MANAGEMENT AND PRODUCTION ENGINEERING

DM 630/CIM4.0 - Additive Manufacturing of MultiMaterials

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Supervisor	SABOORI ABDOLLAH - abdollah.saboori@polito.it

Contact	IULIANO LUCA - luca.iuliano@polito.it

Context of the research activity	The future of the manufacturing industry is increasingly linked to Additive Manufacturing processes, thanks to their potential for shaping designs, enhancing part functionality, and optimizing material usage. Despite these advantages, a notable lack of knowledge regarding the processability of Multi Materials hampers the widespread adoption of these technologies in certain industrial sectors. This research is dedicated to exploring the processability of such materials, with the goal of uncovering their potential and addressing challenges. The objective is to identify viable solutions and expand the applications of Functionally Graded Materials (FGMs) across diverse industries. Progetto finanziato dal PNRR a valere sul DM 630/2024 - CUP E14D24002430004

	Functionally graded/gradient materials (FGMs) as a class of multi materials are defined as materials with the gradual evolution of chemical composition or structural features at different scales across preferred directions to provide site-specific properties without abrupt changes. This concept derived from simple examples of nature (imagine a wood or bone cross-section) has placed FGMs in the latest stage of continuous developments for AM processes. In other words, it was inevitable to combine different materials due to the wide range of service needs in today's advanced applications. However, the main weakness of typical multi-material structures (mainly joints or composites) is sharp interfaces, which cause premature or even catastrophic failure. As a result, FGMs have been suggested to increase efficiency and lifespan in engineering structures by minimizing or eliminating abrupt changes. The FGMs were first proposed for thermal barriers and are now widely employed as advanced materials in high-performance multifunctional or

Objectives	critical conditions in high-tech industries such as energy, aerospace, and medical. Also, FGM prototypes can be used for the rocket nozzle, automotive valve stem, and space mirror, from the design to the final part. One of the aims of this research work is to demonstrate the superiority of FGMs component compared to the commercially produced components. On the other hand, selection of the manufacturing method is an important step in producing an FGM part because the realization of the complex and detailed design of FGMs (in terms of chemical composition and geometrical features) is highly dependent on the manufacturing method. In addition, the production process should be economically viable while considering the environmental aspects. The categorization of conventional manufacturing (CM) methods based on the initial material state and size of FGMs. In general, the mechanism of CM methods for producing an FGM part includes two separate stages: gradation and consolidation. The gradation operation is typically carried out by progressively adding a multi-phase material to a single-phase structure, following a preliminary design, by chemical, physical, and mechanical procedures, or a combination of them. Then, the final FGM part is often achieved through a consolidation process such as solidification and drying or sintering. Although each of the CM methods has its own advantages, the multi-stage production along with some inherent disadvantages such as limitations in terms of geometry (e.g., in centrifugal casting) and density (e.g., in powder metallurgy), high energy consumption, and environmental damage (e.g., in CVD/PVD or SHS) are considered as obstacles to the further spread of FGMs by CM methods. Nevertheless, the emergence of AM technology with the unique features has opened a new window for the development of FGMs. The layer-wise nature of AM allows more precise control over the gradient and geometrical characteristics when producing FGMs with more complex designs. In addition, integrating the two stages of gradation and consolidation processes and reducing materials waste makes AM more economical and environmentally friendly than CM. AM processes, including stereolithography, material jetting, fused deposition modelling, and melting & solidification-based processes, can fabricate FGMs. However, the processes mainly based on melting & solidification, i.e., DED and PBF, are used to produce metallic FGMs. In this regard, DED is more popular due to its powder-blowing or wire injection mechanism and, thus, high flexibility to adjust and alter the chemical composition during the process. All in all, this research will highlight the importance, challenges, and opportunities when the potentialities of AM processes are integrated with the unique characteristics of FGM materials. To enlarge the industrial application of this class of materials processed via metal AM technologies, it is necessary to identify process parameters that optimize the properties of the final parts, such as thermophysical and mechanical properties, tolerances, surface quality, or residual stresses. Furthermore, it is also important to study the efficiency of the process in terms of powder use. This could reduce the material waste and thus the environmental impact of this process. The Interdepartmental Center of Integrated Additive Manufacturing at Politecnico di Torino (IAM@PoliTo) considers collaborating with industrial partners as a central and strategic vision to ensure that the knowledge developed in joint projects will be implemented in the industry. The objectives of this PhD are: • To identify the existing application and products of FGM processed via metal AM processes, detailing advantages and shortcomings. • To identify the potential applications for FGM main challenges in the processability of functionally graded materials processed via powder bed

	fusion technologies. • To define the main challenges in the processability of FGM via powder based technologies. • To identify the possible solutions for the production of components made of FGM (both technological and material solutions). • To combine CAE tools and DoE experimental approach for the definition of optimal process parameters for different FGMs. • To perform full characterization of FGMs specimens and analyze the outcomes for different combinations. • To correlate Process-Structure-Properties relationship in the FGMs parts produced via metal AM processes. • To analyze the results of the assessment activity and define a series of guidelines for selecting the process parameters for different materials with unique properties. The activity will be developed at the IAM center at Politecnico di Torino, and a secondment abroad in a research center such as National Center for Additive Manufacturing Excellence (NCAME) at the Auburn University (USA) for approximately six months.

Skills and competencies for the development of the activity	The PhD candidate's skills required are: • Knowledge of Metal Additive manufacturing technologies is required. • Knowledge of Materials processing together with materials characterization is highly preferred. • Knowledge of Machine learning and Python programming language is an advantage. • A good attitude for lab activities, problem-solving skills, and high motivation to learn through advanced research are requested. • Ability to set priorities, work in a multicultural and multidisciplinary team, plan the work, and respect deadlines are essential.