Politecnico di Torino

ENERGETICS

DENERG - High-performance hydrogen-fueled IC engines

Funded By	Dipartimento DENERG

Supervisor	SPESSA EZIO - ezio.spessa@polito.it

Contact	

Context of the research activity	The road transport sector is shifting toward sustainable solutions to address climate change. For hard-to-abate sectors, hydrogen-fueled internal combustion engines offer a viable low-carbon alternative to full electrification. Despite strong industrial interest, H2 ICEs still face performance gaps compared to conventional engines. This research focuses on identifying and optimizing key performance enablers to maximize power and torque while ensuring ultra-low NO¿ emissions, using a high-performance sports car engine as a benchmark.

Objectives	The objective of this project is to address the existing gaps in the development of an effective hydrogen-fueled internal combustion engine (H2-ICE) solution for high-performance automotive propulsion. In such applications, achieving performance levels comparable to the original gasoline-powered configuration is essential, while simultaneously meeting stringent limits on NO¿ emissions and mitigating the risk of abnormal combustion phenomena. To reach these ambitious goals, several “performance enablers” will be investigated for their contribution to the optimization of the full-load operating curve. These include turbocharger optimization and matching, direct injection strategies, charge dilution techniques, and advanced thermal management and cooling concepts. The proposed research will systematically assess the potential of each enabler, evaluating the trade-offs between torque output, NO¿ emissions, and safety margins related to abnormal combustion events. To this end, the project will adopt a combined 1D–3D numerical approach, which provides the optimal balance between computational accuracy and cost. System-level analyses of the engine and turbocharging systems will be conducted using a 0D/1D modeling framework (e.g., GT-Power), enabling rapid evaluation of global performance trends. In parallel, 3D computational fluid dynamics (CFD) models will be developed to capture the detailed in-cylinder processes governing hydrogen combustion—particularly the reactive behavior of hydrogen–air mixtures, in-cylinder turbulence, and turbulence–combustion interactions. While the use of combined 1D–3D methodologies is gaining wider

	acceptance in advanced engine development, a significant knowledge gap remains in their application to high-performance hydrogen ICEs. This project aims to fill that gap, generating new insights into the design, control, and optimization of such engines. Moreover, it is expected to deliver a substantial advancement in the formulation of accurate and flexible combustion models suitable for highly turbulent, hydrogen-fueled systems. Research Plan and Work Structure Task 1 – 1D Modeling 1.1 Development of a 1D engine simulation model and correlation with experimental data under gasoline fueling (diagnostic and predictive models). 1.2 Preliminary conversion of the 1D model to hydrogen fueling with a Port Fuel Injection (PFI) system, informed by predictive 3D modeling results under H2 fueling (Tasks 2.2–2.4). 1.3 Validation and assessment of the 1D model under H2 fueling. 1.4 Predictive simulation for performance optimization and identification of key performance enablers, including H2 Direct Injection (H2 DI). Task 2 – 3D Modeling 2.1 Development of a 3D engine simulation model and correlation with experimental data under gasoline PFI operation. 2.2 Formulation of a predictive, fuel-flexible (PFI) combustion model. 2.3 Assessment of the 3D model under hydrogen fueling (PFI configuration). 2.4 Characterization of combustion behavior under hydrogen fueling in PFI mode. 2.5 Development of a 3D engine simulation model for H2 DI operation.

Skills and competencies for the development of the activity	The candidate must have knowledge of basic technical characteristics of turbocharged engines working principles and turbomatching optimization. Also, a basic knowledge of 0D/1D modelling (either with commercial or in-house codes) of fluid-dynamics and combustion (diagnostic or predictive models) is welcome. Experience in Computational Fluid Dynamics, in C or Matlab programming may represent an added value.