POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 39th cycle

PNRR 117 Research Field: MULTISCALE MODELLING AND SIMULATION OF LARGE SCALE ADDITIVE MANUFACTURING OF FIBRE REINFORCED THERMOPLASTIC POLYMER STRUCTURES

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	Large-Scale Additive Manufacturing (LSAM) of short fibre reinforced polymers allows a relatively fast manufacturing of large complex shapes. While several factors still limit its application for structural components, it represents an excellent option for tooling and moulds. These applications, however, impose very strict dimensional tolerances, which is in contrast with the tendency of polymers to warp and deform when cooling after printing. It is thus paramount to be able to predict such deformations, so that they may be eventually compensated for in the design phase. The objective of the research will be to develop and validate a numerical modelling strategy to predict the warpage behaviour of polymeric parts produced via LSAM. The research topic addresses a novel research and development topic which constitutes an important advancement in the industrial field of additive manufacturing, as well in the academic/research community, therefore it is fully coherent with the Mission 4 of the PNRR, M4C2 From Research to Business, particularly with respect to the line of action 1 aiming at strengthening Research and Development in the research system and in the economic system and with the Mission1, M1C2 Digitalisation, innovation and competitiveness in the production system.
Methods and techniques that will be developed and used to carry out the research	First of all, the PhD student will be required to study in-

research	depth the literature available on the topics related to the research. These topics include thermal properties and viscoelastic response of 3D printed polymers, LSAM techniques, experimental techniques for the evaluation of polymeric properties, state of the art of the available models for the prediction of the thermo-mechanical response of 3D printed polymers. Moreover, the candidate will be required to select, among all the ones available in the literature, the modelling approach that is best suited for the objectives of this research. This selection will be based on accuracy, model efficiency, usage of commercially available tools and required inputs. The last point will be particularly important to propose a holistic experimental campaign to fully characterise the considered material and gather all the required inputs.Once a modelling approach is selected, the student will implement it in a commercially available Finite Element software. Once developed, the model will be initially validated against data from the literature. In a later stage, the model will be validated on an in-house experimental test, so that the material and LSAM capabilities specific of this project are considered. Both experimental validations will help the identification of drawbacks and limitations of the selected modelling approach, for which the student will propose and develop countermeasures. The research plan will thus involve two extensive experimental campaigns. The first one aims to collect all the required inputs for the selected modelling approach (specific heat capacity, anisotropic thermal conductivities, anisotropic tensor of elasticity, etc.). Process-dependent parameters, like fibre orientation, will also be characterised. The second experimental campaign will serve as validation for the developed model, based on tests performed on large parts.
Educational objectives	The Doctor in Mechanical Engineering will be able to define, start and carry out original research by working in a team or leading a research group. Both theoretical and experimental skills will be mastered.
Job opportunities	The holder of a PhD in Mechanical Engineering will have job opportunities in structures/organizations aimed at

	innovation and/or research and technical development, high-tech SMEs, and government departments ruling on public needs. Specifically, the proposed research topic can offer job opportunities in the field of advanced manufacturing of composite structures. Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to Master of Science holders in the same field.
Composition of the research group	1 Full Professors 1 Associated Professors 1 Assistant Professors 4 PhD Students
Name of the research directors	Prof. Andrea Bernasconi, Dr. Luca Martulli

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)	Camozzi Research Center S.r.l.
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	Ingersoll Machine Tools, USA
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount

of euro 5.707,13.

Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.