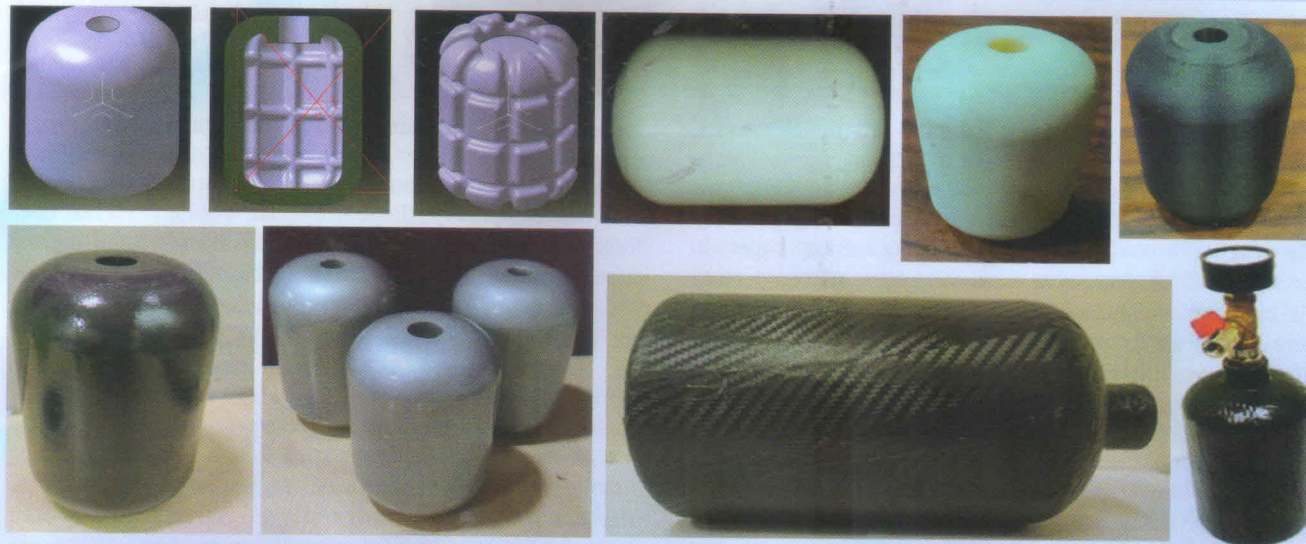


Hydrogen Heroes

The Rise of Composite Pressure Vessels as Next-Generation Hydrogen Storage Solutions

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Different variants of the cylindrical prototypes designed and fabricated by the author's group.

As the world shifts toward cleaner energy solutions, hydrogen has emerged as a promising fuel alternative due to its high energy content and environmental benefits. However, storing hydrogen efficiently and safely remains a significant challenge, driving the need for advanced storage technologies. Previous hydrogen storage technologies, such as Type 1 (metal) and Type 2 (metal-lined composite) pressure vessels, had several drawbacks, including high weight, lower pressure limits, and susceptibility to corrosion. These limitations resulted in reduced fuel efficiency and limited storage capacity, particularly for mobile applications.

Type 4 pressure vessels, characterised by a non-metallic liner fully encased in composite materials, have become the preferred choice for hydrogen storage, particularly for applications in fuel cell vehicles and renewable energy systems. The primary advantage of Type 4 vessels lies in their lightweight design, which significantly reduces the overall weight of storage systems, making them ideal for mobile applications like transportation. Additionally, the use of high-strength composite materials ensures that these vessels can withstand the high pressures (up to 700 bar) required for hydrogen storage, offering both safety and efficiency.

Currently, the global market for Type 4 pressure vessels is growing rapidly, driven by increasing demand from the automotive industry and the broader push toward decarbonisation. Research and development efforts are focused on improving the durability, cost-effectiveness, and manufacturing scalability of these vessels. Innovations in nanotechnology, such as the integration of 2D materials into composite structures, are further enhancing their performance by increasing mechanical strength and enabling real-time

structural health monitoring. Despite these advancements, challenges remain, particularly in reducing manufacturing costs and ensuring widespread adoption. As hydrogen becomes a cornerstone of the global energy transition, the continued development and optimisation of Type 4 pressure vessels will be critical in supporting the safe and efficient storage of this vital energy resource.

The Promise of Hydrogen Energy

Hydrogen, the most abundant element in the universe, offers immense potential as a clean and versatile energy carrier. Unlike fossil fuels, its combustion produces only water vapour, significantly reducing greenhouse gas emissions and air pollution. Hydrogen can fuel vehicles and aircraft, store energy from renewables, and support various industrial processes, potentially revolutionising the energy landscape. Traditional fossil fuels contribute heavily to pollution and climate change, but hydrogen presents a cleaner alternative. In fuel cells, hydrogen reacts with oxygen to produce electricity, emitting only water vapour, thus reducing pollutants like nitrogen oxides and particulate matter. It also serves as a feedstock for industries such as ammonia production and petroleum refining. Moreover, hydrogen can store excess electricity from renewable sources, addressing the intermittency of wind and solar power and ensuring a stable energy supply. However, effective storage solutions for hydrogen remain a challenge due to its low density, requiring high pressures or low temperatures for practical storage. Researchers have explored various methods over the years, each with unique advantages and challenges as described in the book *"The Hydrogen Economy: Opportunities*