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Bachelor's Thesis, Semesterarbeit, Master's Thesis

Mechanical and Permeation Characterizations of CFRP Composite Manufactured using Different Methods – Application of Cryogenic Tank Design

Cryogenic tanks are designed to store fuels, such as liquid hydrogen, at extremely low temperatures. Their design requires specialized considerations to account for mechanical loading and physical constraints, particularly those related to gas diffusion and permeability. The overall tank system design is strongly influenced by the selected manufacturing process, which is chosen based on geometric complexity and intended industrial application. Among the available fabrication methods, Filament Winding, Resin Transfer Molding, and Automated Fiber Placement (AFP) are commonly employed for the high-quality production of composite storage systems. These manufacturing techniques play a critical role in tank design, as they significantly influence the resulting composite material properties and, consequently, the structural behavior of the tank. Variations in manufacturing processes lead to differences in lamina and laminate microstructures, resulting in varying mechanical and physical properties, which in turn strongly affect the gas diffusivity and permeability of the tank wall.

This research focuses on the mechanical characterization and permeability analysis of carbon fiber–reinforced polymer (CFRP) composite structures fabricated using Automated Fiber Placement (AFP) and prepreg hand lay-up methods, both of which are widely recognized as effective manufacturing techniques for tank structures. In the AFP process, CFRP slit tapes are placed with controlled in-plane gaps to form individual laminae, which are subsequently stacked to produce a laminate. In contrast, prepreg hand lay-up laminates are constructed from fully impregnated prepreg plies with no intentional in-plane gaps, which are simply stacked to form the composite laminate. As a result of these distinct fabrication approaches, significant variations in mechanical properties - particularly matrix - dominated properties such as transverse tensile and compressive strengths and in-plane shear behavior as well as gas diffusivity and permeability are expected. Accordingly, this study emphasizes the importance of understanding: (1) laminated composite manufacturing processes, (2) standardized mechanical testing methods for composite materials, and (3) gas permeation testing techniques.

Figure: H2 Tank

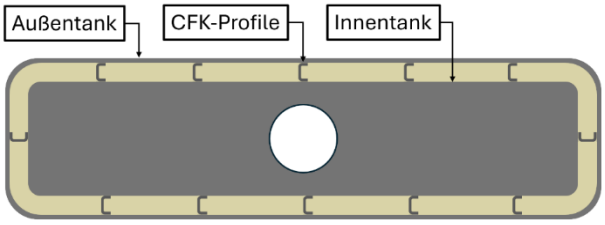

Figure: Cross Section of the Tank

Focus of the Thesis

- literature review on the mechanical characterization of CFRP using different production methods as well as gas permeation and permeability analysis of CFRP.
- Design experimental test plans, manufacture CFRP plates using different fabrication methods, and prepare standardized test specimens.
- Carry out mechanical and permeation experiments and perform limited parametric studies to assess the influence of key manufacturing variables.
- Analyze and evaluate the experimental results from mechanical and permeation testing, followed by critical discussion and documentation of the findings.

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