POLITECNICO DI MILANO

PhD in INGEGNERIA AEROSPAZIALE / AEROSPACE ENGINEERING - 39th cycle

THEMATIC Research Field: FILM COOLING: TOWARD HIGH PERFORMING GREEN LIQUID ROCKET ENGINE FOR SUSTAINABLE SPACE PROPULSION

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	Liquid Rocket Engines (LREs) play a key role in access to space and in-space propulsion. In the next future, this position will be even more prominent. The pursuit of more sustainable space access requires the development of LREs combining high performance with reduced environmental impact (i.e., green propellants). The development LREs has the thermal control of the thrust chamber as a key element. Liquid film cooling is a breakthrough solution for the control of thrust chamber thermal loads in high-performing systems. In liquid film cooling a liquid layer of coolant is injected in the thrust chamber to reduce the heat transfer from the propellant stream to the engine wall. In the liquid pre-saturation regime fluid layer stability plays a critical role due to the possible insurgence of entrainment mass transfer. In the liquid post-saturation region, coolant blowing limits the convective heat transfer coefficient between the propellant stream and the wall. In gaseous film cooling the coolant in injected in the gaseous phase, shielding the thrust chamber wall from the intense thermal loads. In this context, the proposed activity will focus on the analysis of liquid film cooling. The PhD program tackles the criticalities in the film cooling implementation aiming at comprehensive experimental and numerical analyses of liquid film stability and heat transfer effects. The research is funded by Avio SpA in the frame of the Italian Space Agency (ASI) contract(codice unico di progetto (CUP) F83D23000120005, codice identificativo gara

	(CIG) 9296180A69I) for activities financed by the European Union - Next Generation EU through Piano Operativo M1C2.I4.4 relevant to "In-Orbit Economy - In-Orbit Services" PNRR-FC.
Methods and techniques that will be developed and used to carry out the research	The complex nature of the liquid film cooling requires a series of methods to be combined for an effective understanding of the different phenomena involved in liquid/gaseous film stability and thermal effects. Experimental activities are required for the analysis of interplaying effects as liquid jet impingement on the thrust chamber walls (in turn affecting the solid contour wetting by the coolant and the layer development), the hydrodynamic stability of the liquid layer, and the heat transfer in the liquid pre- and post-saturation regimes. Modelling of the gaseous coolant film behaviour in the thrust chamber is required. Together with the existing (though limited) open literature studies, the design and implementation of dedicated experimental setups can provide a dataset for the validation and tailoring of models assisting in the analysis. These models shall combine liquid injection effects with the analysis of the liquid layer characteristics. CFD simulations will support the investigation of (i) coolant flow/propellant stream interaction, and (ii) film cooling effects in the pre- and post-saturation region the coolant flow. For the investigation of the thermal loads to the coolant (liquid/gaseous) film combustion process simulations will be performed.
Educational objectives	The program aims at promoting the cultural growth of the candidate combining technical and soft skills. Film cooling analysis requires the implementation of experimental hardware and of numerical models tackling different aspects of the professional growth of a researcher operating in academic and/or industrial contexts. In the PhD program in Aerospace Engineering the candidate must obtain 20 ECTS. These credits must be obtained respecting the following conditions: (i) at least 10 ECTS from PhD School Courses offering training in soft and

	transferable skills, (ii) at least 5 ECTS from courses in the PhD program in Aerospace Engineering, (iii) a maximum of 5 ECTS from courses offered by other PhD programs. Additional courses can be added. The formation is an integrating part of the research program, aiming at the development of the skills required in high-level and impacting research programs.
Job opportunities	Research activities join experimental analyses and numerical modelling. Both fundamental and applied knowledges are developed in the frame of the project. The candidate will move in an environment promoting professional and technical growth. A series of cutting edge knowledges meeting the demand of the industrial market must be developed.
Composition of the research group	0 Full Professors 1 Associated Professors 2 Assistant Professors 6 PhD Students
Name of the research directors	Prof. Christian Paravan

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 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.


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