POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 38th cycle

PNRR_351_DOTT_RICERCA Research Field: ALL MACH MULTI-PHASE DIFFUSE-INTERFACE METHODS FOR THE DEVELOPMENT AND VALIDATION OF A DUST SUPPRESSION DIGITAL TWIN

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	Funded by PNRR M4C1 (potenziamento dell¿offerta dei servizi di istruzione: dagli asili nido alle università) Contributes to M1C2 (digitalizzazione, innovazione e competitività nel sistema produttivo) Multi-phase flows are present in many engineering problems, ranging from internal combustion to the transport of liquids in pipelines. Some notable examples of multi-phase flows, that are currently of great interest in the decarbonization process our society is undergoing, are the transport of CO2 in pipelines for ¿carbon capture¿ purposes and water hydrolysis in the production of hydrogen for fuel cells. This project will focus on the use of multi-phase flow solvers for the creation of a digital twin, and its subsequent optimization, of a dust suppression system, used to preserve crops and therefore reduce energy consumption and increase the sustainability of agriculture. Applications also include the dispersion of disinfectants to sanitize large environments from COVID or chemicals. The simulations of multi-phase flows can be performed using two main approaches: ¿ the Lagrangian approach, tracking the dispersed phase particle by particle ¿ the Eulerian approach, treating both phases as if they were continuum media

	When the amount of droplets of the dispersed phase is large, such as in inherently 3D cases, it becomes computationally unfeasible to use the Lagrangian approach. For these types of cases, Eulerian multi-phase solvers are much more fit for purpose. There is more than one kind of Eulerian multi-phase solver, but this project focuses on the Diffuse Interface Method (DIM), on the Baer-Nunziato equations. These equations allow for full disequilibrium of pressure and velocity, the simulation of multiple phases, both dispersed and separated, and the use of arbitrary equations of state. This means they can handle liquids, solids, and gasses. The objectives of the research are the following: ¿ Develop a numerical scheme to handle weakly compressible and compressible phases on unstructured 3D meshes ¿ Develop a solver using the new scheme ¿ Validate the solver using academic tests and then matching experimental data ¿ Create a digital twin of the dust suppression system
Methods and techniques that will be developed and used to carry out the research	The Baer-Nunziato (BN) equations will be used to model the multi-phase flows. To handle weakly compressible cases a BN pressure formulation can be employed, while the classical BN formulation can be used for compressible cases. All numerical issues arising from low compressibility must be addressed. A way to blend the two, or a third all-Mach formulation, must be chosen before settling on a numerical discretization. The solver will be finite volume, with the possibility of parallelization for computational cost mitigation. Various equations of state must be tested, and one (or more) must be chosen to best represent the physics of dust suppression. The solver must be validated by testing it against analytic solutions of academic test cases and experimental data. Once the solver has been implemented and validated, test cases must be devised to represent the operating conditions of the dust suppression system, and quantities of interest have to be identified. Having identified these

	quantities, and having characterized a baseline, they must be optimized with energy efficiency and feasibility in mind. For this step, the collaboration with WLP SRL will play a crucial role. The timeline of the work is split as follows: ? First year, development of the numerical formulation for weakly compressible and for compressible cases. ? Second year, development and validation of the solver. ? Third year, creation, validation, and optimization of the dust suppression system?s digital twin. A period of 6 months is spent at the University of Zurich for the numerical discretization of the equations, the development, and the validation of the solver. The creation, validation, and optimization of the dust suppression system's digital twin are done in collaboration with WLP SRL.
Educational objectives	This Ph.D. aims at developing skills in the creation of new CFD tools for multiphase flows, and the use of such tools for the improvement of existing industrial dust suppression systems for the protection of crops. Internships: a period of 6 months are spent at the University of Zurich for the numerical discretization of the equations, the development, and the validation of the solver. The creation, validation, and optimization of the dust suppression system's digital twin are done in collaboration with WLP SRL. Apart from the hard skills required to develop the tools, many soft skills will be acquired such as presenting the research, creating industrial reports, and writing scientific papers. The exposure to the industrial and academic environments will allow the student to adopt a wide range of techniques and methodologies and implement them in his/her future work.
Job opportunities	¿ CFD development, multi-phase flow modelling ¿ Industrial product design and optimization, creation of a

	product¿s digital twin
Composition of the research group	1 Full Professors 0 Associated Professors 2 Assistant Professors 8 PhD Students
Name of the research directors	Prof. Alberto Guardone

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

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	
By number of months at the company	0
Institution or company where the candidate will spend the period abroad (name and brief description)	University of Zurich, Switzerland
By number of months abroad	6

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