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Hybrid-electric power-train modelling for airplane performance analysis and sizing

Lorenzo Trainelli, Alberto Rolando, Carlo E. D. Riboldi, Francesco Salucci, Yasir M. Khan

Abstract

The present paper describes a framework for the parametric modelling of the components of hybrid-electric (HE) power-trains, aimed at conceptual design and performance analysis of innovative aircraft. This methodology has been developed in the EU-funded H2020 MAHEPA project, which includes a substantial effort in predicting the scalability of the currently-developed hybrid-electric propulsion technologies towards regional aviation applications. The MAHEPA project features the full development and flight testing of two serial HE power-trains which adopt a power generation system (PGS) to complement the battery pack: the first uses a thermal engine coupled with an electric generator as a PGS and the second employs a hydrogen-fed fuel-cell system. Both types of power-trains have been modelled and validated with respect to experimental data.

The paper provides an overview of the full modelling framework conceived for airplanes of arbitrary size and mission specifications. Particularly, commuters and large regional propeller-driven aircraft are of interest as they may represent a substantial asset in the near term for enhancing European citizens' mobility while insuring environmental sustainability. We address the modelling of the crucial components of the propulsive system: the battery pack, the fuel cell system and the hydrogen tank, for both the cases of gaseous and liquid storage. These elements are integrated within a preliminary sizing methodology conceived for conceptual design of HE aircraft based on performance and operational requirements, including a detailed sizing mission simulation. Examples of application to both retrofit and clean-sheet design solutions are illustrated.

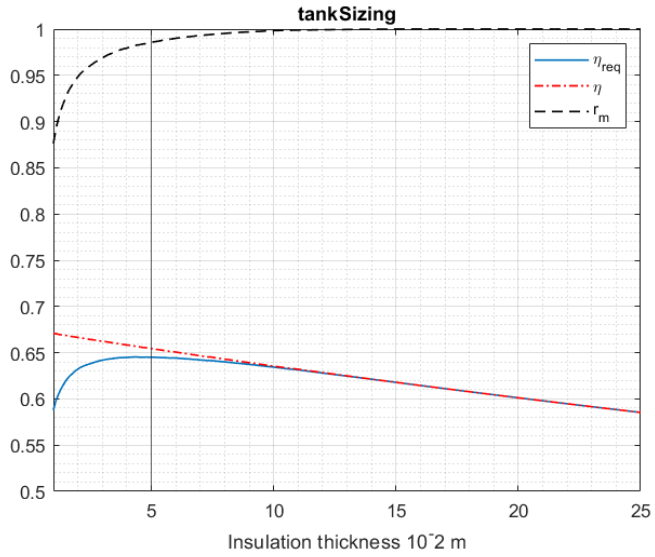

Figure 1: Relationship between insulation thickness and gravimetric index η, the ratio between the fuel required and the total fuel mass r_m, and storage density $\eta_{req} = \eta \cdot r_m$ for a liquid hydrogen tank.

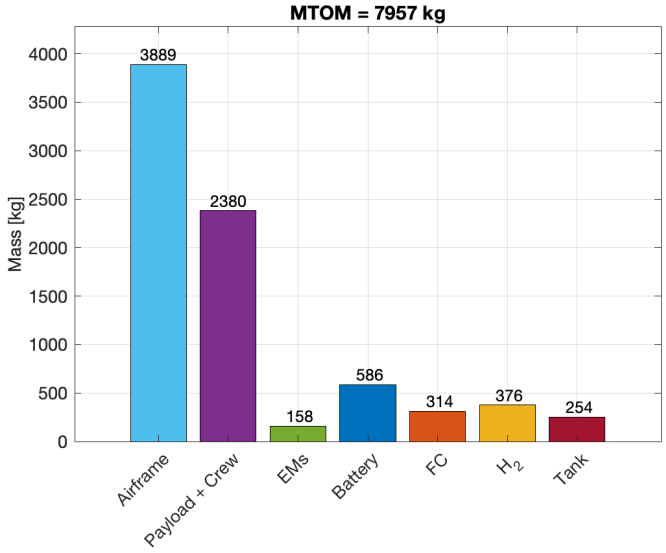

Figure 2: Mass breakdown for a 19-passenger aircraft with a fuel-cell serial hybrid-electric power-train fed by a liquid hydrogen tank.