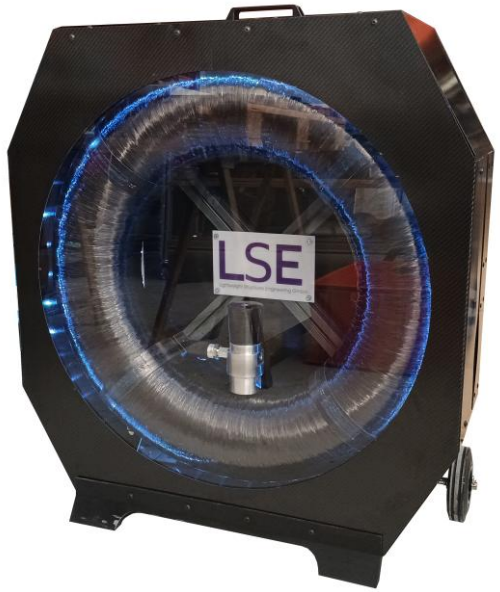
CFRP pressure vessels for mobile hydrogen storage

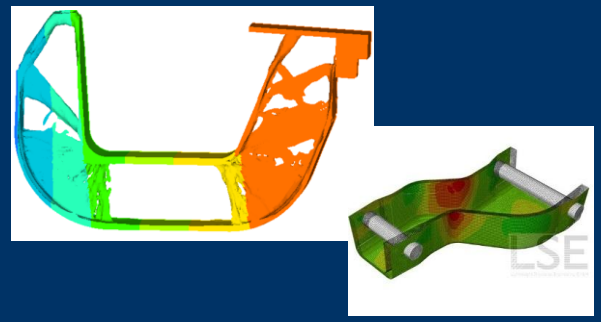


Dipl.-Ing. Norbert Schramm
Managing Director, LSE GmbH

LSE - Lightweight Structures Engineering GmbH

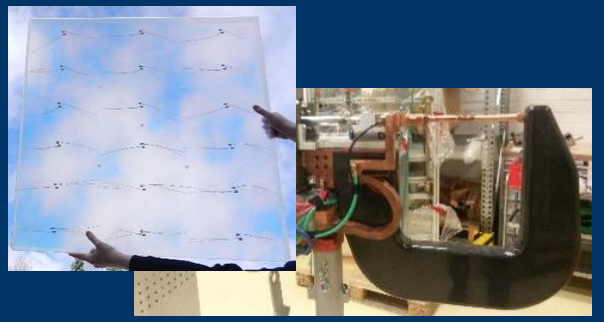
Spin-off from Chemnitz University of Technology, Department of Lightweight Structures and Polymer Technology in 2008.

Design and Simulation

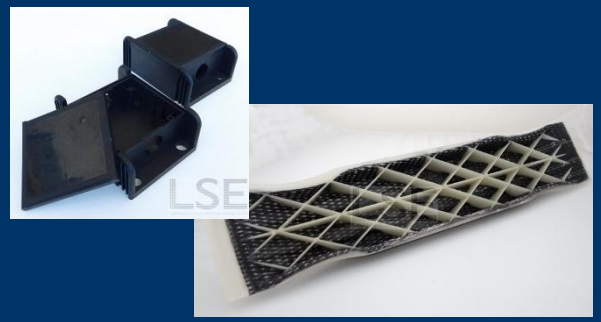


Sensor and Actuator Systems

Thermoset Composites

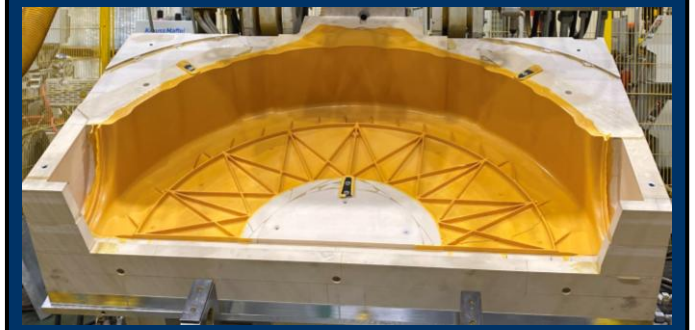


Thermoplastic Composites



Elastomer Material

Tool & Mold Manufacturing



Motivation for a toroidal composite pressure vessel

- Fuel cells as an emission-free and ecologically balanced engine are increasingly being used for electric vehicles and mobile power generators
- FAE Elektrotechnik GmbH & Co. KG offers a fuel cell operated mobile power generator up to 5 kW constant electrical output with a heavy steel bottle (80 kg) or an innovative hybrid bottle GENIE® (33 kg, 300 bar)

Weight ↓
Capacity ↑

Source:
FAE GmbH

- Type IV pressure vessels with an operation pressure up to 700 bar for the on-board storage of compressed hydrogen (CGH_2) are typical designed with carbon fibre reinforced polymer and a thermoplastic liner
- Market suppliers such as Hexagon Purus GmbH offers pressure vessels exclusively in cylindrical design and up to 70% of the total costs are generated by the carbon fibre material
- A toroidal composite pressure vessel offers a high lightweight and a cost-saving potential up to 30% and fit the design space of a fuel cell operated mobile power generator quite well

Source: Linde GmbH

Source: Falk Schellhorn

Motivation for a toroidal composite pressure vessel

cylindrical design

toroidal design

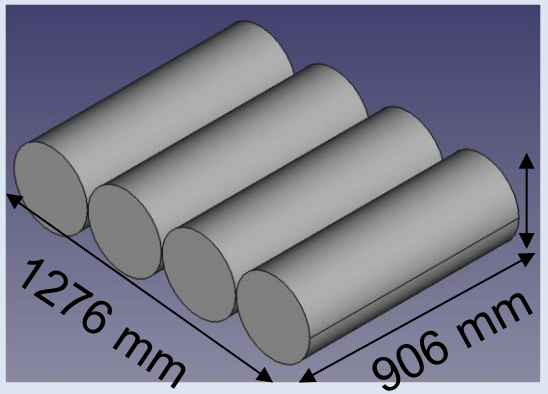
State of the art

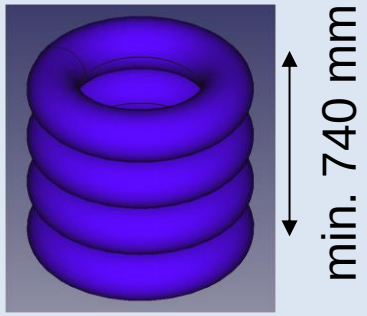
4 cylindrical hydrogen vessels
→ **144 L**

Source:
Hexagon

4 toroidal hydrogen vessels
→ **144 L**

System concept with 4 vessels





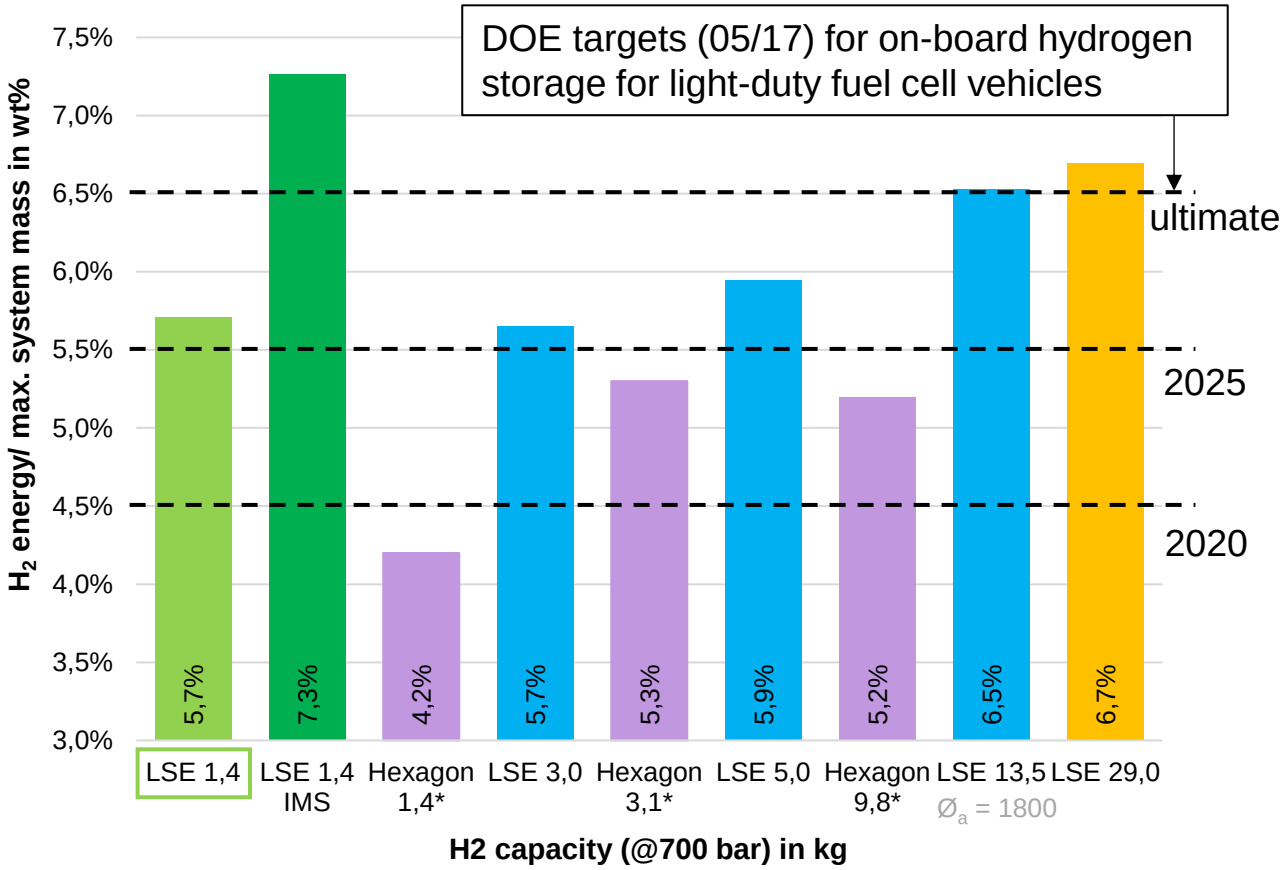
dimensions without filling insert

Comparison

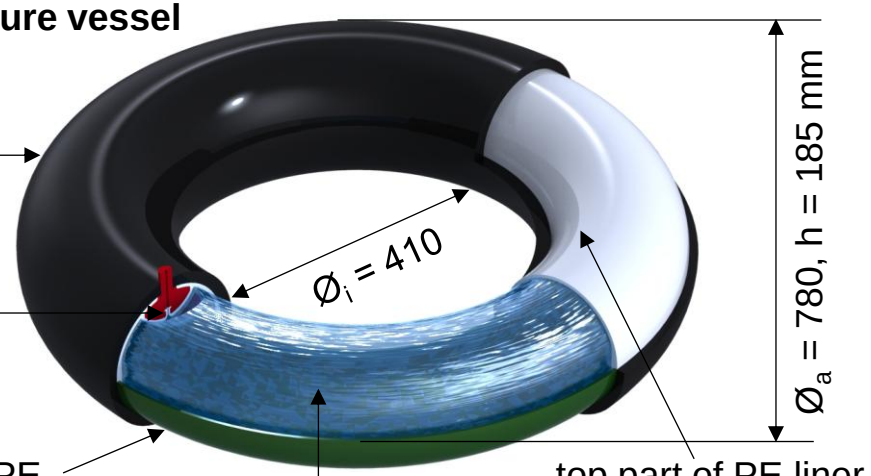
design space	system mass
0,369 m³	136 kg
-3 %	-31 %
0,358 m³	94 kg

CFRP toroidal pressure vessel for mobil hydrogen storage (700 bar)

Overview of 700 bar hydrogen CFRP pressure vessels



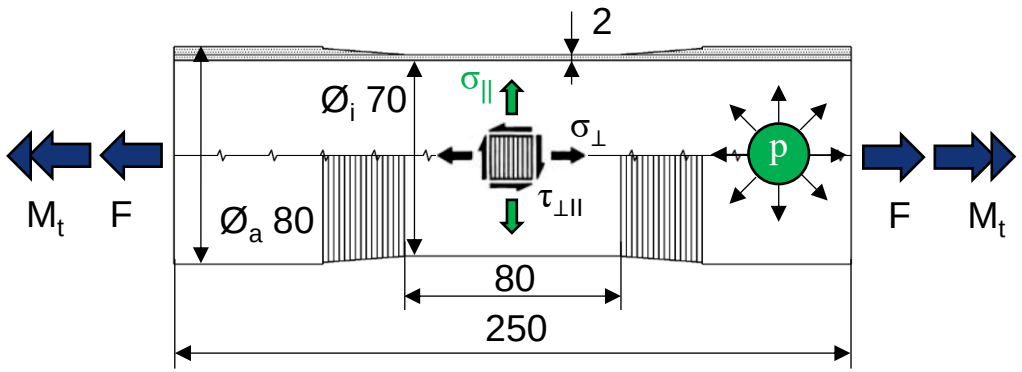
toroidal pressure vessel "LSE 1.4"



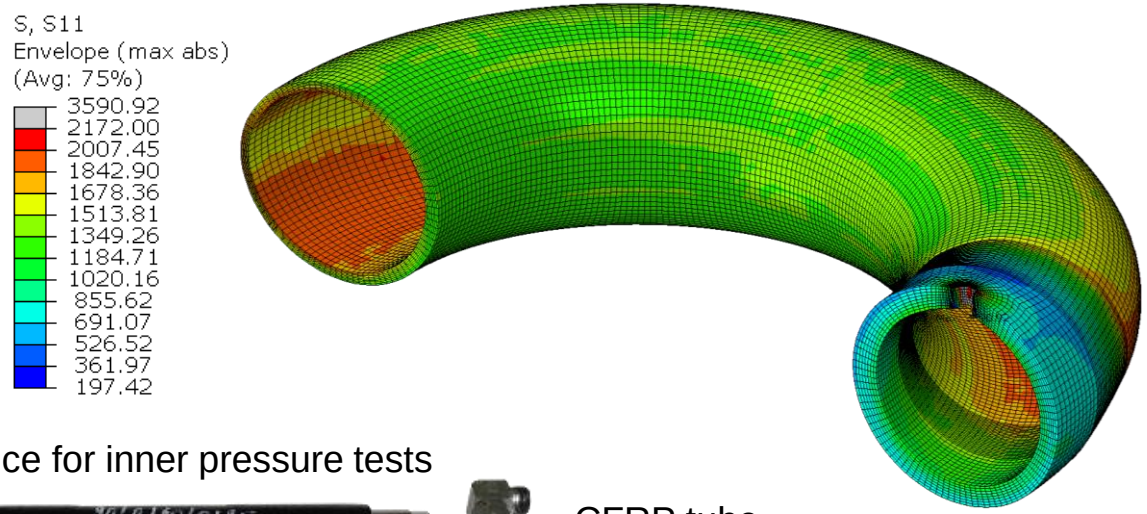
* Hexagon Purus datasheet: Hydrogen type 4 tank information, 2021.

Analysis of the mechanical properties of filament wound tube specimen

Carbon fibre reinforced epoxy:

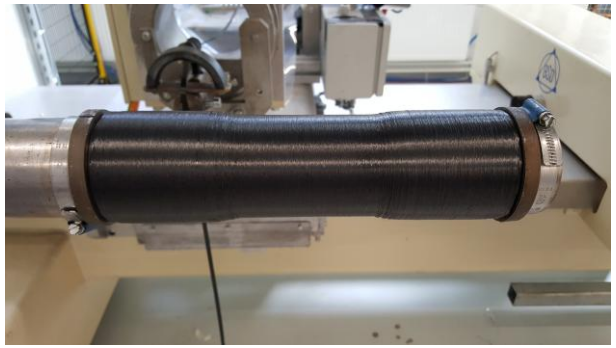


Filament wound 90º-tube specimen



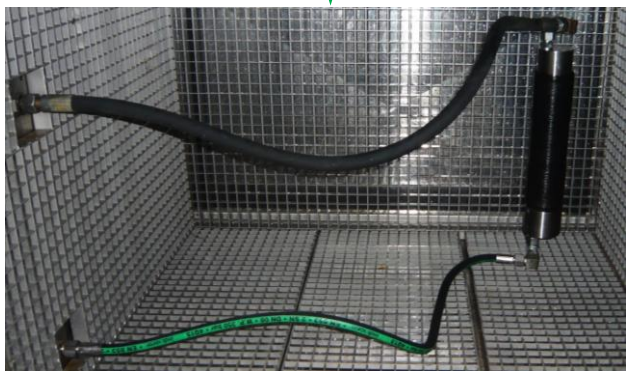
Test device for inner pressure tests

CFRP tube specimen

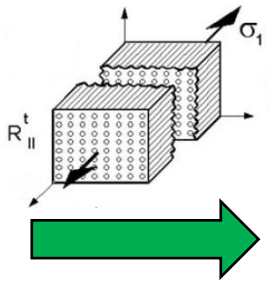


Filament winding machine Bolenz & Schäfer FWA II-4-1 with tube specimen

ZWICK universal testing machine Z250 with climate chamber



test rig with climate chamber for inner pressure

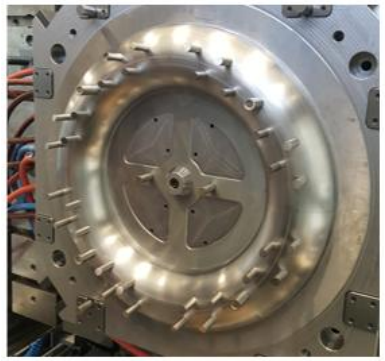


fibre tensile failure

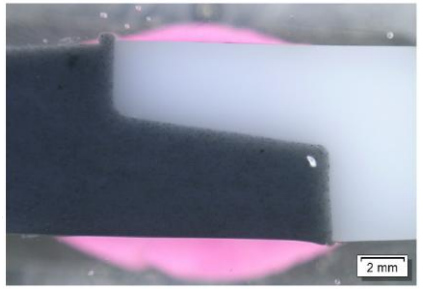
CFRP toroidal pressure vessel for mobil hydrogen storage (700 bar)

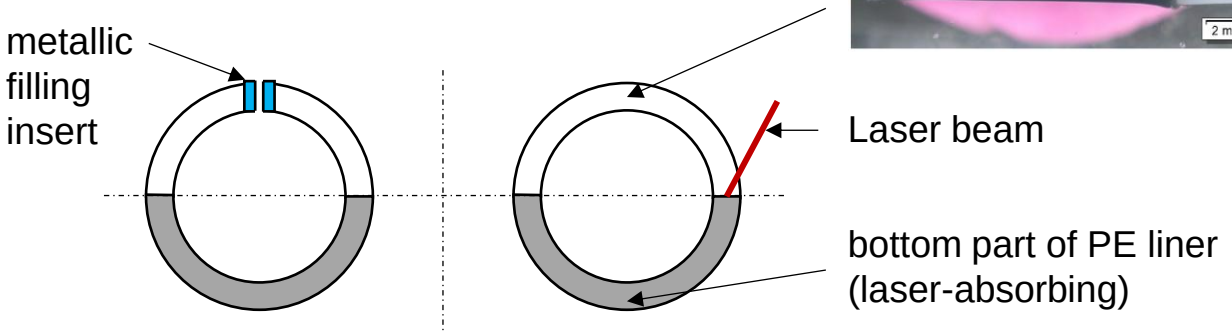
Process chain

1) Injection moulding of laser-transmitting and laser-absorbing liner components



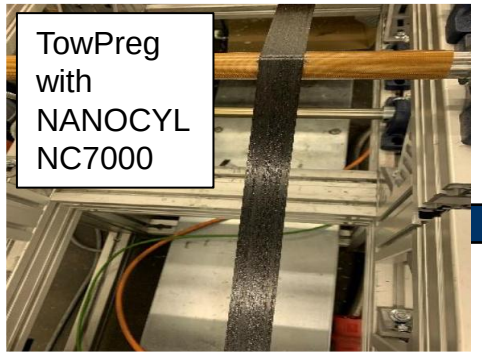
2) Laser welding of liner





cross section

3) Filament winding with TowPregs with 2%-CNT on the ring winding unit

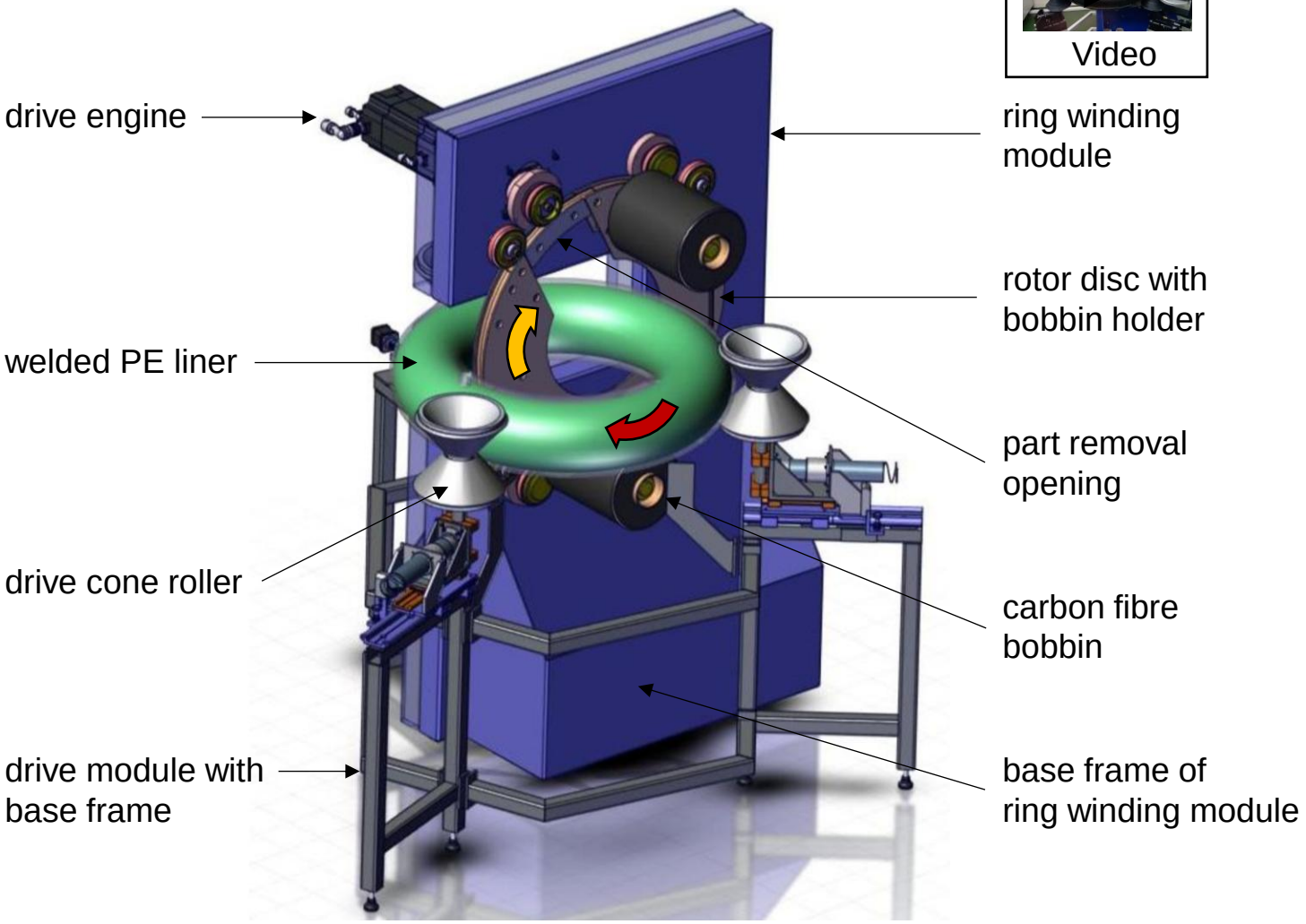


4) Curing the TowPregs in the oven

Ring winding unit

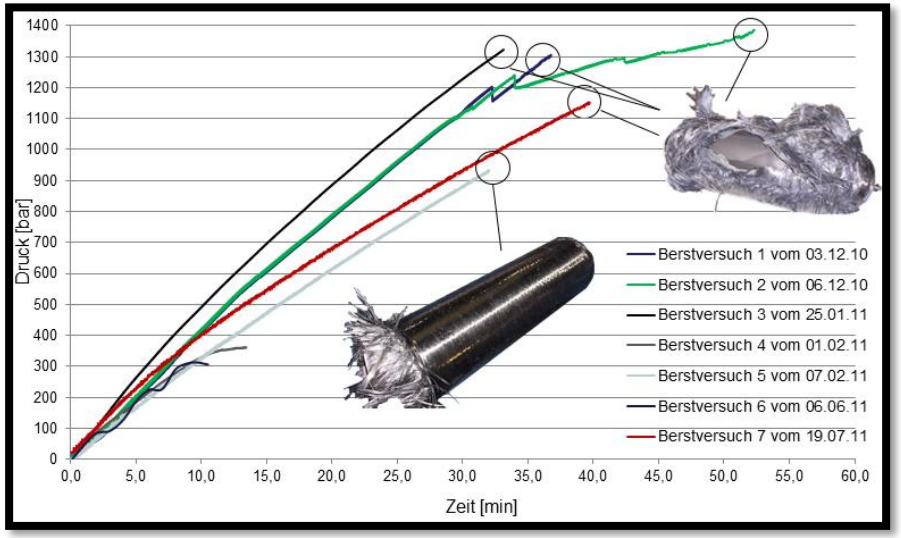
- Developed and designed by Cetex Institut gGmbH, Chemnitz
- Unit size 1450x1650x1600 mm
- Ring winding module to apply carbon fibre (2 bobbin)

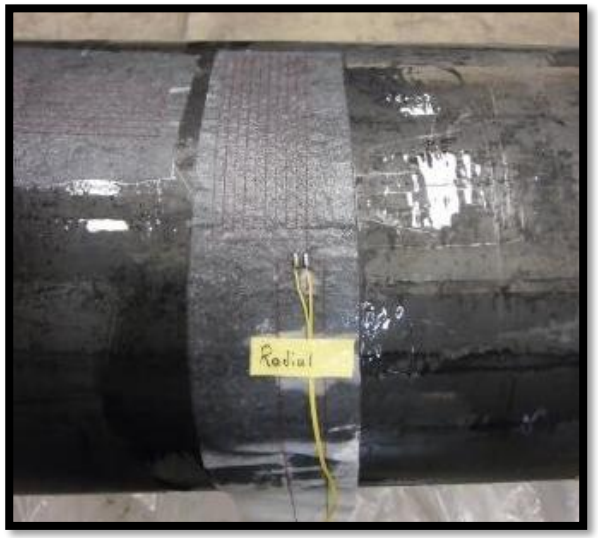

Video



Lightweight pressure vessel with steel liner (Type III)

- Design, manufacture and testing of a pressure vessel with steel liner and CFRP structure (type III)
- Burst pressure approx. 1100 bar
- Derivation of empirically determined design criteria
- Use of natural analogue optimisation algorithms for the analytical design of the FRP structure
- Integration of textile strain measurement elements (LSE)
- Application: Storage of hydrogen for transport on trailers

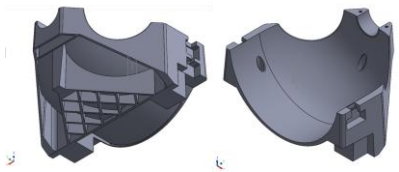




Research project „SmartHydro“ (12/2020 - 11/2023)

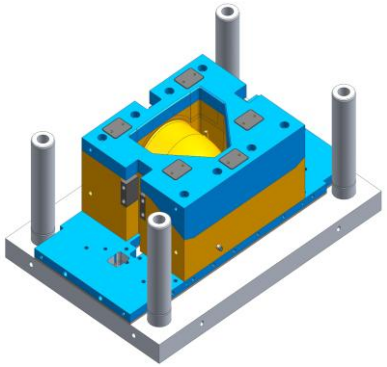
Technology development for intelligent tank carrier systems for hydrogen-powered vehicles

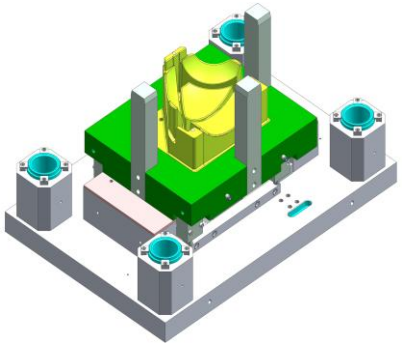
material and part development



development + construction tool

GEBR. FICKER GmbH
Formen- und Werkzeugbau seit 1911

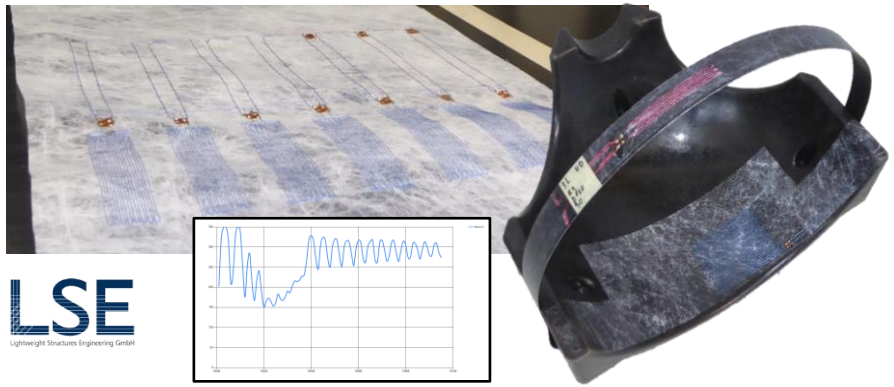




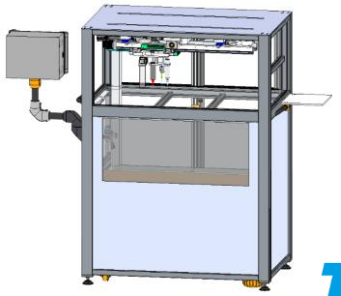
H_2-Rack busroof, 35 kg H_2

Source: https://www.spiegel.de/auto/aktuell/mercedes-citaro-fuel-cell-hybrid-hightech-bus-fuer-sauberen-oepnv-a-661575.html#fotostrecke-4cbd2d33-0001-0002-0000-000000048871

sensors + evaluation electronics



automation unit (contacting)

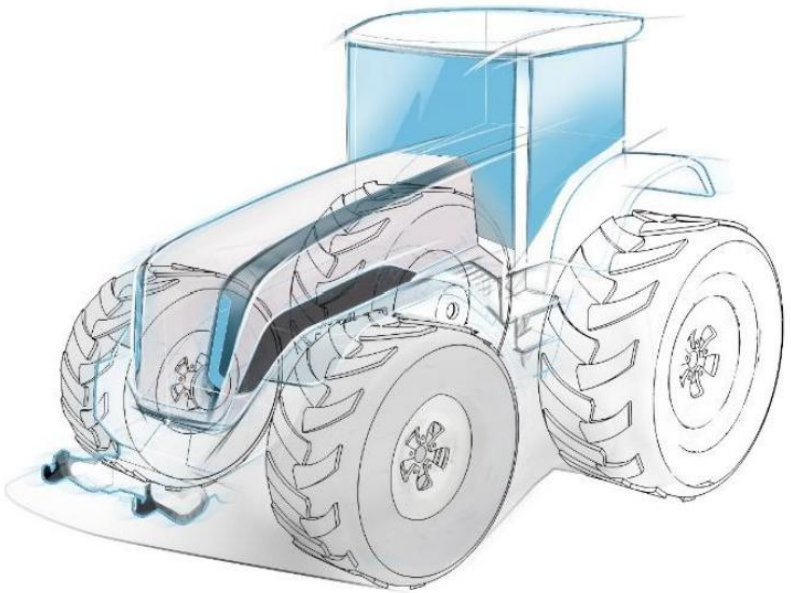


Summary

- Toroidal pressure vessel „LSE 1.4“ is 31% lighter and can be manufactured with less carbon fibres as a comparable cylindrical vessel (Typ IV) on the market
- Reduction of the process time for impregnation and curing by approx. 70% thanks to the use of Towpreg
- Ring winding unit allows automated manufacturing process of toroidal composite pressure vessel

Outlook

- Product approval with the support of TÜV Süd AG until Q2/2026
- Development of a large toroidal pressure vessel with a storage capacity of 22 kg H_2 and $Ø_a$ = 1850 mm for heavy fuel cell-powered agricultural and forestry vehicles until Q4/2026



Thank you very much for your attention

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Online-Shop: https://lse-shop.de/

Acknowledgement

This work has been supported by the ESF-EFRE Technology Funding of the SAB Sächsische Aufbaubank and through the german funding programme „WIR! – Change through innovation in the region“.