Development of fibre-reinforced plastic components

Design of a structural composite hydrogen tank

In December 2019, the European Union adopted the «Green Deal» with the goal of decarbonisation: across all member states and sectors, CO2 neutrality is to be achieved by 2050. The Air Transport Action Group (ATAG) also wants to reduce aviation emissions by 2050 through CO2-neutral growth from 2020 and a 50 % reduction (compared to 2005). Both plans put massive pressure on the aviation industry, even though great progress has been made in the last 30 years. For example, optimisations in technology, organisation and flight altitude have reduced emissions per passenger kilometre by around 50 %. However, as further growth is expected in the coming years, further measures will be necessary.

Efforts to achieve the goals set are diverse: electric aircraft with battery power have already been built and existing aircraft have been converted to hydrogen fuel cell propulsion on a trial basis. This is precisely where several projects in applied research come in, especially with regard to propulsion systems for drones. The Royal Institute of Technology (KTH) in Stockholm is developing a flying platform for the further development and validation of novel propulsion concepts. The project is called «Green Raven» and is intended as modular platform in order to be universally usable for all research areas. About 80 g of hydrogen are required for operation, which at a pressure of 300 bar needs a volume of 3 l in a standard tank and allow a flight time of about 80 minutes. The continuous power of the fuel cell is approx. 1000 W, a buffer battery balances the additional demand during take-off and short-term exceptional situations. The whole aircraft is a completely new development and trimmed for efficiency. Various departments at KTH are therefore developing the blended wing with a wingspan of 4 m jointly. (Fig. 1).

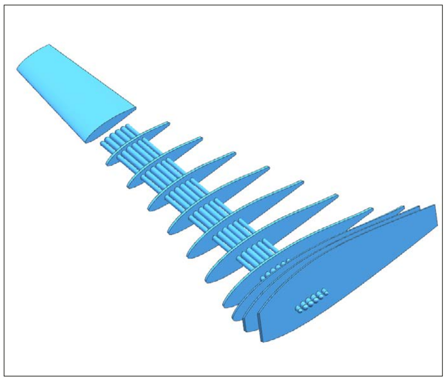
Source: kthaero.com/greenraven

Fig. 1 One-metre version of the Green Raven for first flight test (kthaero.com/greenraven)

One of the challenges in the operation of hydrogen fuel cells is the storage of the extremely volatile but energy-rich and light gas hydrogen. There are basically two ways to do this: One is to cool and liquify the gas at -253 °C, the other to put it under high pressure to increase its density and make it transportable. For large systems that consume the hydrogen quickly, such as rockets, the cooled route is chosen. For small systems that need to store the fuel over a longer period, pressure tanks are preferred, as there is no need for insulation and storage is not time-critical.

A pressure tank that can withstand around 160 bar (design pressure with safety factor: 420 bar) adds some weight to the structure. To reduce the extra weight, one can use the already robust tank structure as a structural component. Thus, KTH aimed for an integral tank - the necessary concept development was carried out together with the IWK Institute for Materials Technology and Plastics Processing in Rapperswil-Jona, Switzerland.

Various tank structures and shapes were evaluated. In the end, the cylindrical tank shape turned out to be the best solution, in accordance with the expectations. By means of optimisation, taking into account the failure behaviour, various layer stack-ups and fibre orientations were tested and simulated. The final version was able to withstand both the internal pressure and



Pictures: IWK

Fig. 2 Tank structure after all optimisation iterations as final version with cross ribs and wingtip

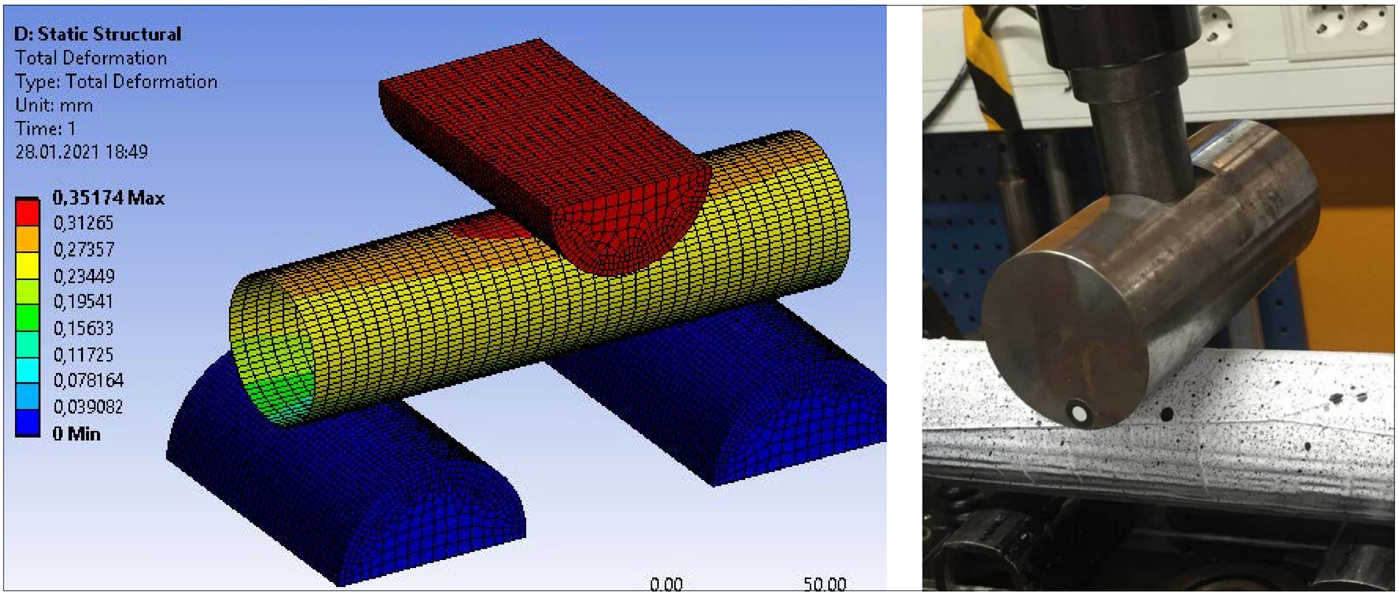


Fig. 3 Bending load in simulation (left) and test (with coloured surface for optical measurement data acquisition)

the extreme loads of flight operations and thus fulfilled the requirements.
The best solution consisted of six long, cylindrical wing tanks, which, in addition to storing the fuel, also hold loads similar to a spar (Fig. 2). The actual spar can be omitted, which saves weight. In addition, the central fuselage section is free for other systems, where in conventional designs the pressure tank would be placed. For transport, the wings are removable, which allows access to the tanks and their replacement, maintenance and inspection. Due to the larger volume (+90 % compared to the original solution) that now is available, the pressure no longer reaches 300 bar, but could be reduced to 160 bar. To validate the simulation results, simple but meaningful tests were carried out. Tube sections produced by the rolling method represented tank segments loaded in bending, which corresponds to the dimensioning load case during extreme flight manoeuvres (Fig. 3). Two aluminium end caps also allowed pressure to build up in the tank to cover both load cases (separately). By means of optical measurement, the deformations were recorded and compared with the simulation. Although the pressurisation was limited, good agreement was found between simulation and experiment.
Scaled models are planned as the next steps. While the 1 m version is already flying, further investigations are taking place in the wind tunnel. In parallel, a 2 m version is in preparation to realise the large drone at the end of 2021. Here, too, the Corona restrictions will have an impact: for example, access to the wind tunnel is more difficult and work in the laboratory is also only possible with restrictions.

The Royal Institute of Technology (KTH) was founded in 1827 and is Sweden's largest technical university with 13,000 students. One third of all Swedish engineers are educated here. The main campus is located in Stockholm on the northern edge of the city centre. In cooperation with the OST Ostschweizer Fachhochschule, Urs Zimmermann from the IWK had the opportunity to complete his Master's thesis in the Department Engineering Mechanics under the supervision of Prof. Dr. Malin Åkermo in the Lightweight Structures department.

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