FLEX4H$_2$

FLEXIBILITY FOR HYDROGEN

Project ID	101101427
PRR 2025	Pillar 4 - H_2 End Uses - Stationary Applications
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Clean H$_2$ JU Max. Contribution	4 178 517.25
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Coordinator Beneficiary	ANSALDO ENERGIA SPA, IT
Beneficiaries	EUROPEAN TURBINE NETWORK, ARTTIC INNOVATION GMBH, ANSALDO ENERGIA SWITZERLAND AG, EDISON SPA, ENERGY AND TURBOMACHINERY NETWORK, ZURCHER HOCHSCHULE FUR ANGEWANDTE WISSENSCHAFTEN, SINTEF ENERGI AS, CENTRE EUROPEEN DE RECHERCHE ET DEFORMATION AVANCEE EN CALCUL SCIENTIFIQUE, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV

https://flex4h2.eu/

PROJECT AND GENERAL OBJECTIVES

FLEX4H$_2$ will design, develop, and validate a highly fuel-flexible sequential combustion system capable of operating with any concentration of hydrogen admixed with natural gas up to 100% at H-class operating temperatures, with the aim of maintaining rated power and efficiency.

FLEX4H$_2$ will:

- Tackle the challenges related to H_2 combustion by developing combustion technology through a combination of design optimisation, analytical research, and validation in a relevant environment.
- Validate scaled and full-size prototypes of the combustor through dedicated atmospheric and high-pressure test campaigns up to technology readiness level 6.
- Demonstrate the combustor's ability to operate in the presence of any mixture of hydrogen and natural gas during testing, without diluents while complying with emission limits.
- Demonstrate the possibility to start-up the engine on any amount of H_2 in natural gas.

NON-QUANTITATIVE OBJECTIVES

FLEX4H$_2$ will assess the replicability of the scientific methodologies applied and the transferability of the results to different gas turbine classes and evaluate the wider retrofit markets.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Combustion system development and testing

- Execution of full-scale high-pressure testing, showing the possibility to operate the FLEX4H$_2$ prototypes with natural gas, hydrogen and all intermediate blends.
- Completion of high-pressure combustion tests in the small-scale optically accessible rig, providing characterisation of the flame stabilisation mechanism of hydrogen auto-ignition driven flames, enabling validation of the latest numerical simulations and providing valuable information for operation of gas turbines fired with high hydrogen contents or pure hydrogen.
- Design of second generation full-scale H_2-optimised prototypes, with an optimised injection system and mixing section aiming at improved operation with higher firing temperatures.
- Atmospheric testing of optimised first-stage burners, showing very promising results for wider flashback margin and improved flexibility.

Numerical modelling

- Execution of advanced high-resolution Large-Eddy Simulation of Ansaldo's 1st and 2nd stage combustors with realistic fuel injection pattern.
- Execution of model refinement to achieve best representation of flame stabilisation and flashback behaviour in the first combustion-stage.
- Conduction of additional numerical-modelling activities for thermo-acoustic assessment and low-order modelling (acoustic forcing of the flame).
- Execution of advanced high-resolution LES calculations of fuel-oxidiser mixing efficiency in second-generation geometry, focusing on aerodynamic improvement of the mixing section.
- Selection of DLR-rig experimental cases from October-2024 FLEX4H$_2$ campaign for additional second combustion-stage numerical model validation on stabilization of undiluted-hydrogen reheat flame.
- Sharing new geometry with SINTEF to conduct the Large Eddy Simulation calculations in 2025.

Thermoacoustics

- Conversion of the exact experimental rig geometry to a network modelling tool capable of predicting the system's overall behaviour regarding velocity and pressure fluctuations to reduce the deviation between model and measurements.

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- Establishment of an algorithm to relate the developed first-stage-only (FOS) network model to the full can setup (FCS), which includes the sequential combustor and additional geometry, to extract FSO behaviour from experimental data which was gained in the FCS configuration.

FUTURE STEPS AND PLANS

Combustion system development and testing:

- Testing of second-generation prototypes (Gen2) at high pressure conditions, focusing on operation with high hydrogen contents (>90%vol) and pure hydrogen.
- Design of Gen3 prototypes for demonstration and achievement of technology readiness level 6.
- Refinement of the burner design based the first two development cycles to optimise mixing section, injection schemes, cooling systems and damping configuration.
- Exploitation of full-scale high-pressure combustion tests to enhance combustor operation.
- Optimisation of the combustion system design considering cooling and mechanical integrity requirements for industrialisation of the developed technology.

Numerical Modelling:

- Execution of advanced high-resolution Large-Eddy Simulation (LES) of H_2-fired simplified 1st-stage burner using a dedicated reduced chemistry scheme (for NO_x-emissions prediction) at selected conditions of interest.
- Execution of thermoacoustically forced LES calculations of the simplified 1st-stage to retrieve the Flame-Transfer Function for model validation versus atmospheric-pressure measurements.
- Validation of LES model against the 2024 FLEX4H_2 DLR-rig measurements of hydrogen flame stabilisation at reheat conditions (relevant to Ansaldo's 2nd-stage combustor).
- Use of thermoacoustically forced LES calculations of the simplified 2nd-stage burner to retrieve the Flame-Transfer Function for model validation versus high-pressure measurements.
- Exploitation of advanced high-resolution LES calculations of fuel-oxidiser mixing efficiency in the third-generation geometry focusing on aerodynamic improvement of the mixing section.

Thermoacoustics:

- Conclusion of ongoing computational fluid dynamics simulation and evaluation of the Flame-Transfer Function (FTF) so as to relate heat release fluctuations to acoustic quantities.
- Improvement of the existing low order network models by inclusion of the FTF.
- Validation of the updated model with hot cases, i.e., experiments with a flame instead of just heated air.
- Setup and execution of an additional LES with adjustments to the boundary layer assumptions and similar configuration elements based on recent experiences and results. The resulting FTF is then used to improve the existing low order network models further.
- Setup of network model for Full Can Setup (FCS) to reflect real world behaviour for both cold and hot cases. This provides insight into the respective contributions and potential modifications of the first stage geometry/flame and the sequential stage.
- Damper manufacturing and testing as part of the second-generation configuration aiming at stable operation of the full-scale system in the upcoming high-pressure tests.

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