CALCULATION OF CYLINDRICAL PRODUCTS MADE OF COMPOSITE MATERIALS USING WRAP TECHNOLOGY

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ARTICLE DETAILS

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 composite 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: \( h = h_k / R_w \leq 1/20 = 0.05 \); 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 WindingComposite, 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: \( h = h_k / R_w \leq 0.05 \)

- 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:

\[
M_v^{\min} = 3P_h V \cdot \frac{\rho_c}{\sigma_c}
\]

in which \( P_h \) is the destructive pressure, MPa; \( V \) - internal volume, dm³; \( \rho_c \) - the density of composite materials, kg/m³; \( \sigma_c \) - 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: 10 bar = 10 atm = 1 MPa;
- Max working temperature: 150°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
   \[ r_0 = R \sin \beta_w \] (1)

2) Determine the breakdown pressure of the flask by formula (2)
   \[ \rho_{bh} = n * \rho_{w} \] (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.
   \[ h_x = \frac{p_{bh} \cdot h_v - h_o}{2 \cdot n \cdot \cos^2 \beta} \] (3)

4) Determine the stress parameters on the pressure vessel shell according to formula (4).
   \[ \lambda = \sigma h \left( \frac{\sigma h}{\sqrt{1 - r_o}} \right) \] (4)

5) Determine the bottom shape of the pressure vessel from equation (5).
   \[ \gamma = \int_{r_o}^{r_f} \frac{d \gamma}{\lambda \sqrt{1 - \frac{r_o^2}{r^2}}} \] (5)

6) Determine the height of the bottom tank \( L_d \) according to (5) when \( r = r_o \).

7) Determine the internal volume of the two bottom flasks according to formula (6).
   \[ 2V_d = V_{bh} = \frac{4}{3} \pi R^2 l_d \]

8) From the volume of the pressure vessel and the volume of the two bottoms of the flask (2Vd) (6) find the length of the cylinder \( l_t \) section of the vessel; combined with the height of the bottom \( L_d \) will determine the length \( L \) of the flask.

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 \( P = 20 \text{ MPa} \) \( \Rightarrow \sigma_{pl} = 10 \text{ MPa} \);
  * Density of PE: \( \rho_{HDPE} = 0.95 \text{ g/cm}^3 \).
- The thickness of the enclosure (selected according to the technological capability and supply marketability): \( h = 3 \text{ mm} \);
- The durability of composite materials (glass fiber reinforced S, epoxy resin substrate), determined from the experiment: \( \sigma_{pl} = 450 \text{ MPa} \).
- The specific volume of composite: \( \rho = 2,1 \text{ g/cm}^3 \).

4. CALCULATION RESULTS

Using 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>
<thead>
<tr>
<th>Table 1: High-pressure composite tank parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural parameters</td>
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<tr>
<td>------------------------</td>
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<tr>
<td>Corner wrap on the cylinder of the cylinder</td>
</tr>
<tr>
<td>Twisted section thickness</td>
</tr>
<tr>
<td>Horizontal wrap thickness</td>
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<tr>
<td>The total thickness of composite shell on the cylindrical part</td>
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<tr>
<td>The height of bottle bottom</td>
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<tr>
<td>Length of cylinder</td>
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<tr>
<td>Total body length</td>
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<tr>
<td>The outer diameter of the bottle</td>
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<tr>
<td>Body weight block sealed</td>
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<tr>
<td>Mass of composite shell</td>
</tr>
<tr>
<td>The mass of the connecting valve and the bottom of the enclosure is sealed</td>
</tr>
<tr>
<td>Total weight of the bottle</td>
</tr>
</tbody>
</table>

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
Discussion: In the world, today, using finite elements to calculate composite materials to supply say pressure tanks especially diesel engines running on biodiesel. 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


