ENABLEH2 Session EASN

Presentation 5:
Integration of Cryogenic Hydrogen Fuel and Propulsion Systems for Commercial Aviation

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The rapid growth in air traffic requires more attention to be paid to its environmental effects, in particular CO_2 and NO_X emissions and their relation to global warming. Therefore, it is crucial to find alternative fuels that can make drastic cuts in these emissions and so liquid hydrogen (LH_2) is being considered as a replacement for conventional oil-based Jet-A fuel. Although chemically bonded hydrogen is abundant, hydrogen production is nowhere near what would be needed to serve the aviation sector. To put it in perspective, the world's largest electrolysis plant could not keep a single Airbus A380 flying, and the total world production would only be enough for two large airports. To ramp up hydrogen production is a great challenge, but it does have some economic credibility as hydrogen production cost is not far off from Jet-A production cost even at today's oil prices. It is reasonable to believe that with increasing oil prices and the benefits of large-scale hydrogen production, this gap can be closed. Thus, sustainable global aviation may be achieved in the long term by using hydrogen, while electrically driven aircraft may be developed for short range flights. To quantify the relative merits of hydrogen, electrical and conventional propulsion, conceptual aircraft design studies are presented in a comparative way.

Compared to the Jet-A, LH_2 has a higher heat of combustion (approximately 2.8 times) which in turn theoretically reduces the fuel weight to a third. On the other hand, LH2 has a much lower density than Jet-A (approximately one tenth). This means that for a fixed amount of energy, more storage volume is required for LH_2 which in turn makes the aircraft body larger. Moreover, due to the extremely low storage temperature (approx. 20 K @ 145 kPa), LH2 tanks require careful insulation increasing their complexity and complicating their supporting structures. These major differences to Jet-A create lots of challenges for aircraft configuration, fuel systems, propulsion systems, safety and overall performance. Amongst all of the technical challenges, the cryogenic fuel container requires special attention. In this perspective, its size, location, material, insulation thickness, mechanical structure and safety must be addressed carefully. Moreover, to improve the performance of the propulsion system while using cryogenic fuel, various concepts for advanced engine cycles must be considered. These may lead to the introduction of additional components such as pre-cooling and intercooling heat exchangers for the engines' compressor air to benefit from the cryogenic fuel's properties. The presentation will review various heat management concepts using LH_2 as a heat sink and show how these will be systematically investigated in the ENABLEH2 project.

The development of a modelling environment coupling a cryogenic hydrogen fuel system and a turbofan performance is also described. Key parameters for the design process are established using sensitivity analysis and parameter variations. Conventional gas turbine simulation software frequently uses a successive execution of component performance calculations during the design process, leading to a good starting point for off-design iteration. However, having separate paths of information flow for the fuel system and the gas turbine makes maintaining causality in the model a challenge and requires good numeric methods. This paper summarizes some lessons learned in developing the simulation tool. Linking external software for the modeling of cryogenic hydrogen is also discussed.

Tabulation and interpolation software usually used for gas turbine simulations is based on either direct interpolation in tables or storing pre-computed interpolation coefficients. These approaches are shown to be inadequate when operating close to the critical point of the working fluid, so means to link external fluid-properties software such as REFPROP are described.