LIQUID HYDROGEN STORAGE DESIGN TRADES FOR A SHORT-RANGE AIRCRAFT CONCEPT

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Abstract

Preliminary design trades for the liquid hydrogen storage system of a short-range aircraft are presented. The hydrogen storage system is integrated in pods located under the wing, which additionally carry the hybrid electric powertrain composed of a gas turbine, an electric motor and the propulsor. The shape of the hydrogen storage tank is identified as a main design driver as well as the maximal pressure and insulation efficiency. The influence of these design parameters on the thermal efficiency, the storage system mass, aerodynamic performance and propeller efficiency is investigated for this special type of integration. The implications of the design trades on aircraft level are separately investigated and published at the DLRK (Title: Hydrogen hybrid electric aircraft: Analysis of a short-range concept, Authors: D. Silberhorn, Y. Cabac, T. Burschyk, G. Atanasov). The aircraft concept is shown in Figure 1 and the corresponding top level aircraft requirements are listed in Table 1.

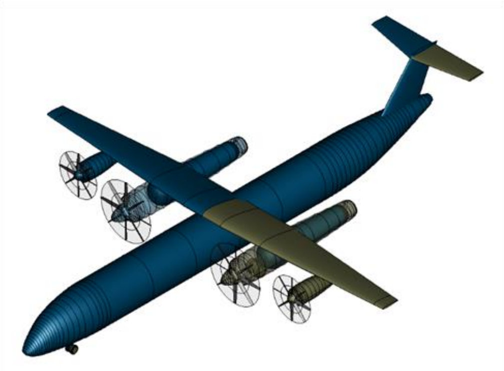

Figure 1: Iso view of the hydrogen hybrid electric aircraft concept

Additionally, the operational aspects of liquid hydrogen are challenging. As a cryogenic fuel the dormancy time of liquid hydrogen is an important requirement. Within this study, the demand for a long dormancy time is discussed and its implications to the design decisions are drawn. The possibility to expand the dormancy time and reduce the storage volume using subcooled liquid hydrogen is investigated.

Table 1: Top Level Aircraft Requirements

PARAMETER	*UNITS*	*VALUE*
Year of Entry Into Service (EIS)	-	2040
Design Range	nm	1500
Design Cruise Mach Number	-	0.62
Initial Cruise Altitude	ft	27000
Service Ceiling	ft	33000
Takeoff Balanced Field Length (SL, ISA conditions)	m	1850
One Engine Inoperative Ceiling (ISA Conditions)	ft	15000
Approach Speed (Calibrated Airspeed)	kts	140
Climb Speed (Calibrated Airspeed)	kts	240
Descent Speed (Calibrated Airspeed)	kts	250
Number of Passengers (Standard Layout)	-	250
Design Mission Payload	kg	23750
Max Payload	kg	25000

Since the operation strategy is time dependent, a dynamical model of the liquid hydrogen storage tank is carried out. It consists of control volumes representing a liquid and gaseous hydrogen phase, as well as the insulation layers. Energy transport between the control volumes is modeled by convective or conductive heat transfer, while the evaporation or condensation at the interface results of a local energy balance. Following this approach the heat capacity of the liquid hydrogen fuel can taken into account and the autogenous pressurization can be predicted. To evaluate the additional aerodynamic drag caused by the pod configuration an empirical method is used providing an overall aircraft design point of view. The storage system mass includes the insulation and the containment wall which is sized by the maximum operating pressure. Moreover, the aerodynamic interaction of the propeller and the fairing of the pod is estimated. Some preliminary design trends are illustrated in Figure 2: For a sizing pressure of 1.5 bar the effect of the insulation thickness and the tank shape on the dry mass, the drag and the vented mass of gaseous hydrogen are shown.

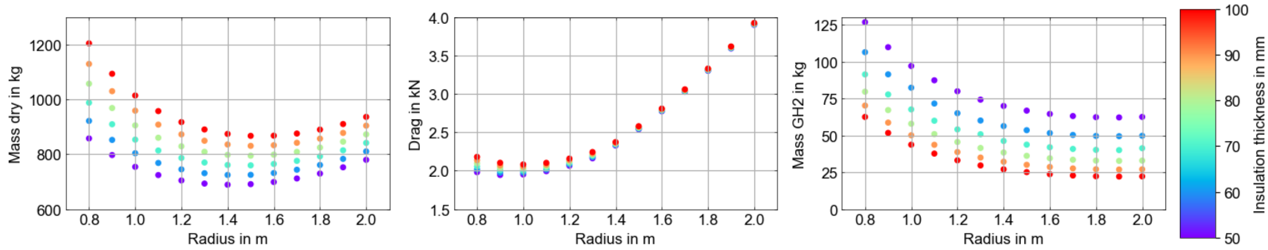

Figure 2: Parameter study and its implications on dry mass, drag and vented hydrogen