AUTOMATED LIQUID HYDROGEN TANK DESIGN OPTIMIZATION USING FILAMENT WINDING SIMULATION AND SUBSEQUENT COMPARISON WITH ALUMINIUM VESSELS

S. Freund*, F. Franzoni*

* DLR, Institute of Composite Strucures and Adaptive Systems, Lilienthalplatz 7, Braunschweig, Germany

Abstract

The design of hydrogen fuel storages in future aircraft configurations is one key enabler for drastic reduction in climate impact of aviation. Due to the volumetric efficiency, liquid hydrogen pressure vessels are the most promising storage solution for short and medium range hydrogen-based aircraft. The aircraft configurations may contain tanks in wing pods as well as in the rear fuselage section which results in a big parameter range of the tank geometries. This study presents an automated design optimization process employing a detailed CFRP winding simulation, which is used to create tank models for aircraft pre design. Additionally, a comparison with aluminium based vessels is shown and mass advantages are presented. The winding process is based on MeFeX's µChain. It features a winding simulation on geodesic paths on liners with arbitrary axially symmetric contours. In addition, a fast analytical structural solver and a FEM model can be used. This allows detailed designs but also features fast, automated models for design optimization of a big variety of tanks. During the design process, each new layer is optimized. The optimization process chooses between hoop and helical layers and minimizes the maximal failure criterion. When all failure criteria are met, the design optimization is finished and no more layer needs to be added. In order to supply an even faster method for tank mass assessment in aircraft pre design, a surrogate model based on machine learning is created. This is achieved by the definition of the parameter space, the setup of a design of experiments and the creation of a kriging model. As third model, an aluminium tank design method is employed in order to evaluate possible mass savings of the CFRP design. This method features the wall thickness estimation, also accounting for fatigue. The fatigue model is based on load cycle sets of two different kinds, S-N curves and a damage accumulation method. The CFRP winding model and the surrogate model are compared and discussed with respect to accuracy and the discrete nature of CFRP layers. The differences in mass for the CFRP and aluminium tank designs are assessed and additional influence factors are discussed.

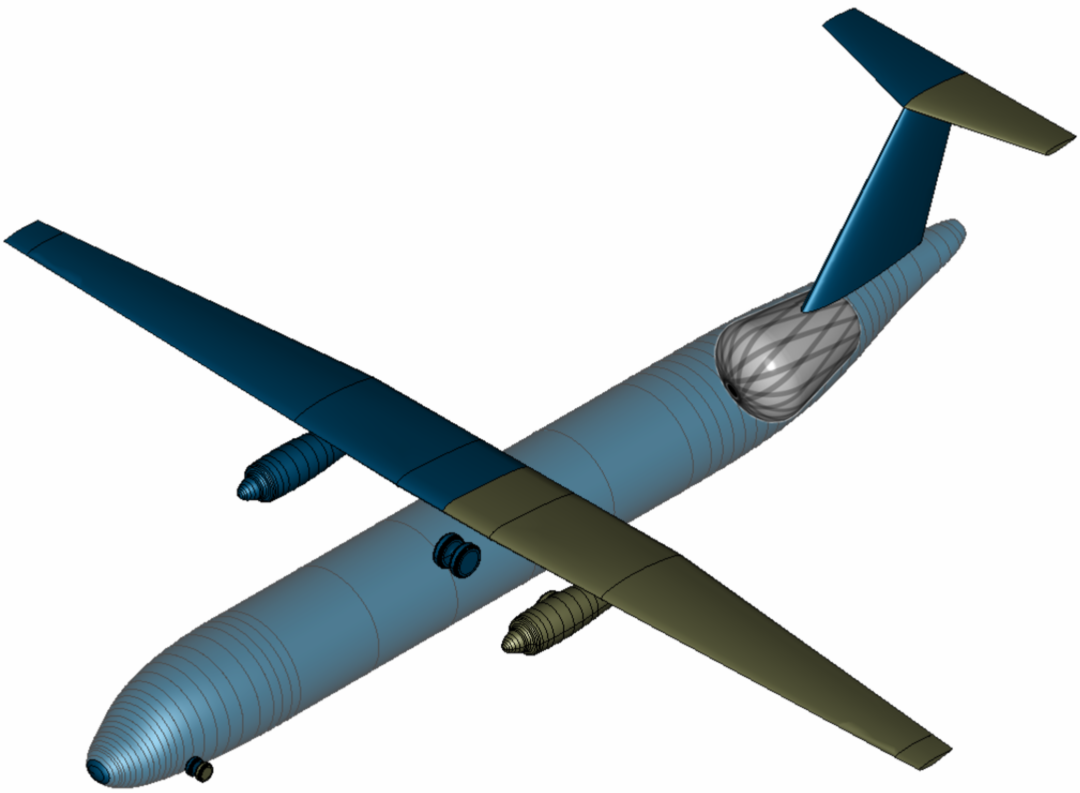

FIG 1. Turboprop aircraft configuration with rear fuselage CFRP tank including a winding pattern