THÈSE DE DOCTORAT D'EXCELLENCE « FUTUR, RUPTURES & IMPACTS » 2026
PHASE 1 SUMMARY SHEET (2 pages)

PLEASE NOTE: assessment will be based solely on the elements described in the application and supported by factual evidence. If any information is missing, the minimum score will be assigned.

TITLE OF THE THESIS: Towards more robust 3D-printed prostheses: Optimizing the mechanical strength of bio-based materials using laser post-processing.

THESIS SUPERVISORY TEAM:
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AFFILIATED SCHOOL OF THE THESIS SUPERVISOR: IMT Mines Albi

THESIS HOSTING TEAM(S):
The thesis will be conducted in two research laboratories: IMT Nord Europe (CERI Materials and Processes, 50%) and IMT Mines Albi (ICA, Metrology Identification Control and Surveillance (MICS) group, 50%).

IMT'S SCIENTIFIC COMMUNITY ADDRESSED: « Procédés avancés » and « Ingénierie et Services de la Santé »

KEYWORDS: Printed prosthesis, Agro-sourced materials, Volume image correlation, Post-laser treatment

SUMMARY IN 30 LINES:

Agro-sourced materials, derived from agricultural sources such as flax fiber-filled PA6, offer an environmentally friendly alternative to traditional materials and thus contribute significantly to the decarbonization of industry. They can be used in 3D printing using Fused Deposition Modeling (FDM) technology to produce temporary prostheses for recently amputated limbs, for example. The complexity of the interrelationships between the specific properties of these materials, the 3D printing parameters, the thermal effects inherent in the process, and the mechanical characteristics of the manufactured parts constitutes a major challenge [1]. To improve the strength of parts manufactured with this material using this process, it is possible to incorporate laser melting post-processing. In addition, recent studies show that it is possible to use volumetric dimensional analysis to characterize the mechanical behavior of textile-reinforced composites [2], despite the complexity of characterizing these materials due to the presence of fibers [3]. It is necessary to develop specific methods that consider the deformation of the fibers within the composite [4].

This thesis proposes to study the impact of laser fusion and its implementation parameters on the mechanical strength of parts manufactured from bio-based materials using 3D printing with the FDM technique. To this end, it is planned to use image volume correlation on mechanical tests carried out in a tomograph to precisely characterize the kinematics of the fibers in the material during traction, compression, or bending. This thesis will include the following steps: (i) the development and performance of in situ tests, (ii) the analysis of the influence of laser fusion parameters, (iii) the implementation of a model of the mechanical behavior of these materials, and (iv) the optimization of fusion parameters in order to obtain the most effective composite material for the production of temporary prostheses. The results of this thesis should lead to the proposal of

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a new manufacturing process in the field of healthcare. The mechanical behavior of the material can be modeled in collaboration with a Latvian research team that has developed numerous tools for characterizing fibrous materials in connection with complex experiments [5].

The originality of this project lies in the combination of innovative techniques, laser melting and volumetric image correlation, to optimize the material properties of a composite incorporating natural fibers. Indeed, the “classical” mechanical characterization of this type of material is limited due to the complexity of the kinematics generated by the presence of these fibers [4]. Better measurement of this behavior should enable better optimization of the material.

ENVIRONMENTAL EXPENDITURE ENVISAGED (COVERED BY THE ADDITIONAL FUNDING OF €15,000)

Consumables: Raw materials and instrumentation for manufacturing and characterizing test specimens/parts (e.g., tensile testing in the tomograph).
Services: Open access publication, access to the tomographic platform, laser post-processing tests.
Travel expenses: Travel to multiple sites (Douai, Albi, Toulouse, Tarbes). Partnership with RTU Latvia for composite simulations that could contribute to the research project (travel included). Mission expenses and registration fees for an international conference during the thesis.

BIBLIOGRAPHY:

[1] Le, A. D., Akué Asséko, A. C., Cosson, B., & Krawczak, P. (2023). Investigating the Effect of Interface Temperature on Molecular Interdiffusion during Laser Transmission Welding of 3D-Printed Composite Parts. *Materials*, *16*(18), 6121.

[2] Lee, S., Hong, C., & Ji, W. (2022). In situ micromechanical analysis of discontinuous fiber-reinforced composite material based on DVC strain and fiber orientation fields. *Composites Part B: Engineering*, *247*, 110361.

[3] Patou, J., Bonnaire, R., De Luycker, E., & Bernhart, G. (2019). Influence of consolidation process on voids and mechanical properties of powdered and commingled carbon/PPS laminates. *Composites Part A: Applied Science and Manufacturing*, *117*, 260-275.

[4] Xu, T. (2023). *FE DIC potential for the mechanical characterization of textile reinforcements* (Doctoral dissertation, Université Paul Sabatier-Toulouse III)

[5] Filipova, I., Irbe, I., Spade, M., Skute, M., Dabolina, I., Baltina, I., Vecbiskena, L. (2020). Mechanical and Air Permeability Performance of Novel Biobased Materials from Fungal Hyphae and Cellulose Fibers. *Materials, 14,* 136.