Position Description

1. General Information

Name of the position	**Mechanics in additive manufactured structures under dynamic loadings**
Foreseen date of enrolment	1 October 2023
Position is funded by	• COFUND, Marie Skłodowska-Curie Actions (MSCA), Horizon Europe, European Union • École Nationale Supérieure D'Arts et Métiers (ENSAM) • University of New South Wales (UNSW)
Research Host	École Nationale Supérieure D'Arts et Métiers
PhD awarding institutions:	École Nationale Supérieure D'Arts et Métiers & University of New South Wales
Locations	Primary: Bordeaux-Talence, France Secondary: Canberra Australia
Supervisors	Philippe VIOT (ENSAM) Paul HAZELL (UNSW Canberra)
Group of discipline	Mechanics, Materials

2. Research topics (only one of these projects will be funded)

Project 1: *Bio-Inspiration: Effect of the density gradient on the mechanical behaviour of an architectural material under dynamic loadings*

The development of new additive manufacturing processes has changed the way we consider process/microstructure/properties relationships of materials. Furthermore, the architectured structures obtained by additive manufacturing can be specifically designed to be used as energy absorbers in the case of an impact, shock or ballistic loading. The light-weighting of these structures, and their capability to dissipate energy are advantageous for the development of components for crashworthiness or other protective applications.

To conceive more efficient structures, it is possible to draw inspiration from nature. Over the millennia, lightweight natural structures have developed heterogeneous architectures to cope with quasi-static, cyclic or impact mechanical loading conditions. One of the features observed in many biological structures is the density gradient. Such feature has been shown to improve the mechanical properties of architectural structures. The aim of this project is to establish how

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a bioinspired density gradient affects energy absorption of such an engineered structure. There is a current lack of detailed understanding of the underlying strain mechanisms of biological and bio-inspired structures during mechanical loading and their dependence on strain and strain rate.

A methodology will be developed to (1) characterize the density gradient in biological structures using SEM and microtomography; (2) conceive and produce by metallic additive manufacturing architectured samples with a bioinspired density gradient; and (3) identify experimentally the mechanical behaviour of the architectured material at different strain rates with high-speed jack, Hopkinson bars and high-velocity gas gun. The final step of this study is to correlate and model the effect of the density gradient on the response of the 3D printed material to mechanical loading.

Supervisors:

Professor Philippe VIOT (ENSAM), Professor Paul HAZELL (UNSW Canberra) & Dr Jérome MESPOULET (Thiot)

Research Fields: Mechanics, Architectured materials, Dynamic loadings, Strain rate effects, Microtomography, Bio-inspiration, Additive manufacturing

Project 2: *Multiscale Architectural Materials: The Effect of Porosities on Mechanical behaviour under Dynamic Loadings*

The development of new additive manufacturing processes has changed the way we consider process/microstructure/properties relationships of materials. Furthermore, the architectured structures obtained by additive manufacturing can be specifically designed to be used as energy absorbers in the case of an impact, shock or ballistic loading. The light-weighting of these structures, and their capability to dissipate energy are advantageous for the development of components for crashworthiness or other protective applications.

In the design of these new parts, the structure is alveolar, mainly to reduce the mass. The walls of these materials can also be considered as a cellular material due to the level of porosity introduced during the manufacturing process. It is therefore possible to obtain a multi-scale architectural material by additive manufacturing. The objective of this project is to study the influence of the porous multi-scale structure on the mechanical behaviour of these architectured materials under complex dynamic loading. The aim is to consider the macroscopic behaviour of the 3D printed geometry of the part obtained by SLM additive manufacturing but also that of its porous microstructure formed during the manufacturing process.

An experimental methodology has to be developed to (1) model and print porous architectured materials; (2) characterize their microstructure by SEM and multiscale microtomographic observations; and (3) identify experimentally the mechanical behaviour of the material at different strain rates with high speed jack, Hopkinson bars and high-velocity gas gun. The final step in this study will be to correlate and model the effect of porosities and architecture on the response of the 3D printed material.

Supervisors:

Professor Philippe VIOT (ENSAM), Professor Paul HAZELL (UNSW Canberra) & Dr Jérome MESPOULET (Thiot)

Research Fields: Mechanics, Architectured materials, Dynamic loadings, Strain rate effects, Microtomography, Additive manufacturing

Project 3: *Methodology for characterising the mechanical behaviour of an architectural material under dynamic loadings*

There have been relatively few studies on the behaviour of metallic architectured structures subjected to high strain rates. This is probably due to the challenges in understanding and modelling the damage mechanisms induced by dynamic loading. Further, the use of classical experimental apparatus in dynamics such as the Split Hopkinson Pressure Bar (SHPB) must be reconsidered for identifying the dynamic behaviour of these materials.

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Hopkinson bars are a classical experimental apparatus for identifying the mechanical response of dense -metallic or polymeric- materials at high strain rates. This experimental SHPB setup has also been modified to study the behaviour of cellular materials with low impedances. In any case, the use of Hopkinson bars to identify the mechanical behaviour of a material under dynamic loading requires assumptions concerning wave propagation in the sample. The SHPB assumptions cannot be verified in the case of architectured materials. During a dynamic compressive loading using Hopkinson bars, the propagation of waves, their multiple reflections in the structure of the material must be analyzed. In this research project, it is proposed to model and develop Hopkinson bars adapted for the mechanical characterization of architectured materials. An experimental methodology coupled with numerical simulations is proposed to (1) design and print a representative metallic structure of an architectured material; (2) model and simulate its behaviour under propagation of waves during an SHPB test; and (3) improve the identification of the mechanical behaviour of architectured material by experimental/simulation comparison in using complementary observations by high-speed camera and digital image correlation techniques (DIC). The final step of this study is to validate the material behaviour identified with a high-velocity gas gun.
Supervisors: Professor Philippe VIOT (ENSAM), Professor Paul HAZELL (UNSW Canberra) & Dr Jérome MESPOULET (Thiot)
Research Fields: Mechanics, Architectured materials, Dynamic loadings, Strain rate effects, Hopkinson Bars, Additive manufacturing

3. Employment Benefits and Conditions

The École Nationale Supérieure D'Arts et Metiers (ENSAM) offers a 36-months full-time work contract (with the option to extend up to a maximum of 42 months). There is a probation period of 3 months and the total working hours per week is 35 hours.

The remuneration, in line with the European Commission rules for Marie Skłodowska-Curie grant holders, will consist of a gross annual salary of 23,098.20. Of this amount, the estimated net salary to be perceived by the Researcher is 1,924.85. However, the definite amount to be received by the Researcher is subject to national tax legislation. The % tax cannot be defined in advance with certainty, but will be between 6 and 7% of the monthly net value described above.

Benefits include

- Access to all the necessary facilities, technical platform and laboratories at ENSAM and UNSW Canberra.
- Tuition fees exemption at both PhD awarding institutions.
- Yearly travel allowance to cover flights and accommodation for participating in AUFRANDE events.
- 10,000 EUR allowance to cover flights and living expenses for 12 months in Australia.
- 25 days paid holiday leave.
- Sick leave.

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4. PhD enrolment

Successful candidates for this position will be enrolled by the following institutions and must comply with their specific entry requirements, in addition to AUFRANDE's conditions.

ENSAM

To be admitted in a Doctorate program, Applicants must hold a Master's degree.

More information: https://artsetmetiers.fr/en/formation/doctoral-school

UNSW

The minimum entry requirement for admission to a PhD includes:

- an appropriate UNSW bachelor degree with upper second-class honours; or
- a completed Masters by Research from UNSW with a substantial research component and demonstrated capacity for timely completion of a high-quality research thesis; or
- an equivalent qualification from a tertiary institution as determined by the Faculty Higher Degree Committee (HDC).

If English is not your first language, you will be required to provide evidence your English language proficiency. Note that your English test needs to be completed no more than two years before your enrolment at UNSW. The English language test scores requirements can be found here: https://www.unsw.edu.au/study/how-to-apply/english-language-requirements

More information: https://research.unsw.edu.au/higher-degree-research-programs

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