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COMPUTATIONAL DESIGN OF A PRESSURE CONTAINER MANUFACTURED BY FIBERGLASS SHEETS TO INDUSTRIAL APPLICATIONS

SUÁREZ G. *, CRUZ J. * AND OLLER S. †

* Centro de Ciencia Básica y facultad de Ingeniería Mecánica
Universidad Pontificia Bolivariana
Circular 1era #70-01, Medellín, Colombia
e-mail: gustavo.suarez@upb.edu.co, luis.cruz@upb.edu.co

† Centro Internacional de Métodos Numéricos (CIMNE)
Universidad Politécnica de Cataluña
Campus Norte UPC, 08034 Barcelona, Spain
email: sergio.oller@cimne.upc.edu.co

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Abstract. Pressurized containers are structures of great importance in both industrial and commercial areas as well as aero spatial applications [1-6]. As a particular study case a simulation was performed in a low hydraulic pressure container, made by manual laminating of unsaturated polyesters and fiberglass, and using the theory of laminated plates. The design was carried out with the criterion of quadratic rupture by Tsai Wu. Finally, the elemental stresses along the fibers, the shear stresses, the stress concentration and the location of the cracked plates, were calculated [1-6]. The results show that the simulation does not over predict the limits of maximum resistance required, thus giving us the possibility to optimize the design during the laminating process.

1 INTRODUCTION

Most of structural models to pressure, handle high relation mechanical between resistance and weight, either between rigidity and weight, relations that can to fulfill if material uses composite, since this it offers the possibility of simulating this mechanical behavior by means of a reinforcement of the material with fibers in the directions where the greater tensions predominate, and to as well optimize the real amount of material required in the construction of the container in function to the reduction of the weight of the same one.

2 SPECIFICATIONS OF FIBERGLASS SHEETS AND LAMINATED SHELLS

Like formulation of the material behavior, it was had a model based on hypothesis of anisotropic elasticity, [1-6]. In order to determine the properties of each lamina the well-known formulation is due to apply as the rule of mixtures. The elastic properties of each component and directions of the stiffener one within the composite, can be determined the mechanical properties of the composite by means of the generalized law of Hooke, [1-6]. Fiberglass sheets were used type E and polymeric matrix of polyester noncsaturated. The containers made by means of the successive piling up of three types of sheets: sheet of matrix reinforced with short fibers, sheet with unidirectional long fibers, and sheet with bidirectional long fibers. General formulation for the laminated, the classic theory of thin plates of Kirchhoff-love, that contemplates the connected effects of flat stress to those of flexion in the composite [1-6].

3 ELEMENT NUMERICAL FORMULATION AND FAILURE CRITERIA

The element used was type Shell 99 for the configuration of the layers, [1-6]. The theoretical formulation for the constituent matrices of the layer element Shell 99 will be:

$$\left[E_1\right]=\sum_{j=1}^{n_L}\int_{r_j^{BT}}^{r_j^{TP}} r\left[T_m\right]_j^T\left[D\right]_j\left[T_m\right]_j\,dr \tag{1}$$

$$\left[E_0\right]=\sum_{j=1}^{n_L}\int_{r_j^{BT}}^{r_j^{TP}} \left[T_m\right]_j^T\left[D\right]_j\left[T_m\right]_j\,dr \tag{2}$$

$$\left\{S_0\right\}=\sum_{j=1}^{n_L}\int_{r_j^{BT}}^{r_j^{TP}} \left[T_m\right]_j^T\left[D\right]_j\left[\varepsilon^{th}\right]_j\,dr \tag{3}$$

$$\left[E_2\right]=\sum_{j=1}^{n_L}\int_{r_j^{BT}}^{r_j^{TP}} r^2\left[T_m\right]_j^T\left[D\right]_j\left[T_m\right]_j\,dr \tag{4}$$

$$\left\{S_1\right\}=\sum_{j=1}^{n_L}\int_{r_j^{BT}}^{r_j^{TP}} r\left[T_m\right]_j^T\left[D\right]_j\left[\varepsilon^{th}\right]_j\,dr \tag{5}$$

Where: n_L number of layers, $[D]$ relation tension and deformation in the point of interest within the layer, $[T_m]$ matrix of transformation of layer in element, r coordinate in a point of interest within layer j. Thus they are defined the forces and moments:

$$\begin{Bmatrix}\{N\}\\\{M\}\end{Bmatrix}=\begin{Bmatrix}[E_0] & [E_1]\\ [E_1] & [E_2]\end{Bmatrix}\begin{Bmatrix}\{\varepsilon\}\\\{k\}\end{Bmatrix}+\begin{Bmatrix}\{S_0\}\\\{S_1\}\end{Bmatrix} \tag{6}$$

Where: $\{N\}$ forces by length unit, $\{M\}$ moments by length unit, $\{S_1\}$,$\{S_0\}$ Vectors because of thermal loads, $\{\varepsilon\}$ deformations,$\{k\}$ curvatures. The criterion of Tsai Wu, is the generalization of the criterion of Tsai Hill with some additional terms as they are: the difference between compression and traction, and the interaction between stress.

4 GEOMETRIC MODELING OF THE CONTAINER

The container is made by four holes of access and drainage and outlet of the liquid, fig. 1. The container was designed to store water to room temperature to a pressure of 827370,8752 Pa.

Were generated 4096 elements type shells that have an amount of 12477 nodes. The geometric description of the elements is constituted from the same geometric definition of the model, fig. 2.

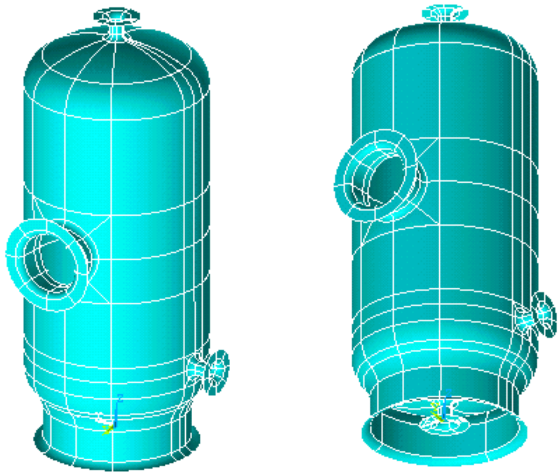

Figure 1: Geometric model of the pressure container.

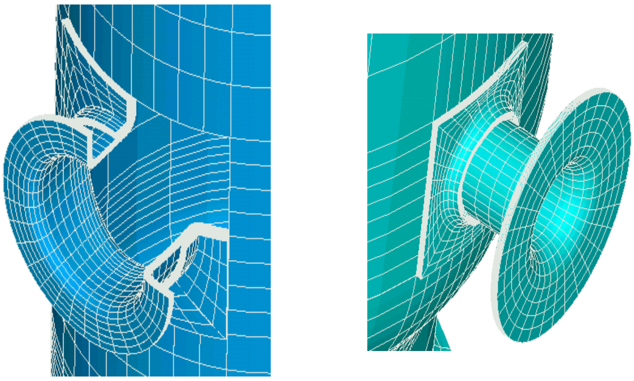

Figure 2: Computational laminated of the pressure container.

Model lamination begins on the areas of the container with a laminate of 20 layers for zones where discharges can be produced concentrations of stress. The laminate of 10 layers, occurs in remaining zones.

5 COMPUTATIONAL SIMULATIONS OF THE CONTAINER

The stress in the direction "x" (Sx), fig. 3; and stress in the direction "y" (Sy), Fig. 4. Other results indicates the zones where it is fulfilled the most value of the quadratic criterion of Tsai Wu, fig. 5; and the one that is put under the most value of the criterion of Tsai Wu, fig. 6.

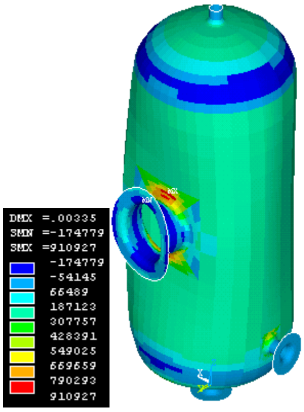

Figure 3: Computational results of the laminate stress, Sx.

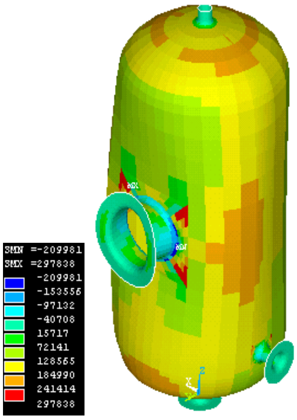

Figure 4: Computational results of the laminate stress, Sy.

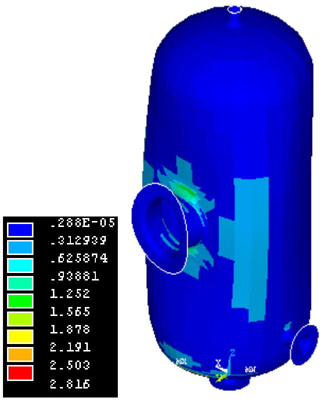

Figure 5: Values of the quadratic criterion, “Tsai Wu”.

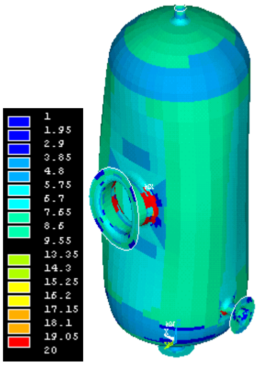

Figure 6: Laminate damage site, “Tsai Wu”.

4 RESULTS

It´s observed that the maximum stress elementary compression (Sx), was value of 0.17478E6 Pa, located in element 2697. The maximum stress to elementary traction had a value of 0.9109É6 Pa to the element number 2304. The maximum stress by elementary compression (Sy) with results of -0.20998E6 Pa and is located in the element number 2403. Was observed the maximum stress elementary (Sxy) with value of 0.19476E6 and 0.19308E6 Pas, it´s located in the elements 2205 and 2219, respectively.

5 CONCLUSIONS

- Were produced stresses of the material at the intersections between the holes intersection and the most cylindrical of the container, with distortions of shapes elliptical and concave.
- There are 3584 elements of sheet that are in the failure limit or that exceeded it, but without implying the failure of the plate laminate of the container. Sheet 2317 obtained the maximum criterion of fault with a without dimensional value of 20.
- The results of the simulation of the maximum criterion showed that it positions with most number of sheet ruptures were between the positions of sheet 5 and the positions of sheet 8. This indicates that the sheet that failed by breaking were the unidirectional ones. In zones you criticize to traction, occurred the breakage of the first sheet and in zones to compression, it was in completes sheet.
- This indicated the breakage in the short fiber sheet, as much in the interior of the container like in the external surface. They are not really transcendental within the plate, since they are those that less contributes to the total behavior of composite.
- The results analyzed in global form show that through the entire container the material bucket of stable way without arriving at a complete rupture of the sheet and without exceeding you limit them of established maximum resistance for composite.
- The results also demonstrate that it is possible to reduce to the thickness of the material and therefore the weight of the same one, degrading the plate y means of the suppression of the laminate that failed.

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