Efficient and Innovative Hydrogen Tank Design for a Lightweight Hydrogen-Powered Drone

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Introduction

Currently, cylindrical hydrogen pressure vessels are mostly used as storage tanks.[1] For hydrogen drones, however, the challenge is to integrate cylindrical tanks into a rotationally symmetric drone platform without causing flight instabilities. This study investigates other innovative type V (all-composite) hydrogen tank designs for a lightweight hydrogen-powered rotary-wing drone. Of particular interest are spherical, ellipsoidal and toroidal tank geometries, suggesting an enhanced integration into the drone platform. Using the finite element method (FEM), a comparison of these three tank geometries is given based on the mass, stability, and storage capacity. Lastly, this study offers new research directions for the optimisation of hydrogen tank design.

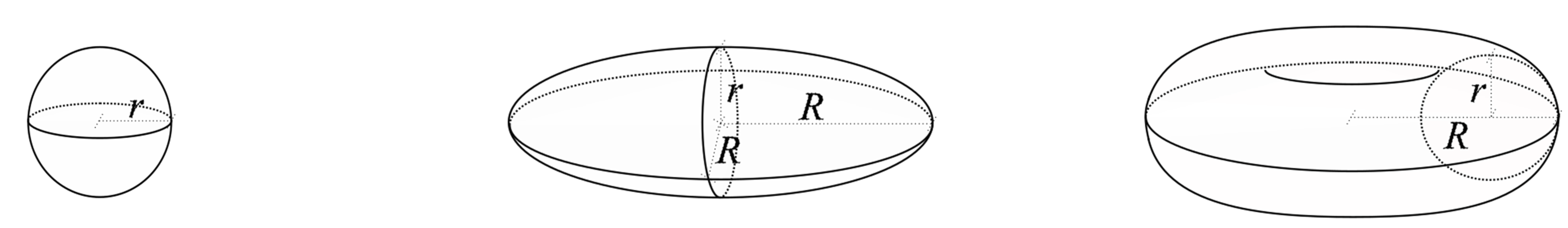
Drone Specification and Tank Geometry Calculation

DroH₂ne

Category "open – A3"[2]

Total Mass	25 kg
Flight Time	3 h
Drive Power	2.5 kW
Drive Energy	7.5 kWh
Energy Output	15 kWh/kg$_{H2}$
Hydrogen Demand	0.5 kg

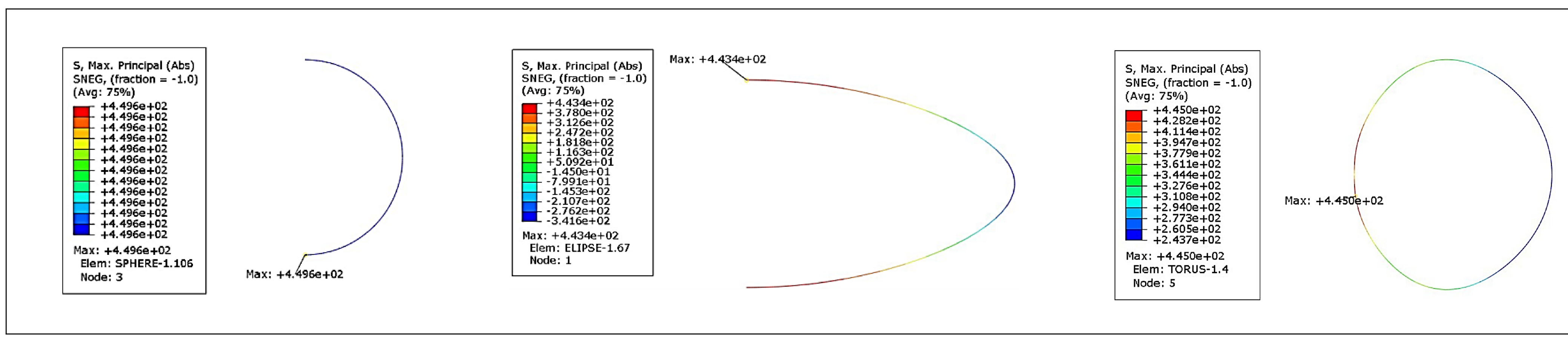
Rotational Symmetric **Tank Geometries** that can Rest Flat on the Drone Platform



Sphere	Ellipsoid	Torus
r = 100 mm, V = 4.19 L	r = 100 mm, R = 300 mm, V = 37.7 L	r = 100 mm, R = 300 mm, V = 39.5 L

❖ **Finite Element Method - ABAQUS CAE**

- Stress profile over tanks cross-section
- Max. main normal stress: 450 MPa[3]
- Tank Material: carbon-fibre-reinforced polymers
- Axisymmetric and deformable shell elements
- Homogeneous wall thickness

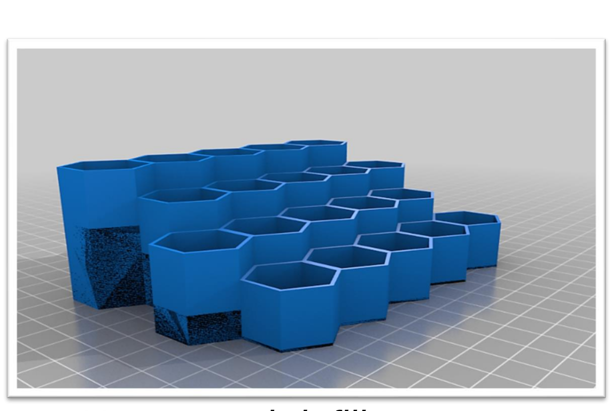


Tank parameters	Sphere	Ellipsoid	Torus
Pressure	1,419 bar	158 bar	151 bar
Wall Thickness	15.8 mm	31.5 mm	5 mm
Tank Mass	3.5 kg	34.2 kg	6.1 kg

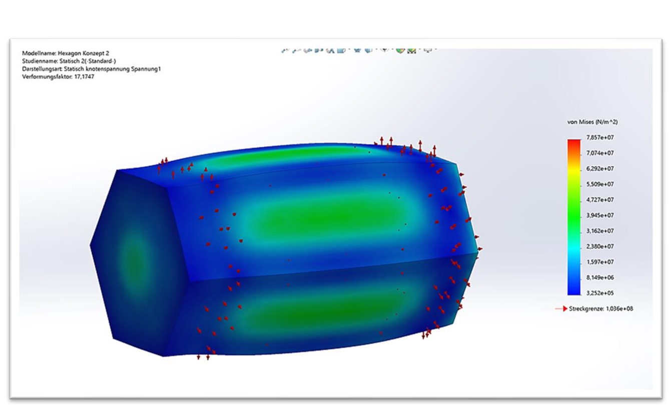
→ Inhomogeneous stress distribution for ellipsoid and torus

→ Torus is the most promising tank geometry, due to its high storage capacity and low tank mass

Outlook



Honeycomb infill structure



Mises stresses on hexagon infill

❖ **Topological optimisation methods**

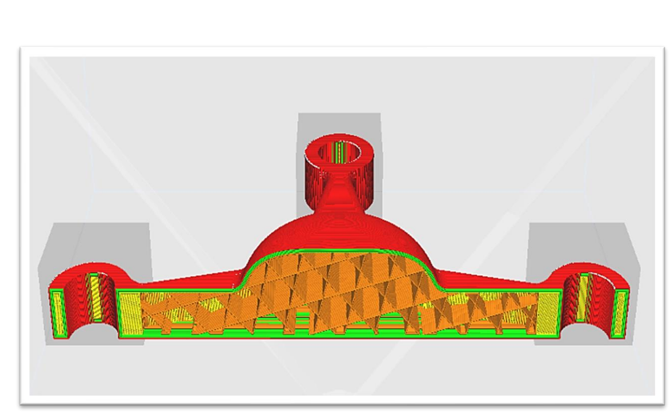
- Freedom in the choice of starting geometries for the tank design
- Non-constant wall thickness for homogeneous stress profile
- Reducing shearing forces on the material walls
- Implementation of infill structures as honeycombs or gyroids

→ Improving structural strength and stiffness

❖ **Additive manufacturing**

- Minimising excess material for weight optimizations
- Integrating hydrogen tank design into drone structure
- Considering different materials for tank manufacturing:
  - Carbon fibre reinforced polymers
  - Metal structures from aluminum combined with liners

→ Improving fuel economy, weight and flight behaviour



Quadcopter with infill tank structure

3D-printed mock-up of fibre-reinforced body

References:

[1] C. P. Fowler, A. C. Orifici, and C. H. Wang. A review of toroidal composite pressure vessel optimisation and damage tolerant design for high pressure gaseous fuel storage, International Journal of Hydrogen Energy. 12 (2016) 22067–22089.

[2] European Commission. Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft. Technical report, 2019.

[3] Swiss Composite. Faserverbund-Werkstoffdaten: Eine Sammlung der wichtigsten Werkstoffdaten für den Anwender von Faserverbund-Materialien sowie allgemeine Daten und Tabellen, (German). 2023.

https://www.hydrone.at/

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