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

Bachelor's Thesis, Term Paper

Experimental Characterization and Process Investigation of Thermoplastic Type-4 Pressure Vessels Produced by T-RTM

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 focus lies on the experimental characterization of thermoplastic Type-4 PVs produced by T-RTM. Several vessels from previous production runs will be systematically examined to assess their impregnation quality, laminate integrity, and interfacial bonding. The characterization will follow an iterative process, beginning with visual inspection and microscopy, and extending to additional characterization methods as guided by the initial findings. The study aims to investigate how process parameters influence the material structure—including features like porosity, voids, and fiber waviness. By correlating these observations, the work will provide an improved understanding of the impregnation behavior in T-RTM-manufactured vessels and deliver practical insights for optimizing future production trials of thermoplastic hydrogen PVs.

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

Figure 2: Cross section of Thermoplastic Type-4 PV

Research focus of the thesis

- Characterization of Type-4 PVs regarding impregnation quality, laminate integrity, and bonding.
- Microstructural analysis of defects, fiber waviness, and dry spots via visual inspection & microscopy.
- Correlation of process parameters with material structure to explain impregnation behavior.

Requirements

- Hands-on, reliable, and precise working style with proven experience in a lab. or workshop environment.
- Excellent knowledge of polymer matrix composites and composite characterization methods.
- Strong analytical skills and ability to interpret experimental data independently.
- Interest in process–structure relationships and willingness to work closely with testing equipment.

Starting date: As soon as possible

For more details please contact:
Cagla Sipahi, Room 5504.01.404, Fakultätsgebäude MW, Tel. +49 89 / 289 - 15203, cagla.sipahi@tum.de