POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

PNRR 118 PA Research Field: MASS FLOW MEASUREMENTS TECHNIQUES IN NON-IDEAL COMPRESSIBLE FLOWS FOR HYDROGEN TECHNOLOGIES AND RENEWABLE ENERGY APPLICATIONS

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	Mass flow measurements in non-ideal conditions are non-trivial due to the non-ideal thermodynamic properties of the fluid and the flow dependence on the total conditions. The latter is responsible for the lack of calibrated pressure-based metering systems since the calibration procedure would require considering an unfeasible large range of flow velocity, pressure, and temperature. Costly Coriolis flow meters are now the only option to measure the mass flow in non-ideal conditions. Non-ideal flows are found in diverse applications: heat pumps, Organic Rankine Cycle power systems, supercritical CO2 power systems, and hydrogen production and distribution systems. The present research aims to deliver a low-cost alternative to Coriolis flow meters based on differential pressure measurements in a Venturi nozzle. The expected cost of the new system is at least one order of magnitude lower than that of existing ones, enabling flow metering devices to be employed in: •hydrogen distribution systems for urban mobility and house appliances; •control and optimization of energy systems for renewable energy applications; •control and optimization of the operation of heat pumps.

Methods and techniques that will be developed and used to carry out the research	The present research moves from an original idea, which was awarded the Switch2Product grant in 2021, to apply differential pressure measurements on the Venturi nozzle to measure the mass flow in non-ideal conditions. The present research leverage on the theoretical, numerical, and experimental background developed at the CREA lab on flow measurement systems for non-ideal flows. In particular, the researcher will use: 1) the Test-Rig for Organic VApours (TROVA) to perform the calibration of the probe in selected conditions, 2) the differential pressure measurements systems developed at CREA Lab for non-ideal conditions; 3) the in-house nozzle design software NIMOC for the design of the Venturi tube. New developments within this research concern the study and verification of similarity laws in non-ideal conditions. Given the dependence of the flow on total conditions, standard similarity approaches based on e.g., Reynolds number similarity are not feasible. Low-fidelity flow simulation techniques, from quasi-1D flows to the Streamline Curvature Method, will be applied to verify the similarity laws in the geometry of interest. The experimental campaign will be carried out at the CREA Lab in the TROVA test rig and at the Lappeenranta University of Technology, where three test rigs will be made available to calibrate the metering systems: an Organic Rankine Cycle Power system operating with siloxane fluids; a heat pump test-rig operating with refrigerants; a supercritical CO2 power system. The present research is closely linked to ongoing activities led by the CREA Lab within the Hydrogen Joint Research Platform, gathering the major industrial players in Italy in hydrogen production, distribution, and use (EDISON, ENI, SNAM). Regione Lombardia will be involved in the present research during two short internships of the PhD candidate at Regione Lombardia. During the first internship, the PhD candidate will interview policymakers to assess the requirements for a viable distributed hydrogen distribution system, to be used for advanced

	mobility within the region. The assessment will set the economic and technical requirements for the metering systems. During the second short internship, the PhD will disseminate the outcome of the research within Regione Lombardia and will leverage public events to reach out to the industrial community of Regione Lombardia, to seek investors and user cases. Timeline: •development of the similarity laws for non-ideal nozzle flows and verification via numerical simulation. •metering system manufacturing and calibration in experimental facilities at Politecnico di Milano and Lappeenranta University of Technology, using hydrogen, siloxane, refrigerants, and supercritical CO2 as working fluids. •numerical calibration of the probe to extend the experimental calibration range. Tests in industrial environments.
Educational objectives	The PhD candidate will receive inter-disciplinary, international and intersectoral training. Inter-discipliner training: the researcher will be trained in the diverse disciplines required to master the study of non-ideal compressible fluid flows (thermodynamics, gasdynamics, computational fluid dynamics, wind tunnel testing). This training will be delivered via formal lectures in courses offered by the PhD school and by training on the job, the researcher being embedded in a relatively large research group. International training: the researcher will be embedded in two international research teams at Politecnico di Milano and at the Lappeenranta University of Technology, Finland. The candidate will participate in international conferences, including the ORC International Seminar and the NICFD International Seminar, of which CREA Lab is the founding chair. Inter-sectoral training: •academic training will be delivered by training on the job.

	The researcher will be embedded in research groups at Politecnico di Milano and Lappeenranta University of Technology, and it will carry out cutting-edge research in the novel field of non-ideal compressible fluid dynamics. •the candidate will work in the industrial sector with partners belonging to the network of the ERC PROVA and of the S2P NICET projects, the members of the Hydrogen JRP, and the industrial of Regione Lombardia. •during the internship in Regione Lombardia, the candidate will be exposed to the public sector, meeting policymakers.
Job opportunities	The project ambition is to train a PhD researcher in the inter-disciplinary, inter-national and inter-sectoral skills that will enable a successful career in: •the academic sector, where the doctoral fellow could continue its fundamental research on non-ideal compressible fluid dynamics, •the industrial sector, as a researcher/technic in one of the partner companies or as an entrepreneur, •the public sector, sharing technical knowledge with policymakers about the available technical options in hydrogen-fueled advanced mobility and in renewable energy applications.
Composition of the research group	1 Full Professors 0 Associated Professors 3 Assistant Professors 11 PhD Students
Name of the research directors	Prof. Barbara Re

Contacts
Dipartimento di Scienze e Tecnologie Aerospaziali - Politecnico di Milano Via La Masa 34, 20156, Milano - Italy +39 02 2399 8350 - email: barbara.re@polimi.it - web site: www.aero.polimi.it

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

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	Regione Lombardia
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	LUT – Lappeenranta (FI)
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
The PhD candidate will receive a desk, possibly through a hot-desking procedure, and a personal computer, if needed. Apart from the compulsory ones, the PhD candidate will have the opportunity to follow additional courses and receive economic support to attend summer schools and participate in conferences. There will be the possibility of paid teaching assistantship.