ENERGETICS

MUR DM 118 - H2-based power units for zero-equivalent mobility solutions

Funded By	MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Dipartimento DENERG
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Context of the research activity	The project is focused on the definition of an optimized H2-ICE design. The research will start from the development and validation of fuel-flexible combustion modeling approaches. Subsequently, specific attention will be given to the combustion concept definition. Finally, detailed CFD analysis of in-cylinder flow, mixture formation and combustion processes will be performed in a few selected engine configurations, to define the final design. The impact of the fuel composition on the engine performance and emission will also be quantified. Progetto finanziato nell'ambito del PNRR – DM 118/2023 - CUP E14D23001620006
	The even more stringent emission regulations together with the increasing concern into environmental issues have thrust the industry to largely invest on R&D to define innovative solutions for IC engines for automotive, marine, and off-roads applications. If the goal of the Paris Agreement of 2015 is to be met, the clean energy transition will need to bring about a rapid reduction in emissions of greenhouse gases to zero on a net basis over the coming decades. Such results constitute a real challenge for the industry and research sectors and can only be achieved if a proper mix of fuels and technology ways will be pursued and developed. More specifically, net-zero CO2 emissions can either be achieved through the use of a bio-fuel or an e-fuel produced from renewable energy sources (such as, hydrogen). Hydrogen holds great promise for the transition to a clean energy production and transportation sectors. With increasing shares of variable renewables in the electricity generation mix, it is one of the very few technology options for storing large amounts of electricity over days, weeks or even months. Hydrogen or hydrogen-based fuels can also be a means to transport renewable energy from regions with abundant renewable resources over thousands of kilometers to regions and cities with growing energy needs. Hydrogen has unique properties which makes it a promising fuel for ICEs.

Objectives	The application of H2 to ICEs has been limited by the absence of cost-effective production processes and the lack of a refueling infrastructure. Nowadays, there is rising interest for H2 as energy carrier for transportation, with significant investments made in Europe for the development of a H2 supply chain using renewable energy. Despite most of the recent H2-related research is focused on the Fuel-Cells, there is also a renewed interest for H2-ICE due its potential to be a cost-effective, "equivalent" zero-emissions powertrain. H2-ICEs can potentially operate at a lower cost compared to fuel-cells. This is because they accept hydrogen with higher level of impurities arising from the supply chain and the storage system (heavy hydrocarbons, H_2O, NH_3, etc.). However, a technology breakthrough to achieve the same Fuel Cell efficiency, power density and emission levels is still required. Moreover, complementary solutions involving readily available, variable composition, renewable fuels, as well as hydrogen-blended ones have to be considered. The impact of the fuel composition on the engine performance and emissions has to be characterized. The present project aims to provide mid- and long-term sustainable solutions to support Hydrogen (H2) as the fundamental energy carrier for long-haul transport (truck and buses) in Europe and Italy, finally enabling the zero-emission target for the transportation sector. However, the specific chemical and physical properties of H2 require fundamental and applied research beyond the state of the art to develop suitable engine components and combustion systems. The project thus aims at making a significant progress beyond the literature state of the art, concerning the development and application of flexible and reliable simulation models to the engine design process. Starting from the analysis of the state of the art concerning hydrogen-based fuel-flexible powertrains, the project will pursue the objectives below: OBJ 1 Development and validation of numerical tools for the analysis of engines running on fuels holding a low environmental impact, with specific reference to fuel flexibility, variable composition and low carbon content. OBJ 2 Optimization of the engine design parameters by means of 0D/1-D modeling and DoE, with specific focus on combustion concept (lean stratified combustion with no, passive or active prechamber), overall A/F ratio, compression ratio, intake/exhaust configuration and valve timing. OBJ 3 Detailed CFD analysis of in-cylinder flow, mixture formation and combustion processes in a

Skills and competencies for the development of the activity	• Thorough background on engine fluid-dynamics, thermodynamics, combustion, and control; • Background on 1D/3D CFD modeling of IC engines; • Experience in the use of commercial 1D/3D simulation tools in the engine context will constitute an added value.