Composite Hydrogen Storage & Chassis

OXFORD BROOKES UNIVERSITY

Introduction

Automotive industry is rapidly evolving toward sustainability, energy efficiency, and high-performance mobility. A key strategy in this shift is vehicle lightweighting, making composites essential due to their strength-to-weight ratios, design flexibility, and directional properties [1]. This poster presents a hydrogen storage system and structural chassis for electrified fuel cell vehicles (Fig. 1). Through laminate analysis, critical load cases were evaluated to ensure compliance with safety and stiffness requirements. Two manufacturing volumes are assessed to compare production methods, balancing performance, cost, and environmental impact, and highlighting composite's growing role in future automotive applications.

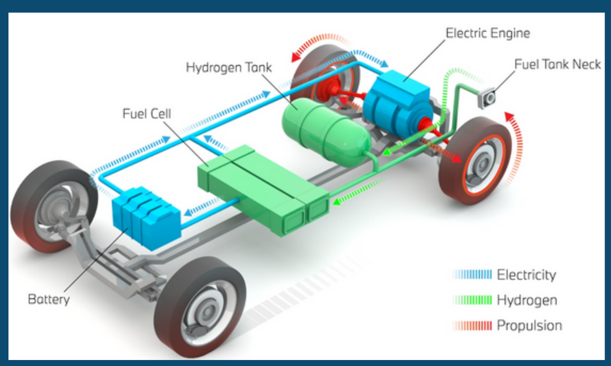


Fig. 1. Hydrogen fuel cell vehicle [2].

Design Targets

Max Torque = 48560 Nm
Min Torsional rigidity = 45000 Nm/deg
Min Bending rigidity = 10000 N/mm
Max impact deflection = 5 mm
Stress safety factor = 1.5
Max cylinder pressure = 700 bar
Target chassis weight = <110 kg
Service conditions: -40° to 100 °C

ASSUMPTIONS

Thin-walled equations (r=0.08)
H_2 volume tank calculated at 23 °C
Impact speed limited to 4 m/s
Impactor area > chassis front/side area
Loads in worst-case scenario

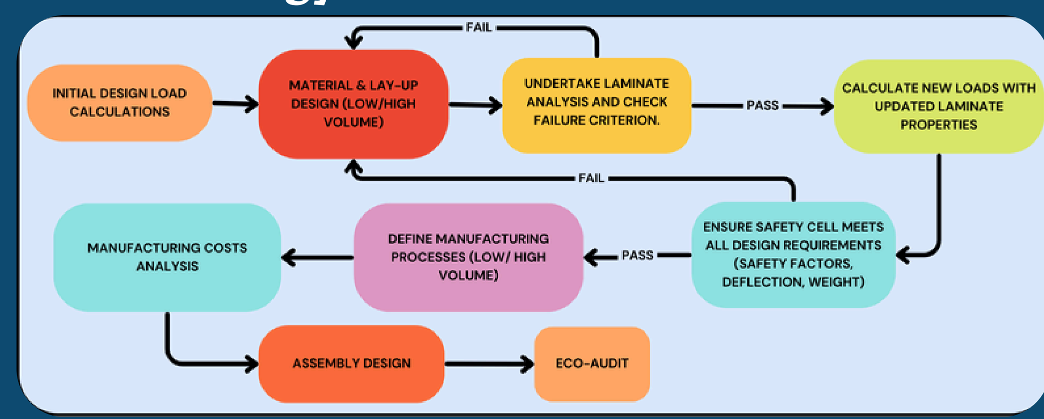
Aim

Design and evaluate an integrated hydrogen storage enclosure and chassis using composite materials, optimized for both low and high-volume automotive production.

Objectives

- Determine the distributed loads based on the proposed geometry.
- Investigate the properties of fibers, resins, and laminates to select suitable materials.
- Perform laminate analysis to verify the mechanical integrity and compliance with requirements.
- Optimize the structure through iterative design.
- Evaluate manufacturing strategies including cost, Eco-audit, and joining techniques.

Methodology



Hydrogen Tanks

Four type IV tanks (485 bar) were designed using **T1100G UD CF** and **TC380 epoxy resin**, offering high strength and durability [3] [4]. The HDPE liner ensures hydrogen compatibility and gas containment [5]. The symmetric stacking sequence [90 / 45 / −45]s was applied, with 8.16mm thickness. **Filament winding** was used for its precision and suitability for cylindrical structures [6]. This configuration was implemented for both low- and high-pressure applications.

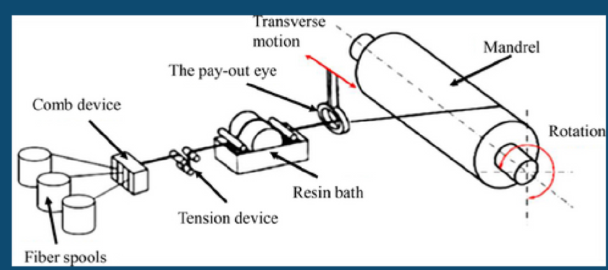
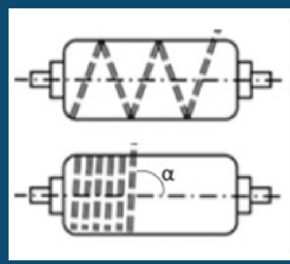


Fig. 2. Filament winding process [7].



90°	Hoop stress resistance	Main load direction, maximizes burst strength
±45°	Shear, torsion, axial balance	Improves shear handling, laminate balance, and fatigue strength
No 0°	Not practical in winding	Replaced by ±45° to simulate axial load handling

Table 1. Fiber winding angles and their structural roles

T1100G UD CF	Structural reinforcement	Very high tensile strength and strain-to-failure; excellent strength-to-weight ratio for high-pressure applications [3].
TC380 Epoxy Resin	Matrix / Load transfer	Offers fatigue resistance, low moisture absorption, and strong bonding with T1100G for structural integrity [4].
HDPE Liner	Internal barrier / Gas containment	Prevents hydrogen permeation, resists corrosion, and is lightweight and cost-effective for liners [5].

Table 2. Selected materials and their functions.

Low Volume Enclousure

Materials

12 layers of prepreg CFRP fibers with epoxy resins, mated to a nomex core (Fig. 3) were used:

HS0838, 8020 Prepreg [8]	Twill prepreg CFRP	High Tensile Modulus, contributes mostly to bending and torsional rigidity.
P173EBN-7, 3960 Prepreg [9]	UD prepreg CFRP	Low Tensile Modulus, contributes mostly to torsional rigidity and aids maintaining low weight.
HRH-10 Nomex [10]	Honeycomb nomex core	Reduces laminate weight while improving the bending stiffness and increasing moment of inertia

Table 3. Low volume enclosure materials.

In order to achieve the enclosure design requirements, a [+45,-45,-45,+45,0,+45] lay-up was used.

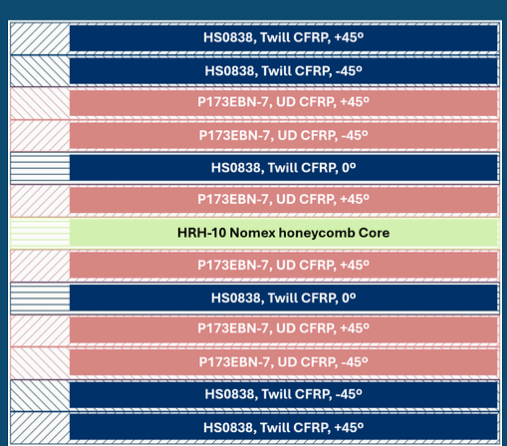


Fig 3. Low volume lay-up.

Manufacturing

In order to ensure both excellent quality and adequate production costs, hand lay-up was chosen as the manufacturing method [11].

With a curing time of 67.5 hours and a yearly target of 20 units, 1 production line is sufficient to meet demand.

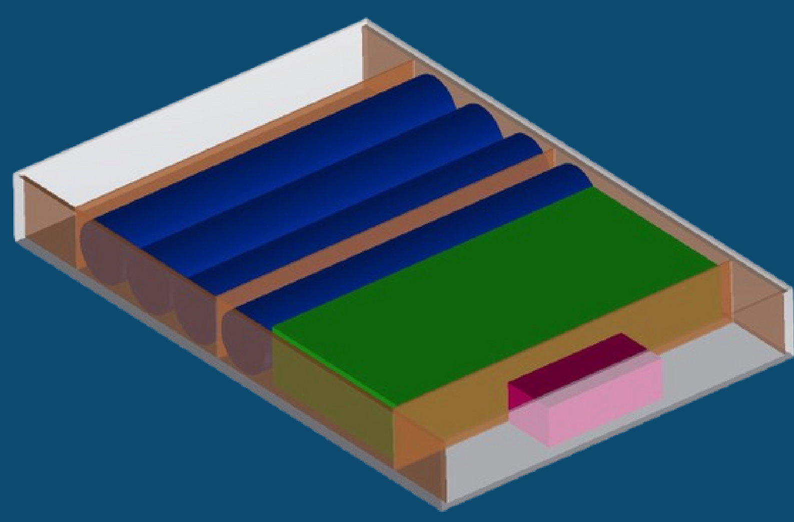


Fig. 5. CAD Model of the Structural Enclosure Assembly

Fig. 6. Top View Schematic of Component Layout within the Enclosure

The enclosure's internal layout was designed based on insights from academic research and practical fuel cell vehicle implementations. The configuration was guided by considerations of safety, packaging efficiency and component integration [12].

High Volume Enclousure

Materials

The lay-up of the sandwich structure is as follows:

- **Twill (M46JB, TC 346 prepeg)** [13] is used on the outermost layers (plies 1 and 13) to provide balanced in-plane shear strength.
- **Unidirectional T800s-24K** [14] prepeg is placed between Twill layers an the core, oriented at ±45°, to offer high stiffness and strength in critical loading directions.
- **5056 Aluminium Honeycomb** [15] core is used at the center to maximize out of plane stiffness and energy absorption while minimizing weight.

Manufacturing

Reinforced Reaction Injection Moulding (RRIM) was selected due to its suitability for producing lightweight, high-strength parts with complex geometries. The process offers fast cycle times, good surface finish, and allows for fiber reinforcement integration [16]. With a curing time of 20.47 hours and a yearly target of 20,000 units, at least 47 production lines are needed to meet demand.

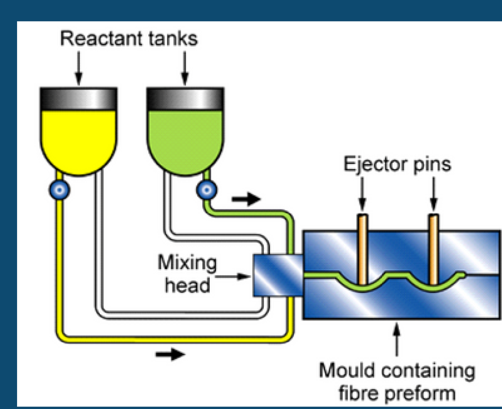


Fig. 7. Diagram of the RRIM process with fibre preform mould.

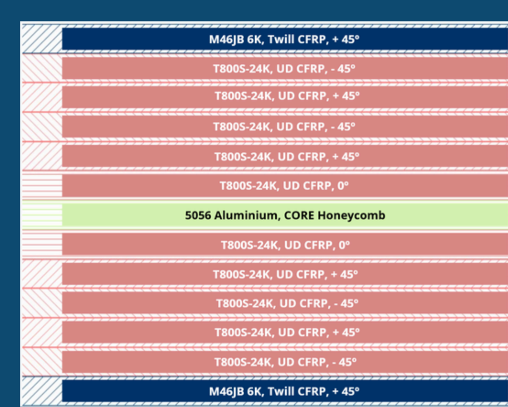


Fig. 8. High Volume Lay-Up.

Low Volume Reinforcements

Materials

- The Material **TC346 M46J** is used for the laminate, with 66% fiber volume, which delivers compression properties while keeping high fracture toughness.
- Front impact structures are 14.52mm thick (2 reinforcements) with 4.956 mm deflection and side structures are 6.733mm thick (3 reinforcements), deflecting 4.9mm, remaining within the deflection target.

Manufacturing

Autoclave manufacturing method is used to obtain high-quality laminates utilizing precise heat and pressure ensuring structural strength at low cost. Resin cure procedure is 2 hrs at 180°C (356°F) at 2°C/min.

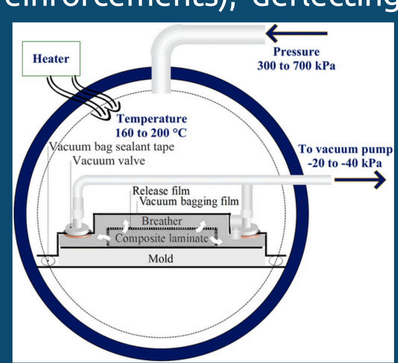


Fig. 4. Autoclave schematic process [17].

High Volume Reinforcements

Materials

- **TC380 T1100G** [3] [4] is used for high volume production of laminates which has high tensile strength that withstands the external forces.
- The front impact structures are 17.92mm thick, with 2 reinforcements and the side impact structures are 8.12mm thick, with 3 reinforcements. A deflection of 4.963 mm and 4.9 mm, respectively, has been achieved.

Manufacturing

Compression molding is used ensuring consistent results with avoiding the risk of void formations and to strengthen the laminate while minimizing cost and material waste [18].

The curing is done at the temperature of 150 degrees at 30 minutes cycle

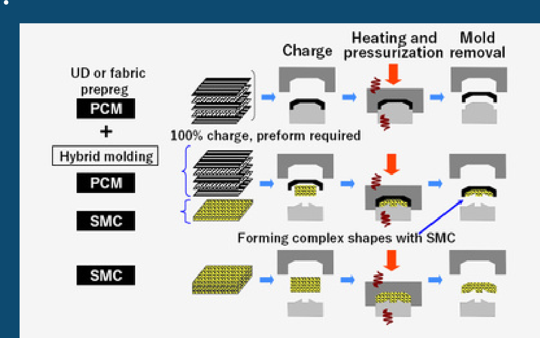


Fig. 9. Compression molding process.

Assembly

The number of bolts required for the enclosure was determined considering shear flow generated by both bending, (Nxx, Nyy) and torsion (Nxy) loads. Bending shear flow defined the fastener distribution along the top and the bottom panels in both longitudinal and transverse directions, while torsional shear flow governed the bolt layout along the perimeter of the front and rear faces. The total number of bolts required to ensure structural integrity is **114 M10 bolts (Grade 10,9)**.

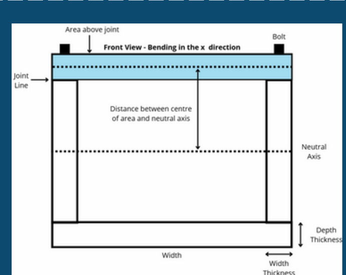


Fig. 10. Shear Flow Due to Bending – X Direction Analysis.

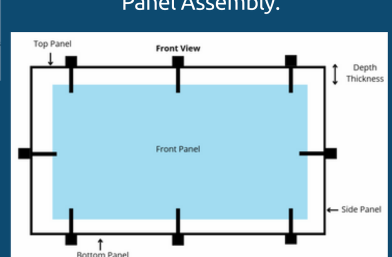


Fig. 11. Bolt Layout for Front Panel Assembly.

Fasteners are secured into the CFRP-honeycomb sandwich panel, which requires the use of specialized inserts to prevent local crushing or delamination of the core. **Aluminium edge inserts** are employed at lateral interfaces, providing continuous load paths and improved edge bearing strength [19]. For the top and bottom faces, **aluminium potted inserts** are installed through the sandwich thickness, ensuring reliable load transfer while preserving panel stiffness and integrity [20].

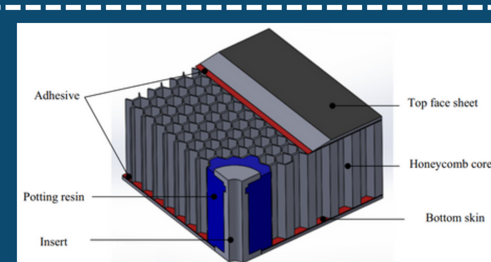


Fig. 12. Potted Insert in CFRP-Honeycomb Sandwich Panel [20].

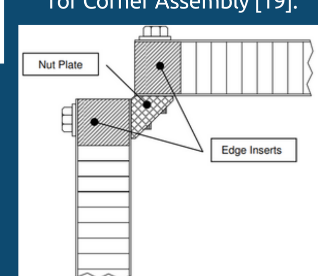


Fig. 13. Edge Insert Connection for Corner Assembly [19].

Eco-Audit

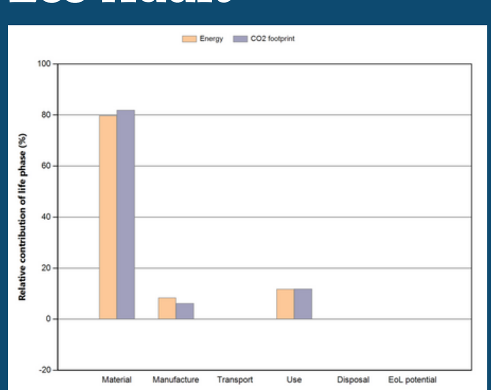


Fig. 14. Eco-Audit Analysis low volume

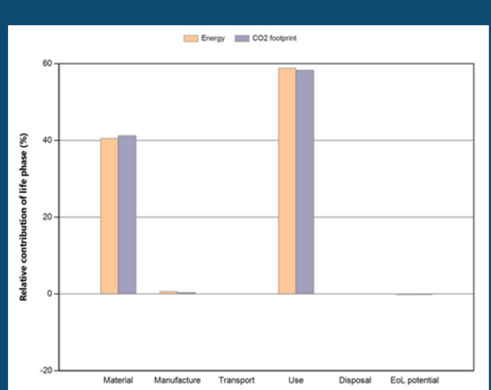


Fig. 15. Eco-Audit Analysis high volume

Low volume manufacturing

- Lifetime emissions are approximately 5,690 kg of CO_2
- Emissions during material production contributes to over 80% of the total footprint.

High volume manufacturing

- Lifetime emissions are approximately 12,500 kg of CO_2
- 15 years of estimated use produces 7,300 kg of CO_2 making up over half of the overall footprint

Recycling potential is limited in both cases, as majority of carbon composite materials are not recyclable.

Metallic components like bolts can be recycled, contributing to small CO_2 savings in both production scales.

Manufacturing Costs

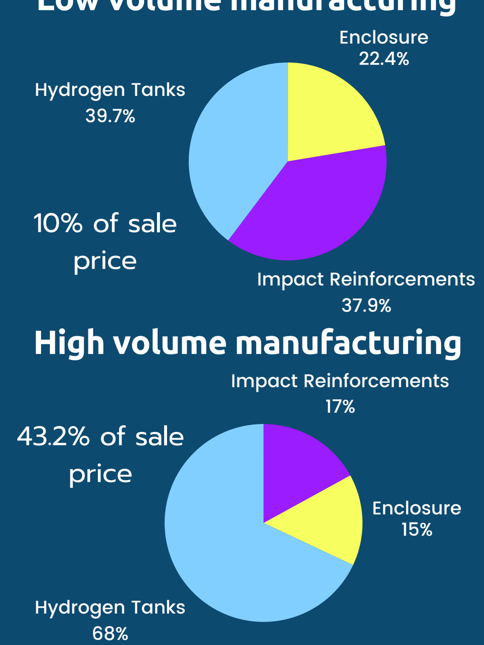


Fig. 16. Manufacturing costs for low and high production volumes.

Low volume (20 units, £250,000/car):

- Lower total cost (10% of sale price), but higher per-part costs
- Processes: hand layup (cheapest), autoclave, filament winding
- Cost distribution is more balanced across components

High volume (20,000 units, £55,000/car):

- Manufacturing cost rises to 43.2% due to tooling and automation
- Processes: injection molding, compression molding, filament winding
- Hydrogen tanks dominate the cost

Most expensive: Filament winding

Cost mitigation strategy: Use multiple lines to produce 3–4 tanks at once.

Conclusions/Summary of Findings

This poster details the design of an integrated hydrogen enclosure and the findings are presented:

- Four Type IV hydrogen tanks, each with a wall thickness of **8.16 mm** and a weight of **42.7 kg**, are used and operated at a pressure of 485 bar.
- Chassis enclosures are designed using different CFRP materials and honeycomb structures, and accounts to a weight of **19.10 kg** with a thickness of **12.494 mm** in low volume and **22.83 kg** with a thickness of **12.5 mm** in high volume production.
- **Two** front and **three** side reinforcements with different dimensions are used for both volume productions.
- Total weight is **94.87 kg** for the low volume design and **102.27 kg** for the high volume design, meeting the targets regarding safety, legislation, packaging, production rates and service conditions.

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