Innovative Mandrel Design and Development for Future-ready Type V Hydrogen Pressure Vessels

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DigiTain

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AERO HYDROGEN & BATTERY SUMMIT

Universität der Bundeswehr München Professur für Verbundwerkstoffe und Technische Mechanik

Agenda

- Introduction
- Projects
- Hydrogen for Aerospace
- Overview
- Motivation
- Concept
- Preliminary results
- Conclusion
- Further Steps

Introduction

Akshay Deshmane, M.Sc. (Product Refinement Focus on Materials)

Research Assistant (Mandrel and Tank development)

Prof. Dr-Ing. Tobias Dickhut

Chair of Composite Materials and Engineering Mechanics

Institute of Aeronautical Engineering

University of the Bundeswehr Munich

Projects

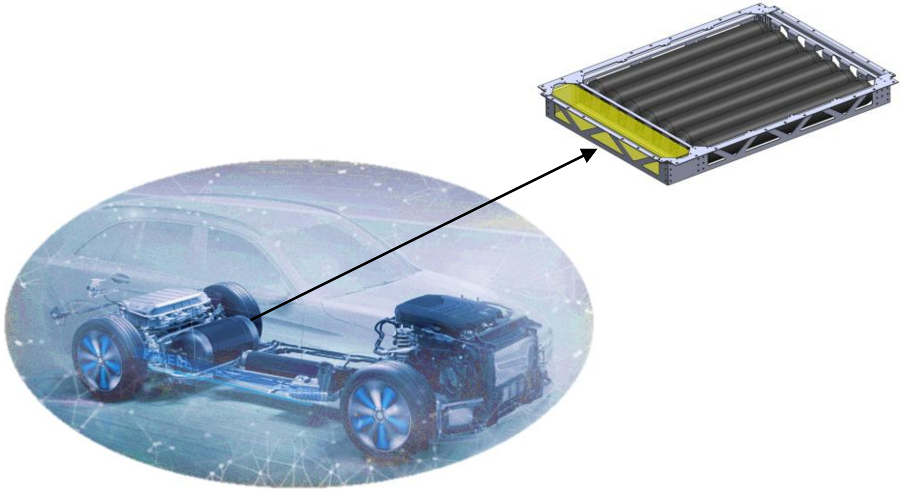
- **CHiLL**
  - Development and qualification of a volume-scalable secondary tank family (type 5) made of FRP for use in microlaunchers/ satellites
- **INTAKT**
  - Development of a multi-layer type 5 tank wall concept for LH2, which allows partial and controlled H2 permeation to occur
- **SeRANIS**
  - Development of a high-pressure xenon tank made of FRP with integrated functional layers as a diffusion barrier
- **DigiTain**
  - Development of a high-pressure 700 bar gaseous hydrogen tube accumulator for the automotive industry
- **CHoSe**
  - Development of a non-cylindrical cryogenic hydrogen tank including sealing and insulation layers for space-adapted applications and the absorption of structural loads
- **MODULOX** ✓
  - Construction of a newly developed, modular LOX test rig including infrastructure for investigating external influences and the reaction mechanism in liquid oxygen
- **CryoFuselage** ✓
  - Development and qualification of a cryogenic low-pressure LH2 tank made of FRP with functional integration in load-bearing fuselage structure for aircraft

DigiTain - Digitization for Sustainability

- Objective
  - Road approved linerless Type V H_2 tank for automobile

- Focus
  - Leakage control
  - Cost-effective integrated mandrel concept

DigiTain



Gaseous Hydrogen for Aerospace

- Mature Technology – Proven in Automotive Industry (700 bar)
- Easy Integration – No Cryo Handling
- Fast refueling
- Prototyping ready – Used in HY4, ZeroAvia
- Validated safety

Source: Image left : H2FLY ; Image right: ZeroAvia

Overview

Type I

Full metal tank

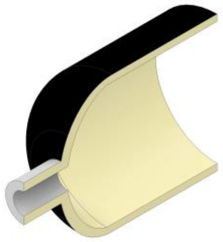
Type II

Metal liner + Composite Hoops

Type III

Metal liner + Composite Overwrap

Type IV



Polymer liner + Composite Overwrap + Metal Boss

Type V

Full Composite + Metal Boss

Type V tank

- Lightweight Design - up to 30% weight reduction (1)
- Improved storage efficiency
- Design Flexibility
- More complex tooling
- Expensive

Type V

Full Composite + Metal Boss

1. https://www.hydrogen.energy.gov/pdfs/15013_type_v_tanks.pdf

Motivation

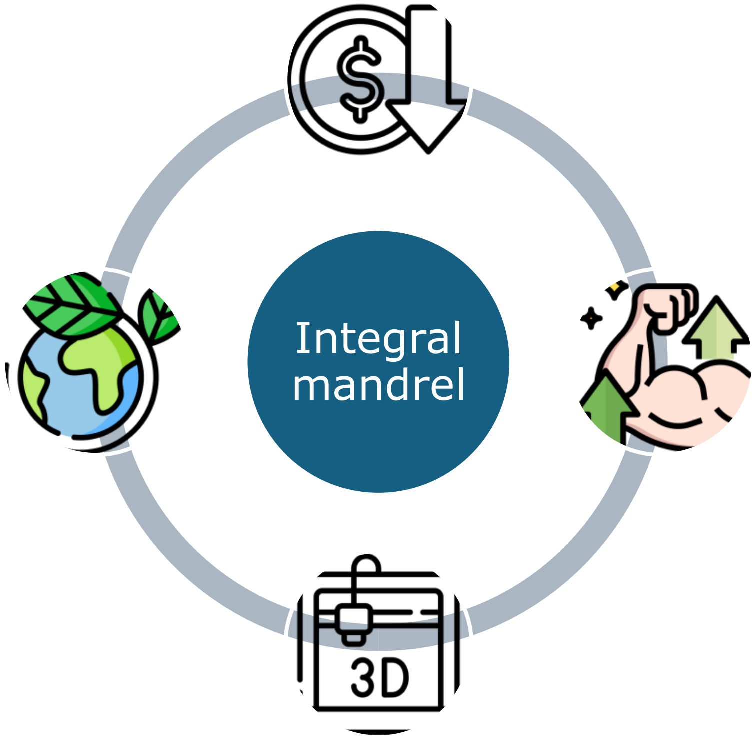
Water Soluble Mandrels

- Sand/Plaster
  - Cracking of the mandrel
  - Heavy – Handling is difficult

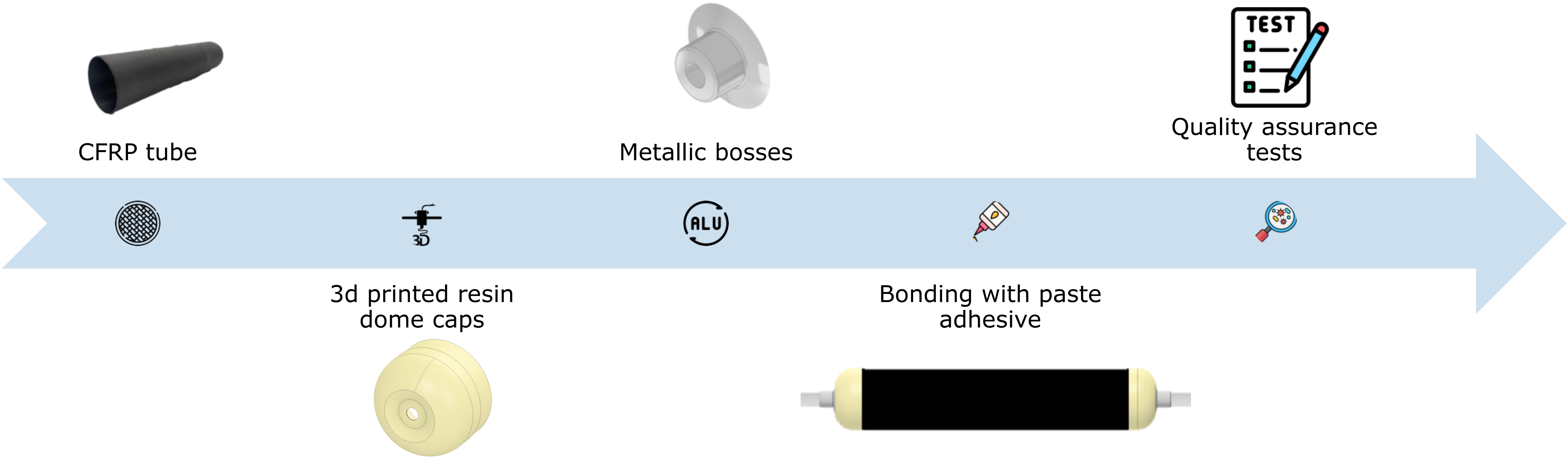
- 3D printed mandrels
  - In certain cases, disintegration/softening during curing process
  - High cost

Concept

- **Integral Mandrel Concept**
  - Partial load carrying
  - Rapid prototyping
  - Easy integration
  - No complex manufacturing
  - Cost effective



Workflow – Integral Mandrel

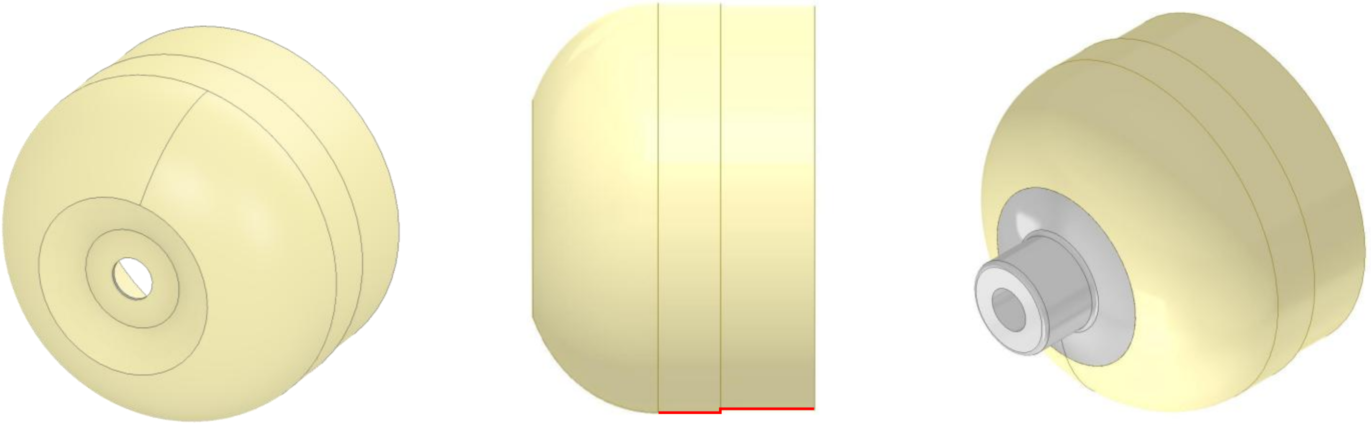


CFRP Tube

- Layup: +/-/+ hoops
- Length: 1050 mm
- Inner Diameter: 135 mm
- Commercial towpreg with T700 24K fibers

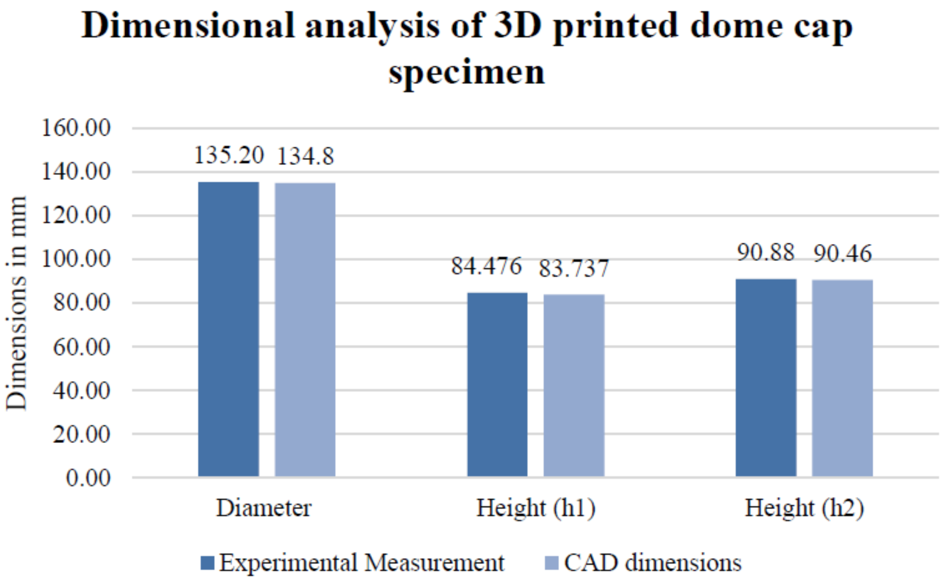
Dome and Boss

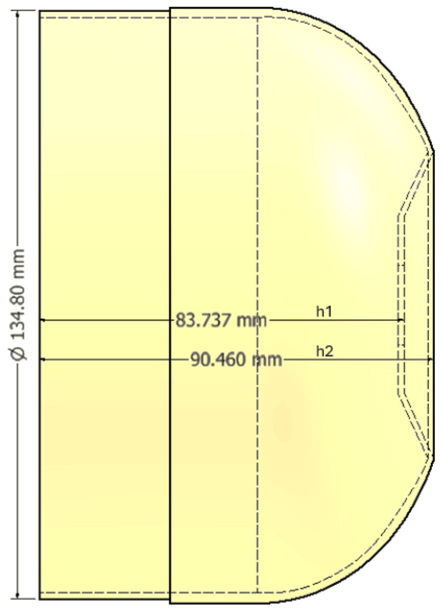
- Custom Dome and Boss geometry
- 3d printing (SLA) domes
- Slit for sliding dome into the CFRP tube
- Slot for boss attachment



Preliminary tests: Dome

- Visual Inspection
  - Surface defects in initial prints
- Dimensional variation
  - Less than 1%
- 3 Dome samples were measured and below are the average results



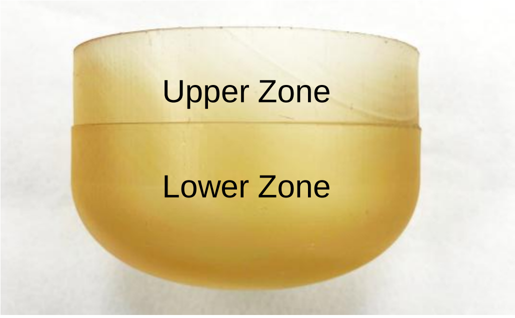


Preliminary tests: Dome

Thermal Pretest:

- Dimensional analysis after thermal exposure
- In oven at curing cycle of the towpreg
- 3 Dome samples were measured and below are the average results

Dimensions	Before thermal exposure (mm)	After thermal exposure (mm)	Change in %
Wall thickness at lower zone	1.20	1.18	1.1
Wall thickness at upper zone	1.40	1.38	1.3



Preliminary Tests: Dome

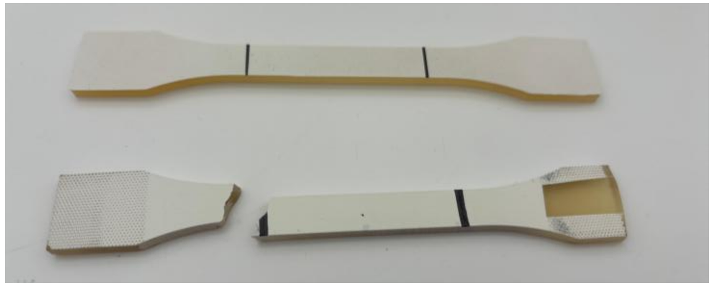
Tensile test: ISO 527-2

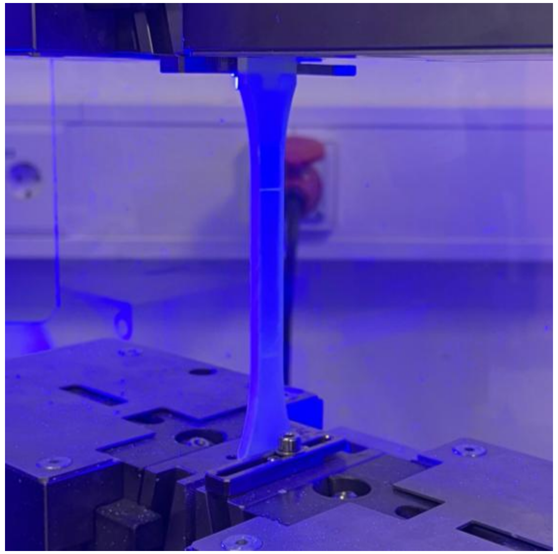
- Set 1
  - 3d printed dog bone

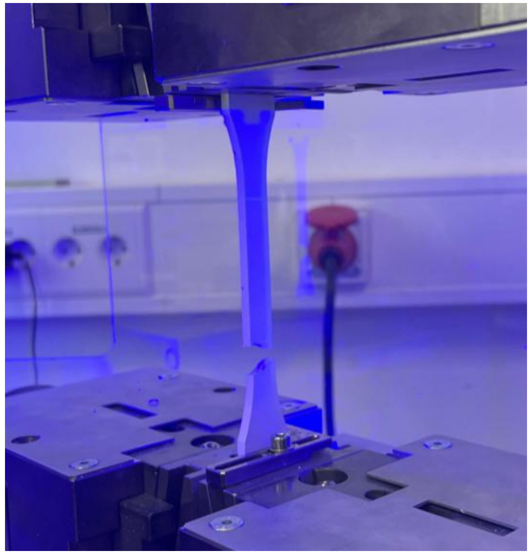
- Set 2
  - 3d printed dog bone post cured at the curing cycle of the towpreg

- Material – SLA Dome Resin

- 10 dog bone samples of each set were measured

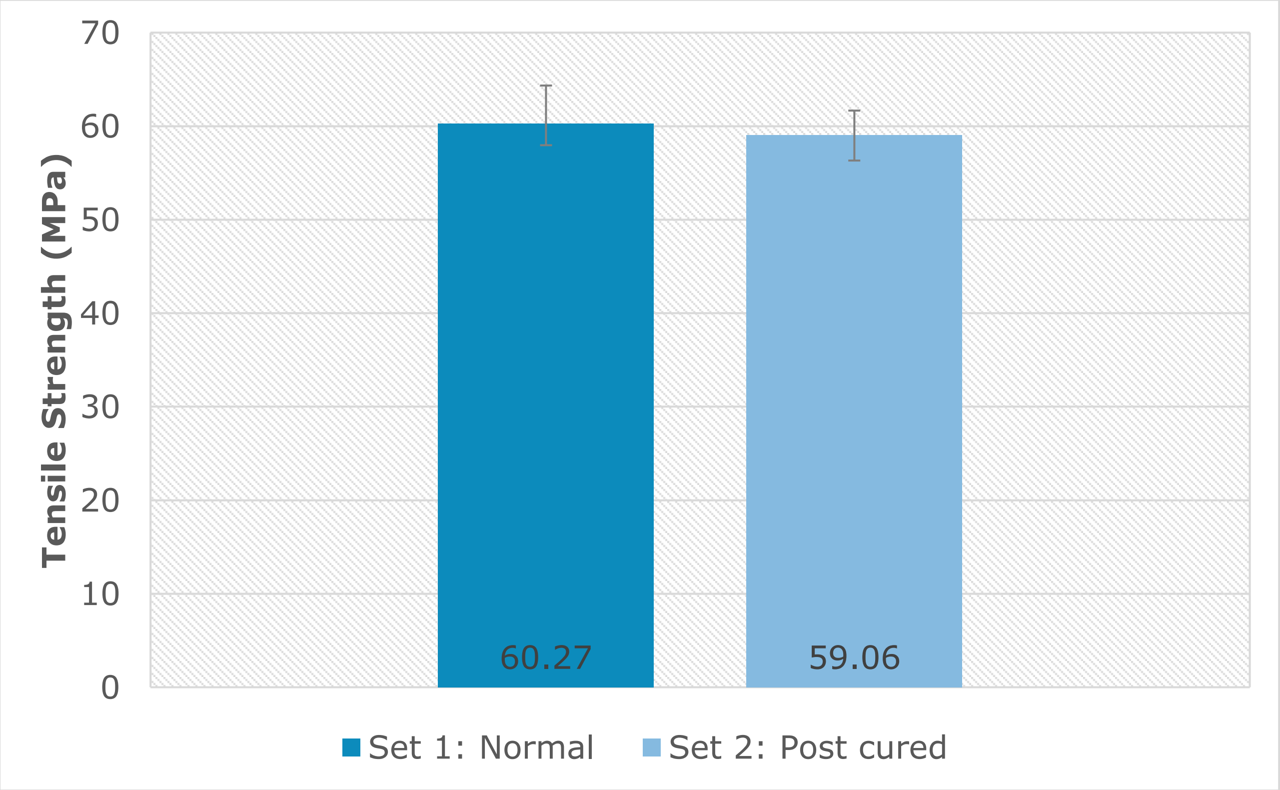






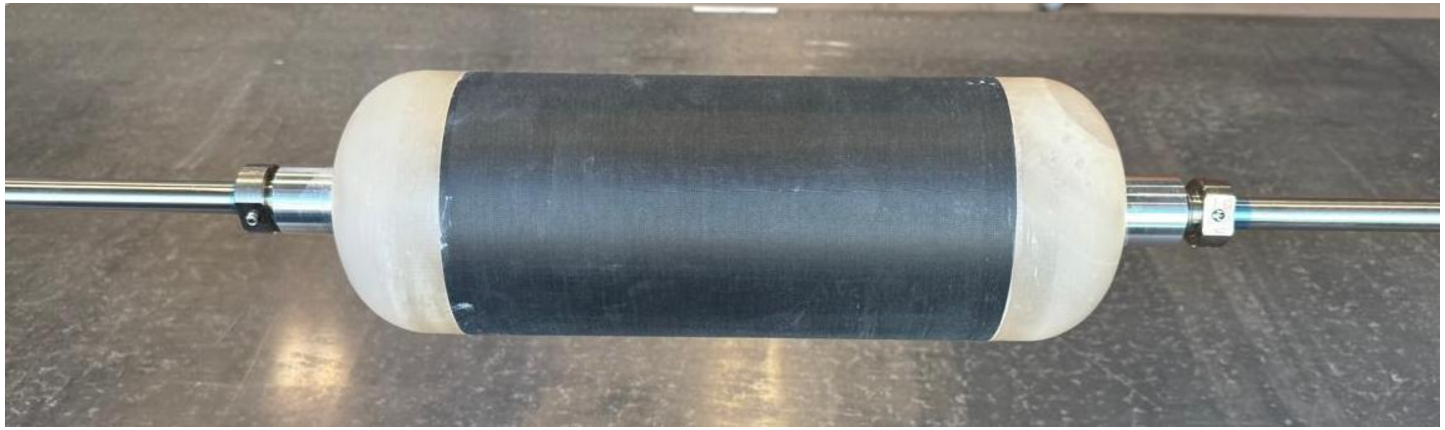
Preliminary Tests: Dome

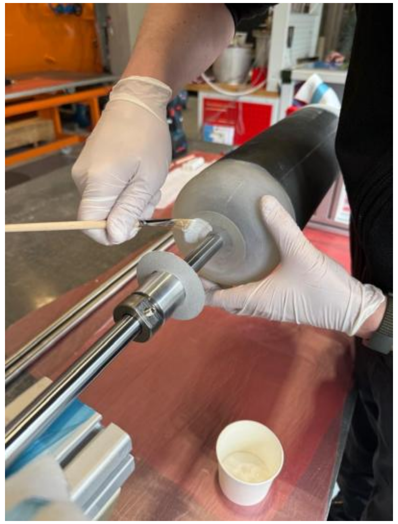
Tensile test: ISO 527-2



- Post cured samples do not show significant reduction in strength due to hardening

Manufacturing Pictures





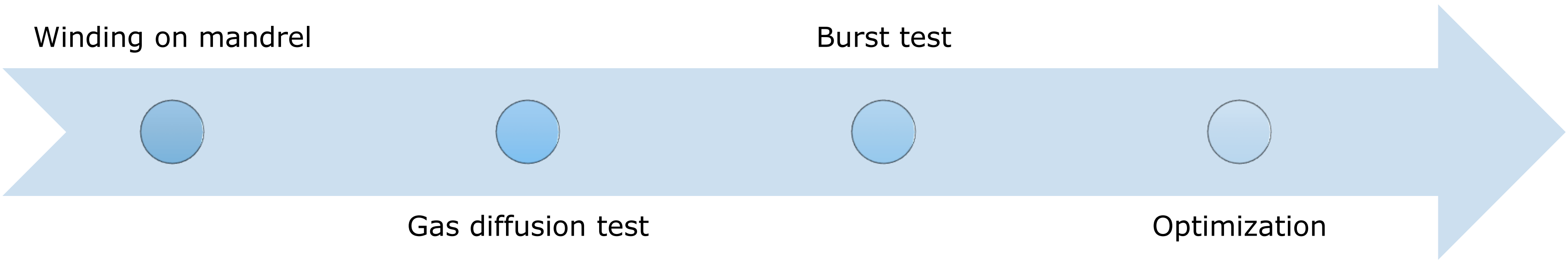
Conclusion

The integral mandrel concept:

- Lightweight
- Cost effective
- Sustainable
- Reduced number of overwrap layers

Further Steps

TO DOs



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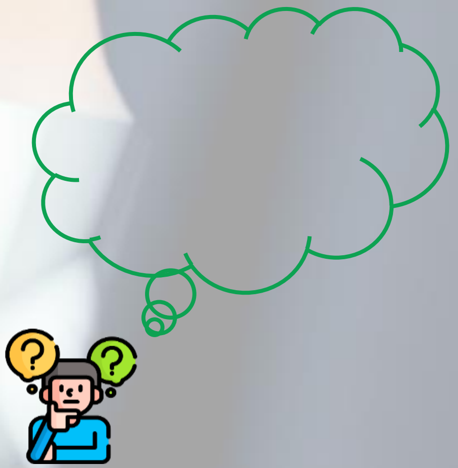
Thank you!

Anything on your mind?



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References

- https://www.flaticon.com/