HEAVEN
Cryogenic Hydrogen Tech Aircraft

NEWSLETTER 03

JUNE 2020

CONTENTS

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under Grant Agreement No 826247. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.

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PROJECT PROGRESS REPORT

Air Liquide

From January to June 2020, the design of the Cryogenic Hydrogen Fuel system has entered into a deeper detailed design phase. Theses tasks are mainly under the WP3 tasks.

Complete set of requirements has been defined, including the missing requirement regarding hydrogen vent location on the aircraft, specific mechanical loads that were missing.

Safety analysis has been continued: Functional Hazard Analysis is being finalized. ALAT has organized a safety workshop session dedicated to accidental scenario and hydrogen specific risks, in order to answer to partner's interrogation, and. A great outcome of this sessions is a vision of effect distances assessment of accidental scenarios.

Detailed process study has been carried out to move forward on thermal and hydraulic aspects. In particular, protection devices (pressure safety valves, burst disc) has been defined, thermal ingress has been assessed, line diameters have been defined to meet the pressure drops requirements. Liquid Hydrogen behaviour during flight has been modelized to verify that the liquid movement will not affect the functionality of the tank.

Detail mechanical design has been performed with integration of the pre-selected component.

This design also helps to assess the mass of the system, and compare it with specifications for the tank. As actual solution may lead to overweight compared to the specification, therefore, possibility of modifying the design to meet the requirements are still ongoing.

For this subsystem, special components are developed to fulfill the requirements. In particular, a cryogenic electric actuated valve has been developed, and is now tested on ALAT test zone. Tests are constituted of air tests, cryogenic LH2 tests and finally vibration tests.

In case this valve does not bring the satisfactory results, a second option, heavier, has been investigated with another supplier. The external heat exchanger technology has been defined also, and is being supplied for manufacturing of the tank by the end of year.

First tests related to control command of the tank have started on a test bench. Grafcets are finalized, and software program is being elaborated.

Functional and environmental qualification plan has been defined for controlling the manufactured units are tested to cover all the functional and environmental conditions. These test will be carried out from early 2021, that the HFS subsystem can be delivered for aircraft integration for october 2021.

PROJECT PROGRESS REPORT

elringklinger

Progress has been made in the design of the NM5 fuel cell stack in terms of mounting. For the current B-Sample design an Add-on solution was developed while for the upcoming C-Sample an integrated feature is worked on. The design allows for easy integration on customer side while maintaining the flexibility/movement needed for the stack to operate properly. First tests on the shaker have shown that the design is also working fine while facing vibrational profiles and shock loads.

In addition to the design adaptation also possible improvements in terms of stack operation at cell level are examined. Focus here is the dry operation of the stack meaning without extra humidification which would be highly beneficial for system integration aspect. First results are expected to be available in the next weeks.

For supporting system design works two short stacks with 10 cells each have been built and supplied to the partner. These are going to be used to learn about necessary controls strategies and parameters for the system design.

Furthermore, a FMEA on stack level has been established. In addition, also a complementary risk analysis will be created.

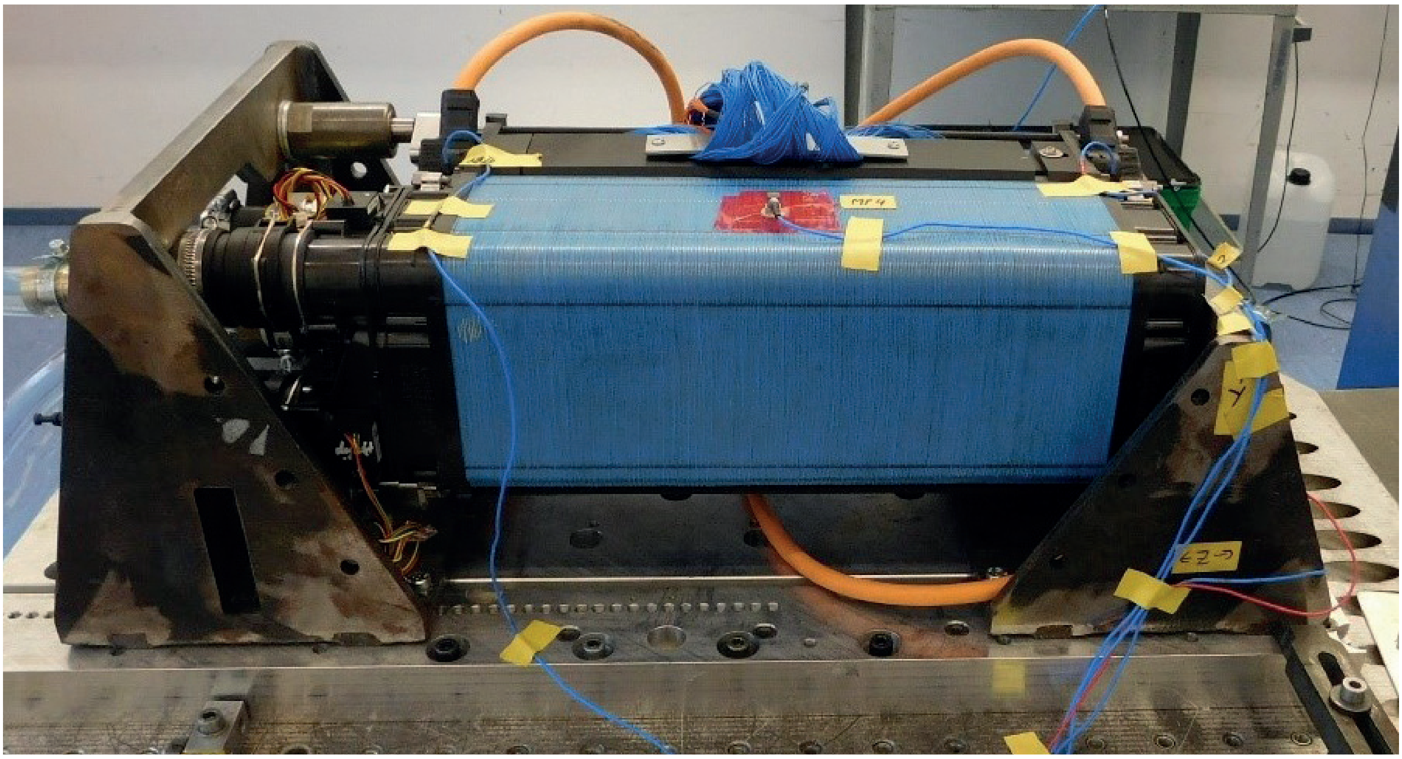


Figure 1. NM5 Stack on shaker table with new developed loose bearing mounting attachment

SYSTEM ARCHITECTURE REPORT

The main objective of the Work Package 1 of HEAVEN project "System Architecture" is to define the architecture of the overall powertrain. To that end, the main work carried out has been the definition of the technical specification and the functional requirements of the overall powertrain, as well as the conceptual design of the fuel cell system, hydrogen storage, aircraft drive train and power electronics.

In order to be able to define the requirements and pass them on top-down, the operation envelope has been determined. For this purpose, three different mission profiles have been established, the normal mission profile that describes the normal operation during test flights, the emergency mission profile that considers fuel cell failure during take-off and the target mission profile which is suitable for commercial passenger transport.

After the specification of the multiple mission profiles, the thrust and power requirements for aircraft propulsion with the specified profiles have been estimated, describing the minimum basic requirements, such as required power, energy content or load dynamics. In this way, the requirements have been derived on top down, defining the requirements and specifications of different subsystems, such as fuel cell system, hydrogen storage system, powertrain system and drivetrain system.

In addition to that, the overall powertrain conceptual design as well as the conceptual design of the subsystems have been designed with respect to the requirements previously established.

The overall block diagram of the powertrain is shown in Figure 2. The powertrain consists of the cryogenic H2 tank, gaseous H2 tanks, fuel cell system and battery system, the drive train, and the thermal management.

One of the main innovations of this system is the high power density FC system fuelled by a liquid hydrogen tank. In that respect, a solution will be developed for the heating up of the hydrogen from cryogenic temperature to the temperature suitable to feed the FC.
With the aim of guarantying a safe, redundant operation, a battery system is used in the FC based powertrain.

The hydrogen fuel system is based on cryogenic technology. Besides, a secondary pressurized H2-buffer will be integrated for safety redundancy.

Regarding the drive train, the DC-links supply power to the motors and the Power Management Control and Delivery (PMCD) module provides power to the DC-links from both FC system and battery. The main feature of the PMCD is to distribute the power between the drive train components. Therefore, the PMCD supplies the drive train interface to the HMI and determines the distribution of the power from the source to the propeller.

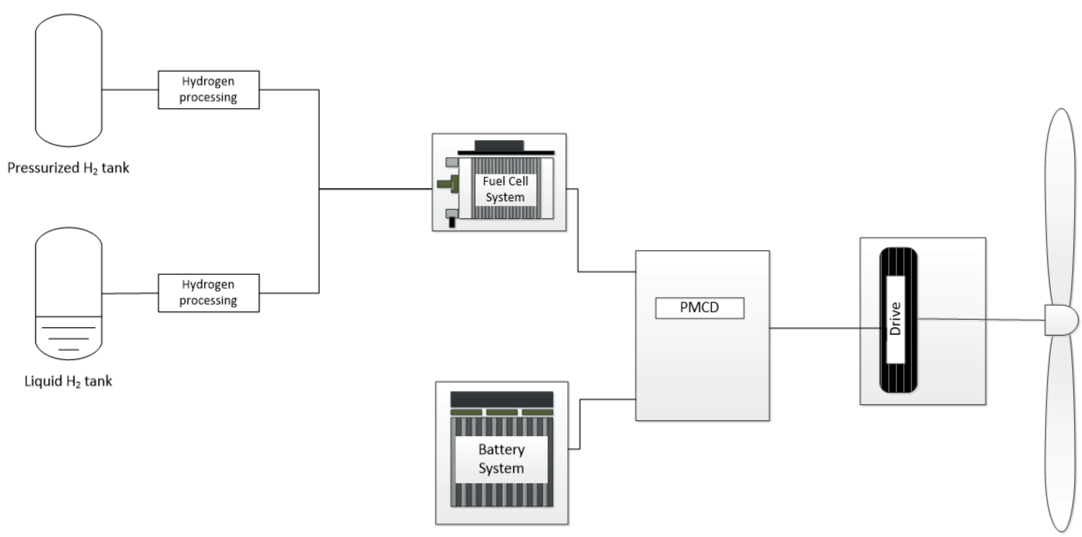


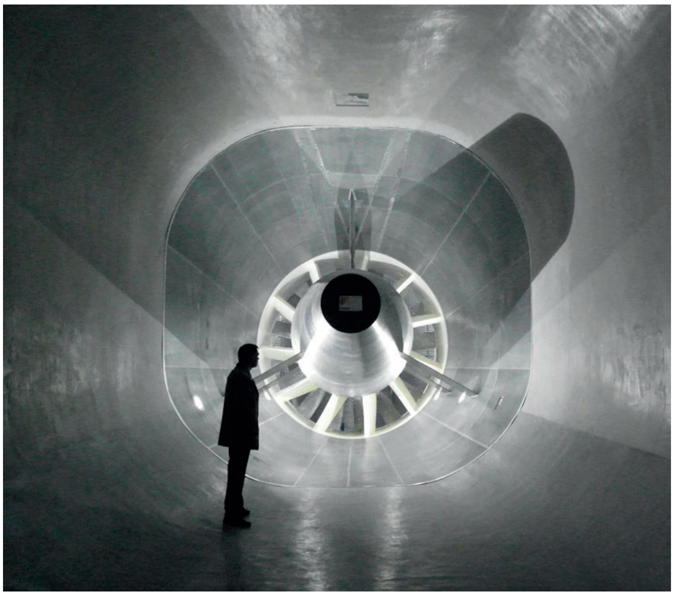
Figure 2. Overall powertrain

The German Aerospace Center (DLR, Deutsches Zentrum für Luft- und Raumfahrt)

PRESENTATION

The German Aerospace Center (DLR, Deutsches Zentrum für Luft- und Raumfahrt) is Germany's national research center for aeronautics and space. Its extensive research and development work focuses on aeronautics, space, transportation, security, digitalisation and energy.

DLR is also in charge of the planning and implementation of Germany's space activities on behalf of the federal government. The Institute of Engineering Thermodynamics at the Stuttgart Research Center, with further research facilities in Cologne, Ulm and Hamburg, conducts research and technology development in the field of renewable energy, efficient and environmentally clean energy storage systems that conserve natural resources, and next generation energy conversion and utilization technologies. Besides, one focus of the Institute's research and developments activities are energy systems for aircraft applications.



Images source: www.dlr.de

The German Aerospace Center (DLR, Deutsches Zentrum für Luft- und Raumfahrt)

INTERVIEW Ana Fernández

Ana Fernández Barquín works in the DLR's team of HEAVEN project. Since having joined the Energy System Integration group of the Institute of Engineering Thermodynamics at DLR in 2019, she works for the manned electric aircraft Hy4, whose powertrain will be based on a high power fuel cell system and high energy density liquid hydrogen fuel system.

Ana Fernández Barquín has a master in chemical engineering. After graduating in the University of Cantabria (Spain), she continued her studies obtaining a PhD in Chemical, Energy and Process Engineering.

1. What is DLR Role in the project?

In HEAVEN project the German Aerospace Center acts as the system designer, developing a high power fuel cell system fuelled by liquid hydrogen for an electric powertrain of a 4 seater aircraft, the Hy4. In this regard, the main responsibilities of DLR in the project are the conceptual design of the overall powertrain, the development of the high power fuel cell system and the systems coupling.

2. What is in your view the main challenge of the project?

HEAVEN project will fly the manned electric aircraft, the Hy4, whose powertrain is based on fuel cells fed by liquid hydrogen. The project has great objectives such as designing a fuel cell system with high power density.
In order to reach the high power density, it is necessary to develop new fuel cell sub-systems, selecting the suitable balance of plant components and to manage the fuelling of the fuel cell by liquid Hydrogen. This feat would be a premiere and a first step to demonstrate the great potential of this technology for commercial electric air transport.

3. Actually, what is your stage project? What advancements have you done?

During this first stage of the project the main focus of DLR work has been on the conceptual design of the architecture of the overall powertrain, the systems and subsystems. Besides, DLR has also focused on the FC system development. A test rig has been designed and built in the laboratory in order to determine the stack limits, principal operational parameters and verify the operation algorithms.

4. What are next steps in the project for DLR?

The next step will focus on the fuel cell system development, including the design and selection of the balance of plant components and their assembly into a test bed for operation testing.

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