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Influence of Geometry on Performance of Type-4 Filament Wound Composite Cylinder for Compressed Gas Storage

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Abstract : Composite pressure vessels are low weight structures mainly used in a variety of applications such as automobiles, aeronautics and chemical engineering. Fiber reinforced polymer (FRP) composite materials offer the simplicity of design and use, high fuel storage capacity, rapid refueling capability, excellent shelf life, minimal infrastructure impact, high safety due to the inherent strength of the pressure vessel, and little to no development risk. Apart from these preliminary merits, the subsidized weight of composite vessels over metallic cylinders act as the biggest asset to the automotive industry, increasing the fuel efficiency. The result is a lightweight, flexible, non-explosive, and non-fragmenting pressure vessel that can be tailor-made to attune with specific applications. The winding pattern of the composite over-wrap is a primary focus while designing a pressure vessel. The critical stresses in the system depend on the thickness, angle and sequence of the composite layers. The composite over-wrap is wound over a plastic liner, whose geometry can be varied for the ease of winding. In the present study, we aim to optimize the FRP vessel geometry that provides an ease in winding and also aids in weight reduction for enhancing the vessel performance. Finite element analysis is used to study the effect of dome geometry, yielding a design with maximum value of burst pressure and least value of vessel weight. The stress and strain analysis of different dome ends along with the cylindrical portion is carried out in ANSYS 19.2. The failure is predicted using different failure theories like Tsai-Wu theory, Tsai-Hill theory and Maximum stress theory. Corresponding to a given winding sequence, the optimum dome geometry is determined for a fixed internal pressure to identify the theoretical value of burst pressure. Finally, this geometry is used to decrease the number of layers to reach the set value of safety in accordance with the available safety standards. This results in decrease in the weight of the composite over-wrap and manufacturing cost of the pressure vessel. An improvement in the overall weight performance of the pressure vessel gives higher fuel efficiency for its use in automobile applications.

Keywords : Compressed Gas Storage, Dome geometry, Theoretical Analysis, Type-4 Composite Pressure Vessel, Improvement in Vessel Weight Performance
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