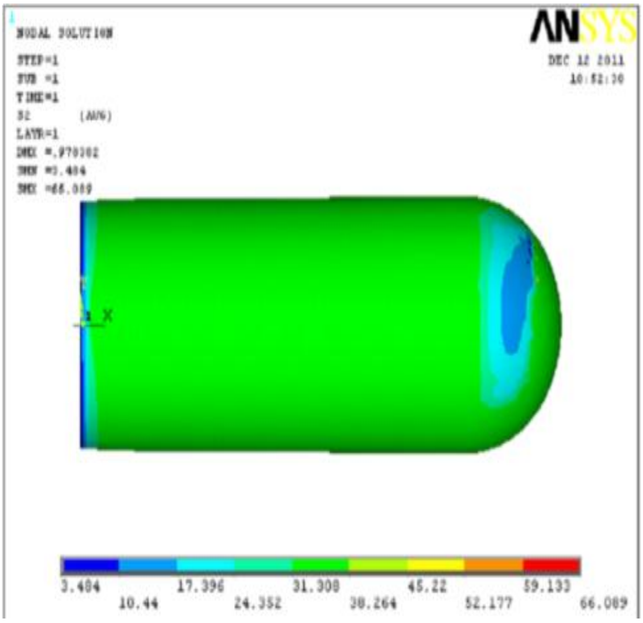

Figure 2. Stress plot along σ_1 direction for layer 1

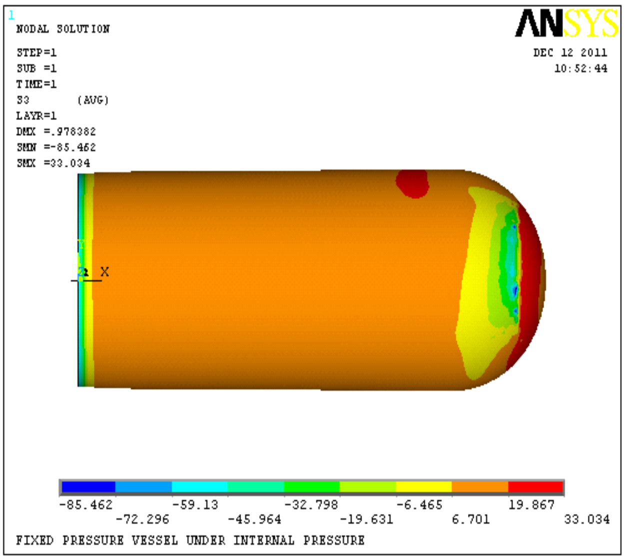

Figure 3. Stress plot along σ_2 direction for layer 1

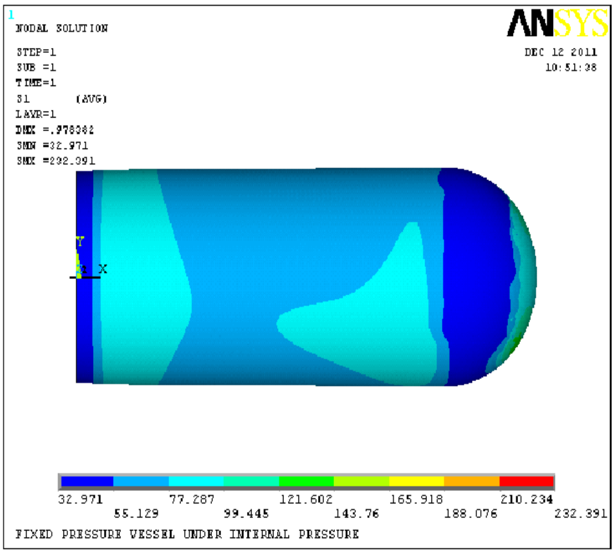

Figure 4. Stress plot along σ_6 direction for layer 1

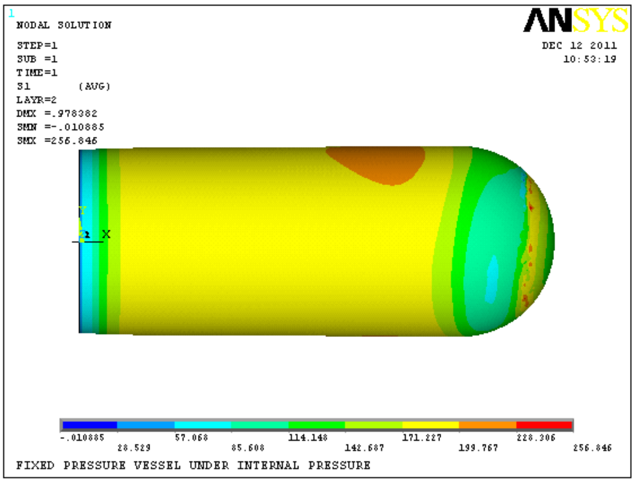

Figure 5. Stress plot along σ_1 direction for layer 2.

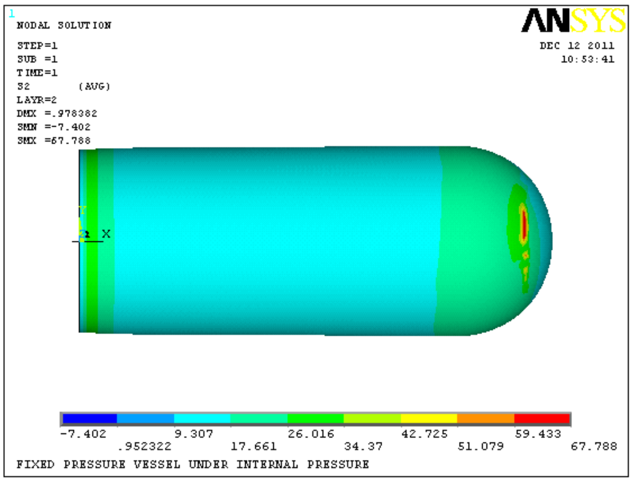

Figure 6. Stress plot along σ_2 direction for layer 2

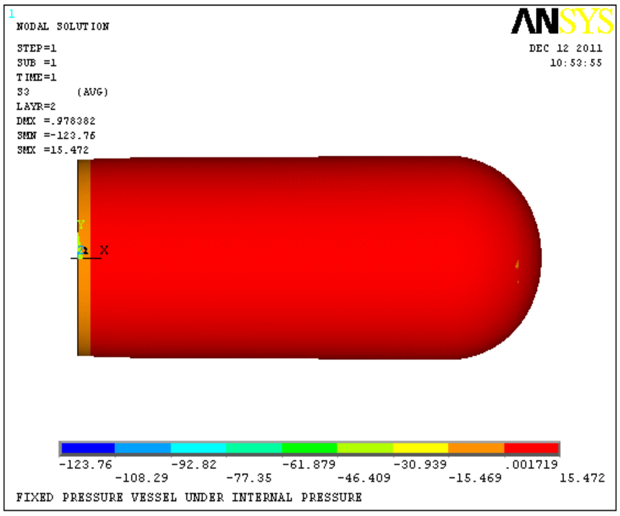

Figure 7. Stress plot along σ_6 direction for layer 2

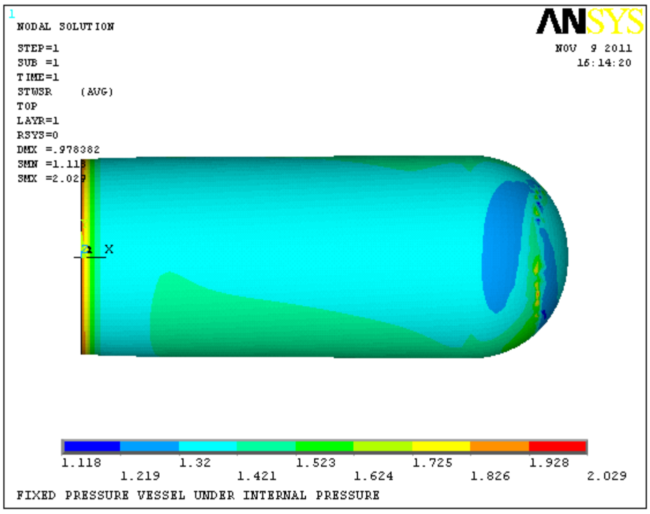

Figure 8. Inversion of T-Saiwu strength ratio aliureindexs

Good agreement is shown between the theoretical and experimental results for the burst pressure of CFRP pressure vessel. By using CLT theory, the burst pressure is computed as 36.0 MPa and the burst is computed using FEA method as 33.0 MPaand Literature Experimental 39.1 MPa. Stresses of the pressure vessel along σ_1, σ_2, and σ_6 directions for layer 1 & 2 are shown in the figure 1 to figure 8.

CONCLUSIONS

Burst pressure of the vessel is calculated by classical laminated theory. Then the failure assessment is made by stiffness degradation model. The burst pressure value is computed as 36MPa. Netting analysis is used to determine the diameter of the pressure vessel. By using finite element method, the burst pressure value is computed as 33MPa. Finally experimental resultis compare with analytical result.

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