CIDETEC lead four-year exFan research initiative

A consortium led by CIDETEC Surface Engineering is designing an out-of-bath system for the treatment of heat exchanger geometries

The exFan research initiative is funded by the European Union under GA 101138184 and over the course of four years has brought together a consortium of 10 partners from across Europe

The exFan project, short for *Novel Recuperation System to Maximize Exergy from Anergy for Fuel Cell Powered Geared Electric Aircraft Propulsion System*, is a research initiative funded by the European Union under GA 101138184 as part of the HORIZON EUROPE programme. Starting in December 2023, the project has spanned four years and brought together a consortium of 10 partners from five countries.

CIDETEC Surface Engineering leads the project co-ordination, in collaboration with ADT, acting as technical co-ordinator, and TUW as a research co-ordinator, while partners Fraunhofer IAPT, DLR, PowerID, EASN-TIS, IRES, FZG/TUM, and Egile Mechanics contribute expertise and resources to drive the project forward.

In the exFan project, CIDETEC is working on the design of an ad-hoc out-of-bath system for the treatment of the most promising heat exchanger geometries designed and manufactured in the project by the German partner Fraunhofer IAPT. In addition, it will optimise the chemical treatments for polishing and deposition of metal layers, by adjusting parameters, such as temperature, flow rate and electrolyte composition, as well as the process time, to achieve the objectives set. CIDETEC is currently immersed both in the design phase of the experimental system for the application of the chemical treatments, and in the optimisation of the working conditions at laboratory scale in order to, once defined, apply them on the real demonstrators.

The heat exchanger designed in the exFan project will have a bionic design with a suitable surface finish to prevent particle buildup, corrosion and erosion. In addition, a novel thermal management system is being designed to optimise waste heat quality and control the heat flow of the propulsion system. Optimal operating conditions are also being investigated, and a simulation model will be created to optimise operating parameters. The first functional tests of exFan at laboratory scale will be used to verify this model.

CIDETEC SURFACE ENGINEERING

The Coatings and Surface Treatments Unit of CIDETEC Surface Engineering is focused on the design, development, application and characterization of coatings and surfaces to improve the aesthetic and functional properties of materials. It has 4,000m2 of facilities equipped with the latest technology. The research to be carried out in the exFan project covers different areas such as the metallization of non-conductive substrates, the development of multi-functional coatings, surface preparation and cleaning, the post-processing of components obtained by AM and the development of coatings for extreme environments. For this purpose, the unit has a highly qualified team in different wet application technologies, such as electrodeposition, electroless deposition, anodizing, electrophoretic deposition, formulation and application of enamels, electro-polishing processes, chemical and mechanical polishing.

HYDROGEN-POWERED ELECTRIC AIRCRAFT

Hydrogen fuel cells produce no CO2 emissions in flight and are more efficient and sustainable than traditional kerosene-fuelled turbine engines. Moreover, hydrogen is an abundant and renewable natural resource, so hydrogen aircraft propulsion can be key to achieving climate neutrality in aviation by 2050. However, several challenges, such as thermal management and heat dissipation of fuel cells in the aircraft, need to be addressed and solved before fuel cell-based electric aircraft can be a viable solution for air transport.

Although turbine engines produce more heat than fuel cells, they can easily dissipate it in the form of hot exhaust gases. In contrast, a fuel cell, like a battery, heats up during operation and requires a special thermal management system to keep it at its optimum operating temperature. The electrical efficiency of fuel cells is expected to reach 50% by 2030, meaning that every watt of electricity produced in the fuel cell will generate one watt of waste heat. Recovering this heat for further use in the aircraft would be an additional advantage of the technology.

In this context, the European exFan project partners are investigating a solution that allows dissipation of the waste heat generated in the fuel cells, without additional drag losses and the use of this waste heat to generate additional thrust for the aircraft.

The European Green Deal: climate-neutral aviation by 2050

Climate change and environmental degradation are an existential threat facing Europe and the rest of the world. To address this threat, the European Green Deal aims to achieve climate-neutral aviation by 2050, and to achieve this goal hydrogen fuel cell-based propulsion technologies is one of the available alternatives.

HEAT RECOVERY DEVICE BASED ON THE MEREDITH EFFECT

The heat recovery device on which the exFan project focuses is based on the Meredith effect. This effect is a physical phenomenon that takes place in an aircraft duct where the air is flowing through it, which is moving faster than the aircraft, is heated by a heat exchanger. The air is flowing in the duct where the cross section is diverging resulting in a pressure increase of the gas since its speed is reduced. This is called the ramjet effect. As it flows through the exchanger the air is heated, increasing its heat energy and the enthalpy of the flow, i.e. its total energy. This heated and pressurized air exits through an exhaust duct that has a converging design (it becomes narrow towards the end) that accelerates the exiting air with a higher velocity than its inflow (thanks to the energy obtained through the heat exchanger). The difference in the amount of air flow motion between the inlet and outlet of the duct generates a force that by Newton's third law translates into an effective thrust.

The heat recovery device being designed in the exFan project consists of the fan, the aerodynamic components of the flow path and the heat exchanger. The fan is driven by a high-speed electric motor through a gearbox and compresses the aspirated air. This architecture allows the highest specific power to be obtained. The electric motor and its associated power electronics and controllers are mainly powered by a fuel cell and during peak power demand, a battery shares the load with the fuel cell (e.g. during take-off). A thermal management system is connected to all of the above components to provide suitable thermal operating conditions.

The exFan system encompasses all components that are not related to energy storage and conversion. This proposed new propulsion concept requires heat exchangers with a number of features that make them more efficient and durable.

EFFICIENT, DURABLE HEAT EXCHANGERS PRODUCED BY ADDITIVE MANUFACTURING

In this scenario, one of the objectives of the project is the design and fabrication of an efficient and durable heat exchanger, i.e. high resistance to fouling, wear and corrosion. The design objectives to achieve the balance between thrust and resistance - high heat transfer and low pressure losses - are somewhat opposed in the design of the heat exchanger. Therefore, they must be carefully balanced. High heat transfer in heat exchangers is achieved with structures or geometries that lead to turbulent flow, but low resistance is achieved with structures that lead to laminar flow. The exFan project is working on the efficient design of the heat exchanger to be produced by Additive Manufacturing (AM) using Laser Powder Bed Fusion (L-PBF) technology. The use of AM allows the production of more efficient heat exchangers due to the complex geometries and internal channel design that can be produced with this technology and that would not be possible to obtain by conventional methods.

SURFACE TREATMENTS TO INCREASE THE EFFICIENCY AND DURABILITY OF HEAT EXCHANGERS

The use of additive manufacturing makes it possible to produce heat exchangers with complex geometries, which do not allow the application of most of the surface treatments necessary to reduce the roughness of the components and protect them against wear and corrosion. In this context, chemical surface treatments are the only ones that can be used to treat any type of geometry regardless of its internal structure, since they only require contact between the surface to be treated and a specific electrolyte at a specific temperature for a specific time.

Therefore, the application of chemical surface treatments, such as polishing or metallizing, improves the performance of the heat exchanger in terms of efficiency, resistance to corrosion and wear and/or fouling.

To find out more, visit exfan-project.eu.