Chair of Carbon Composites
TUM School of Engineering and Design
Technical University of Munich

Term Paper, Master's Thesis

Life Cycle and Cost-Benefit Analysis of Thermoplastic Type-4 Pressure Vessels for Hydrogen Mobility

Hydrogen is a cornerstone of sustainable mobility, especially in the automotive sector where long driving ranges, fast refueling, and zero local emissions are key advantages. A central component enabling this technology is the high-pressure storage vessel, which must withstand operating pressures of up to 700 bar while remaining lightweight to ensure vehicle efficiency. Today, this requirement is met by Type-4 pressure vessels, consisting of a polymer liner reinforced with carbon fibers. Conventional wet-winding manufacturing processes, however, are time-intensive and poorly recyclable. To achieve mass production and improved sustainability, alternative processes are needed. Advances in thermoplastic composites, particularly dry winding combined with thermoplastic resin transfer molding (T-RTM), present a promising solution. These innovations enable significant reductions in cycle times and costs, making them more competitive for large-scale automotive applications. In addition, they allow the production of fully recyclable Type-4 vessels using a mono-material design of Polyamide 6 (PA6) reinforced with carbon fibers. Unlike thermosets, which are difficult to recycle, thermoplastic composites can be repurposed in secondary applications such as additive manufacturing, greatly increasing their potential for resource efficiency and circular economy integration.

In this thesis, the goal is to assess thermoplastic Type-4 hydrogen pressure vessels by combining a Life Cycle Assessment (LCA) with an economic evaluation of the complete T-RTM production chain, including liner production, winding, injection, and recycling. The study will quantify CO_2 emissions, energy demand, and cost structures, and compare the results with conventional reference tanks. In doing so, the thesis aims to provide a clear picture of both the economic viability and the environmental sustainability of this technology, thereby demonstrating its potential role in advancing hydrogen mobility within a circular economy.

Figure 1: Drive system of the BMW iX5 Hydrogen [bmwgroup.com]

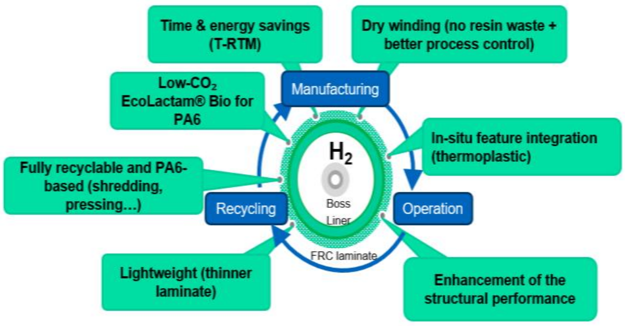

Figure 2: Lifecycle Benefits of Thermoplastic Type-4 PVs

Research focus of the thesis

- LCA : CO_2, energy use, and environmental impacts of production and recycling.
- Cost-benefit analysis of the T-RTM process chain and comparison with reference tanks.
- Integrated sustainability assessment combining technical, economic, and ecological factors.

Requirements

- Reliable, analytic and independent way of working (full-time remote work is not possible).
- Good knowledge on polymer matrix composites.
- Basic knowledge of LCA and sustainability concepts or willingness to acquire it.
- Experience with programming and data processing is beneficial (e.g. Excel, Python, LCA software).

Starting date: October 2025 onwards

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