POLITECNICO DI MILANO

PhD in SCIENZE E TECNOLOGIE ENERGETICHE E NUCLEARI / ENERGY AND NUCLEAR SCIENCE AND TECHNOLOGY - 39th cycle

THEMATIC Research Field: DEVELOPMENT OF CFD METHODOLOGIES FOR THE SIMULATION OF HIGH-EFFICIENCY INTERNAL COMBUSTION ENGINES OPERATING WITH LOW-CARBON FUELS USING OPEN-SOURCE SOFTWARE

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Internal Combustion Engines (ICEs) are widely employed as a prime mover for mobility, marine, offroad and power generation applications. Within this context, suitable developments are needed to reduce the greenhouse gas (GHG) emissions of ICEs and, at the same time, increase their efficiency. Solutions are represented by: 1. Use of alternative fuels with a reduced tank-to-wheels (TTW) carbon content (biogas, hydrogen, ammonia, methanol, DME, HVO and synthetic fuels); 2. New combustion modes enabling the use of alternative fuels with >45% efficiency 3. (eventually) new engine concepts aimed to increase the thermodynamic cycle efficiency using intra-cycle heat recovery, opposed-piston configurations and non conventional kinematics to convert the piston work into available energy. Currently, Computational Fluid Dynamics is now part of the ICE development and design process reliyng on consolidated approaches whose validity is acceptable on conventional engines (spark-ignition operating with gasoline, compression-ignition operating with diesel fuel). However, relevant technology changes require suitable

	However, relevant technology changes require suitable model developments to properly account for the properties of new fuels and operation with new combustion systems. The proposed PhD project focuses on points 1-2 and the candidate work will be mainly dedicated to the development of CFD methodologies for the simulation of ICEs operating with alternative fuels using OpenFOAM, an open-source code. This will make possible to implement and improve existing approaches accounting for the properties of low-carbon fuels which are different from the conventional ones. In particular, the PhD activities will include: •investigation of the effects of alternative fuels thermo-chemical properties (laminar flame speed, flame thickness, reaction rate) on premixed and diffusive combustion models; •simulation of the full-cycle process in ICEs operating with alternative fuels focusing on mesh generation/management techniques aimed at keeping high quality during mesh motion and reducing the total number of required grids also employing topological changes or coupled non-conformal mesh interfaces; •modeling the in-cylinder fuel-air mixing process in gas and liquid fueled engines with attention on near-nozzle flow (gaseous fuel); primary/secondary breakup, standard/flash evaporation and liquid film evolution (liquid fuels). CFD methodology assessment and validation will be carried out with real engine geometries in operating conditions of interest for fuel consuption and pollutant emissions reduction.
Methods and techniques that will be developed and used to carry out the research	The Phd candidate will work with the Lib-ICE code which is a set of libraries and solvers for the simulation of internal combustion engines and it based on the OpenFOAM technology. CFD simulations will be carried out with the RANS approach, which is widely employed in the industrial environment. In-depth analysis of the

	the industrial environment. In-depth analysis of the following topics will be carried on: •premixed combustion: understanding the diffusion effects of hydrogen in the estimation of turbulent flame speed; identification of suitable correlations to estimate the flame wrinkle factor for different low-carbon fuels; development of reliable techniques for tabulation of laminar flame speed and thickness; •diffusion combustion: extensive validation of flamelet models on compression-ignition engines of different size using conventional and alternative fuels; understanding the effects of spray modeling, flame wall interaction and heat transfer on heat release rate in large bore engines; •dual-fuel combustion: modeling the ignition process from pilot jet in different main fuel charge conditions (fully premixed, partially premixed, fully diffusive); •influence of the mesh management in full-cycle simulations: displacement of internal points from boundary motion of piston and valves; mesh-to-mesh solution interpolation; HPC simulation scalability;
Educational objectives	The Phd student will develop specific knowledge related to: •technology of internal combustion engines and future sustainable propulsion systems; •computational fluid dynamics modeling with focus on turbulent, multi-phase and reacting flows •use of zero and low-carbon fuels in combustion systems; •academic to industry technology transfer.
Job opportunities	Thanks to the knowledge gained during his doctoral studies, the graduated PhD student will be able to choose among different job opportunities: •continuation of the academic career focused on CFD

	modeling; •research and development in the field of future propulsion systems; •computational fluid dynamic software development.
Composition of the research group	3 Full Professors 2 Associated Professors 2 Assistant Professors 5 PhD Students
Name of the research directors	Angelo Onorati

Contacts
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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The Phd student could be involved in teaching assistantship in fluid machines, CFD and internal combustion engine courses for a maximum number of 20 hours per semester. The PhD student will work at the Department of Energy of Politecnico di Milano (Bovisa Campus) in a dedicated desk located in the ICE Group PhD and post-doc room. The ICE Group will provide to the student a PC and access to HPC infrastructure for CFD simulations.