Journal of Mechanical Engineering Research and Developments (JMERD)
DOI : http://doi.org/10.26480/jmerd.02.2019.76.78
ZIBELINE INTERNATIONAL PUBLISHING
ISSN: 1024-1752
CODEN : JERDFO
CrossMark

CALCULATION OF CYLINDRICAL PRODUCTS MADE OF COMPOSITE MATERIALS USING WRAP TECHNOLOGY

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ARTICLE DETAILS

Article History:

Received 01 February 2019
Accepted 14 March 2019
Available online 28 March 2019

ABSTRACT

The paper has developed the calculation method of composite structure design according to wrap technology, the main results have been achieved: (i) - Constructing a mathematical model of composting tank under pressure of two sealed cylindrical layers by "grid method" with the following solutions: All tensile loads absorbed by the fibers, the tensile strength of the substrate in composite materials can be ignored; Composite shell is a non-torque shell with a relative thickness within the limits: $\bar{h} = h_k / R_{об} \leq 1/20 = 0,05$; Stress on all fibers everywhere, at any point of the surface, is constant or durable shell is uniform; and (ii)- The applied mathematical model to calculate structural parameters of fabrication of water filter.

KEYWORDS

Pressure vessels, Anisotropy, Winding patterns, Stress analysis, Filament Winding Composite, Optimisation.

1. INTRODUCTION

Composite materials are increasingly being used and developed in all industries. This is explained because this material promotes the characteristics of each individual material. In the maritime industry, composite materials have been constantly researched and developed in recent years. Because most marine equipment such as oil storage systems and pressure-resistant systems in the rescue sector need harsh working conditions [1-5]. The heavy metals in engine waste also cause corrosion and abrasion to marine equipment components. Therefore, the study of manufacturing composite materials to serve the maritime sector is particularly necessary [6].

Pressure vessels made of composite materials are usually cylindrical, working volume from a few liters to hundreds of liters, the compression pressure of 20 to 30 Mpa, used for air, nitrogen, and helium ... Previously it was often made from high-quality steel, titanium alloy, today using composite materials for fabrication. Using composite materials in manufacturing cylindrical pressure vessels to reduce magnetic mass (1.5-2.5) times, good corrosion resistance, long life, and safety in use. Cylindrical pressure-resistant cylinders are made of winding technology. Wrapping technology is easy to automate and is a production process with high productivity in manufacturing details from polymer-based composite materials, ensuring that the products with the smallest volume are obtained [7-9].

Calculation of structural design of cylindrical water filters received by the method of wrapping unidirectional composite materials is to determine the size, geometric shape and structural parameters of the composite shell. The design of composite shells of pressure vessels is carried out according to the following basic assumptions [10,11]:

- The design is done according to the "grid method". This means that all pull loads absorbed by the fibers, the tensile strength of the substrate in the composite material can be ignored.

Composite shells are non-torque (thin shell theory), Thin shell conditions: $\bar{h} = h_k/R_{00} \leq 0.05$

- Optimized for mass when the shell satisfies stable principle. In order to obtain the smallest value of the mass of pressure-resistant composite shells, it is necessary to arrange so that the stress on all fibers is everywhere, at any point of the surface is constant. Such a crust is a uniformly stable crust, which will achieve the minimum mass that can be determined by the formula:

$$M_e^{min} = 3P_{ph} * V * \frac{\rho_c}{\sigma_c}$$

in which P_{ph} is the destructive pressure, MPa; V - internal volume, dm^3; ρ_c – the density of composite materials, kg/m^3; σ_c - Strength limit of single-direction composite materials when pulling, MPa.

The coordinate system, the equilibrium equation of the rotating round shell is obtained by the method of wrapping composite materials

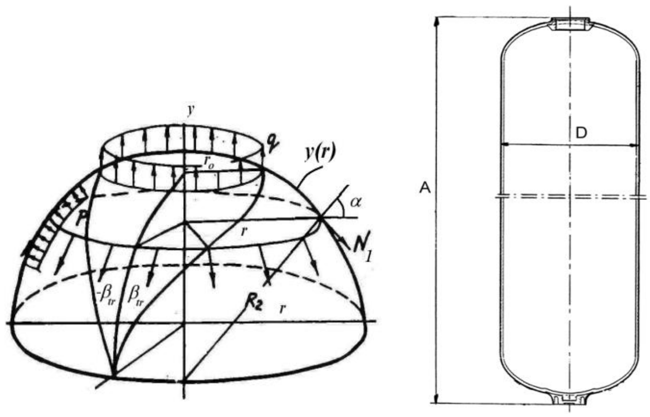

Figure 1: Model of calculating the cylinder

- Pots made in Belgium - Europe;
- Lined composite compartment (sealed enclosure) with PE with glass fiber and epoxy resin substrate;
- Uses water containers.
- Maximum working pressure: 10bar = 10 atm = 1 MPa;
- Max working temperature: 150^o C;
- Neck of 2 ½ ” diameter = 63.5 mm;
- The number of inspection cycles: 250,000 times at the capacity (0.7-10) bar.

2. THE ORDER OF CALCULATION

1) From formula (1) determine the wrap angle on the cylinder portion of the pressure vessel.

$$r_0 = R \sin \beta_{tr} \quad (1)$$

2) Determine the breakdown pressure of the flask by formula (2)

$$P_{ph} = n * P_{lv} \quad (2)$$

3) Calculate the thickness of the twisting section and the horizontal winding of the pressure tank based on (3) the formula in which the durability factor n is taken into account.

$$h_x = \frac{P_{ph}*R-2*h_v*\sigma_v^*}{2*\sigma_c^**cos^2\beta} = \frac{P_{ph}*R-2*h_v*\sigma_v^*}{2*\sigma_c^**(1-r_0^{-2})}, mm$$

$$h_n = \frac{P_{ph}*R-\sigma_v^**h_v}{\sigma_c^*} - h_x*(\bar{r}_0)^2, mm \quad (3)$$

$$h_{tr} = h_x + h_n = \frac{3*P_{ph}*R-4*\sigma_v^**h_v}{2*\sigma_c^*}, mm$$

4) Determine the stress parameters on the pressure vessel shell according to formula (4).

$$\lambda = \sigma_v^* h_v \Big/ \left(\sigma_c^* h_x \sqrt{1-\bar{r}_0^2}\right). \quad (4)$$

5) Determine the bottom shape of the pressure vessel from equation (5).

$$\bar{y} = -\int_1^{\bar{r}} \frac{(\bar{r})^3 \, d\bar{r}}{\sqrt{\left[\frac{\lambda \bar{r}^2 + \sqrt{\bar{r}^2 - \bar{r}_n^2}}{\lambda + \sqrt{1-\bar{r}_n^2}}\right]^2 - (\bar{r})^6}} \quad (5)$$

6) Determine the height of the bottom tank Lđ according to (5) when r = r$_0$.

7) Determine the internal volume of the two bottom flasks according to formula (6).

8) $2V_d = V_{el} = \frac{4}{3}\pi R^2 l_d.$

9) From the volume V of the pressure vessel and the volume of the two bottoms of the flask ($2V_d$) (6) find the length of the cylinder Ltr section of the vessel; combined with the height of the bottom Lđ will determine the length L of the flask.

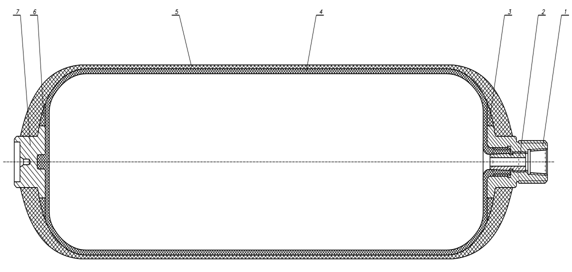

Figure 2: Structure of the composite water filter tank with sealed plastic cover: 1- connecting valves (neck cylinders), 2-taper, 3, 6-section stress relief, 4-sealed housings from HDPE, 5-pressure bearing from composite, 7-bottomed

3. INPUT DATA

- Tank capacity: 16.2 liters (16.2 dm3);
- Sale of valves: 63.5 / 2 = 32 mm;
- Inside radius: 86 mm (select);
- Working pressure: 1 MPa;
- Reliability reserve factor: n = 2.2.
- Elastic limit and density of PE plastic as a closed body:
+ Elastic limit of PE plastic is equal to 0.5 strength limit: The strength limit of PE plastic PE = 20 MPa ➔ $\sigma_{PE}^{dh} = 10$ MPa;
+ Density of PE: $\rho_{HDPE} = 0{,}95$ g/cm^3.
- The thickness of the enclosure (selected according to the technological capability and supply marketability): h = 3mm;
- The durability of composite materials (glass fiber reinforced S, epoxy resin substrate), determined from the experiment: $\sigma_c^* = 450$ MPa;
- The specific volume of composite: $\rho = 2{,}1$ g/cm^3.

4. CALCULATION RESULTS

Using of Mathcad software to conduct calculations to determine the composite parameters of composite water filter with HDPE resin in the order given above. The calculation results are presented in the table. The bottom profile of the pressure vessel in two cases is shown on the figure.

Table 1: High-pressure composite tank parameters

Structural parameters	Units	Results
Corner wrap on the cylinder of the cylinder	β_{tr}, độ	21
Twisted section thickness	h_x, mm	0,18
Horizontal wrap thickness	h_n, mm	0,35
The total thickness of composite shell on the cylindrical part	h_Σ, mm	1,5
The height of bottle bottom	l_d, mm	63,7
Length of cylinder	l_{tr}, mm	566
Total body length	l, mm	693
The outer diameter of the bottle	D, mm	181
Body weight block sealed	m_v, kg	1,5
Mass of composite shell	m_c, kg	2,0
The mass of the connecting valve and the bottom of the enclosure is sealed	m_v kg	0,6
Total weight of the bottle	m_b, kg	4,1

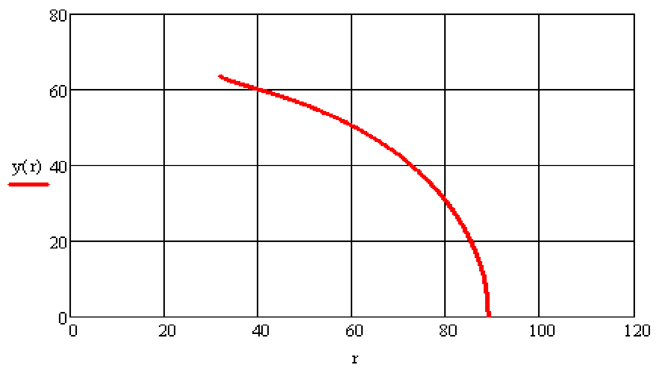

Figure 3: The profile of the bottom of the water filter tank is made of the composite after calculation

Discussion: In the world, today, using finite elements to calculate composite materials to say supply and pressure tanks in particular [12-16]. In the process of assuming the calculation in the direction of anisotropic materials, the results are accurate but do not pay much attention to the appropriateness of manufacturing technology. The article of the author gives a calculation model based on the grid method, the calculation is quite simple, and the results are relatively accurate and especially suitable for wrapping technology to create rotating round products.

5. CONCLUSION

- The article has given a calculation model based on the assumption of "grid method" for cylindrical pressure vessels made of composite materials.
- To verify the model, it is proposed to apply the calculation for the water filter and the results show the suitability.
- Calculation model can be applied to rotating round products made of composite materials.

REFERENCES

[1] Hoang, A.T., Nguyen, D.C. 2018. Properties of DMF-fossil gasoline RON95 blends in the consideration as the alternative fuel. International Journal on Advanced Science, Engineering Information Technology, 8 (6), Pp. 2555-2560.

[2] Zhu, W., Wang, E., Hou, Y., Xian, L., Ashraf, M.A. 2018. Hybrid Filtering Optimization Method for Denoising Contaminated Spot Images at Near-Sea-Surface Intervals. Journal of Coastal Research: Special Issue 82. Coastal Ecosystem Responses to Human and Climatic Changes throughout Asia: pp. 70 – 7.

[3] Hoang, A.T., Pham, V.V. 2019. A study of emission characteristic, deposits, and lubrication oil degradation of a diesel engine running on preheated vegetable oil and diesel oil. Energy Sources, Part A: Recovery, Utilization, Environmental Effects, 41 (5), Pp. 611-625.

[4] Hoang, A.T., Le, A.T. 2019. A review on deposit formation in the injector of diesel engines running on biodiesel. Energy Sources, Part A: Recovery, Utilization, Environmental Effects, 41 (5), Pp. 584-599.

[5] Elmnifi, M., Amhamed, M., Abdelwanis, N., Imrayed, O. 2018. Solar Supported Steam Production for Power Generation In Libya. Acta Mechanica Malaysia, 2 (2), 05-09.

[6] Hoang, A.T. 2019. Experimental study on spray and emission characteristics of a diesel engine fueled with preheated bio-oils and diesel fuel. Energy, 171, Pp. 795-808.

[7] Hoang, A.T. 2018. Waste heat recovery from diesel engines based on Organic Rankine Cycle. Applied energy, 231, Pp. 138-166.

[8] Yan, Z. 2018. Modeling and Kinematics Simulation of Plane Ten-Bar Mechanism of Warp Knitting Machine Based on Simcape/Multibody. Acta Mechanica Malaysia, 2 (2), 15-18.

[9] Hoang, A.T., Pham, X.D. 2018. An investigation of remediation and recovery of oil spill and toxic heavy metal from maritime pollution by a new absorbent material. Journal of Marine Engineering Technology. https://doi.org/10.1080/20464177.2018.1544401.

[10] Chang, R. 2000. Experimental and theoretical analyses of first-ply failure of laminated composite pressure vessels. Composite structures, 49 (2), Pp. 237-243.

[11] Dastani, M., Panahi, S., Sattari, M. 2019. Webometrics Analysis of Iranian Universities About M edical Sciences' Websites Between September 2016 And March 2017. Acta Informatica Malaysia, 3 (1), 07-12.

[12] Cohen, D., Mantell, S.C., Zhao, L. 2001. The effect of fiber volume fraction on filament wound composite pressure vessel strength. Composites Part B: Engineering, 32 (5), Pp. 413-429.

[13] Azzam, B. 1995. Comparison between analytical and experimental failure behavior of a proposed design for the filament-wound composite pressure vessels. Current Advances in Mechanical Design and Production VI, Elsevier. Pp. 323-332.

[14] Xu, D. 2019. Research on Supply Chain Management Strategy Of Longtang Electric Engineering Co. Ltd. Acta Electronica Malaysia, 3 (1), 10-13.

[15] Oñate, E. 2013. Structural analysis with the finite element method. Linear statics: volume 2: beams, plates and shells. Springer Science & Business Media.

[16] Chen, Z. 2004. Nonlinear stress analysis and design optimization of ultra-high-pressure composite vessels.