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Exploring Type V Hydrogen Storage Tanks: Shape Analysis and Material Evaluation for Enhanced Safety and Efficiency Focusing on Drop Test Performance

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Abstract : The shift toward sustainable energy solutions increasingly focuses on hydrogen, recognized for its potential as a clean energy carrier. Despite its benefits, hydrogen storage poses significant challenges, primarily due to its low energy density and high volatility. Among the various solutions, pressure vessels designed for hydrogen storage range from Type I to Type V, each tailored for specific needs and benefits. Notably, Type V vessels, with their all-composite, liner-less design, significantly reduce weight and costs while optimizing space and decreasing maintenance demands. This study focuses on optimizing Type V hydrogen storage tanks by examining how different shapes affect performance in drop tests—a crucial aspect of achieving ISO 15869 certification. This certification ensures that if a tank is dropped, it will fail in a controlled manner, ideally by leaking before bursting. While cylindrical vessels are predominant in mobile applications due to their manufacturability and efficient use of space, spherical vessels offer superior stress distribution and require significantly less material thickness for the same pressure tolerance, making them advantageous for high-pressure scenarios. However, spherical tanks are less efficient in terms of packing and more complex to manufacture. Additionally, this study introduces toroidal vessels to assess their performance relative to the more traditional shapes, noting that the toroidal shape offers a more space-efficient option. The research evaluates how different shapes—spherical, cylindrical, and toroidal—affect drop test outcomes when combined with various composite materials and layup configurations. The ultimate goal is to identify optimal vessel geometries that enhance the safety and efficiency of hydrogen storage systems. For our materials, we selected high-performance composites such as Carbon T-700/Epoxy, Kevlar/Epoxy, E-Glass Fiber/Epoxy, and Basalt/Epoxy, configured in various orientations like [0,90]s, [45,-45]s, and [54,-54]. Our tests involved dropping tanks from different angles—horizontal, vertical, and 45 degrees—with an internal pressure of 35 MPa to replicate real-world scenarios as closely as possible. We used finite element analysis and first-order shear deformation theory, conducting tests with the Abaqus Explicit Dynamics software, which is ideal for handling the quick, intense stresses of an impact. The results from these simulations will provide valuable insights into how different designs and materials can enhance the durability and safety of hydrogen storage tanks. Our findings aim to guide future designs, making them more effective at withstanding impacts and safer overall. Ultimately, this research will contribute to the broader field of lightweight composite materials and polymers, advancing more innovative and practical approaches to hydrogen storage. By refining how we design these tanks, we are moving toward more reliable and economically feasible hydrogen storage solutions, further emphasizing hydrogen's role in the landscape of sustainable energy carriers.

Keywords : hydrogen storage, drop test, composite materials, type V tanks, finite element analysis
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