

Master Research Internship

Towards the design of engineering products made of metallic lattice material: manufacturing, testing and modelling aspects

Keywords: lattice materials, mechanical testing, numerical modelling, computed tomography, product scale additive manufacturing.

Context

Bringing additional weight saving in the design of modern engineering products relies upon a simple idea: increasing the percentage of voids in the material in a well organised, architected manner. The rapid development of additive manufacturing (AM), in particular Selective Laser Melting (SLM) for metals, enabled the design at the material scale in order to create, so called, lattice materials (LM). These meta-materials are on the small-scale topologically ordered, three-dimensional open-celled structures composed of repeating unit cells (UC), see Fig 1. In the literature LM are usually created of beam-based or surface based UC as presented on Fig 1. but the number of options and possible realisations is endless.

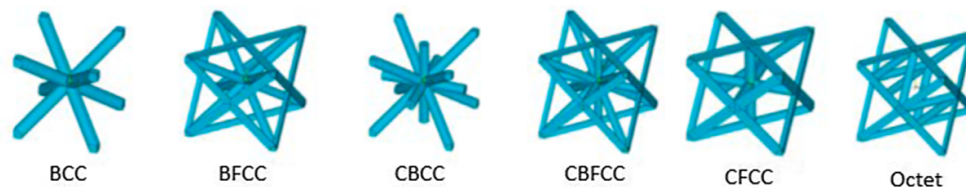


Fig 1. Some of the typical examples of beam-based unit cells used to generate engineering lattice materials.

On the macroscale, the product's behaviour depends on different parameters related to: 1. cell topology (Fig 1) and geometry (relative density, beam diameter, ...), 2. material and manufacturing process, 3. loading conditions. By carefully choosing and optimising the LM design space one can achieve different functional purposes and remarkable macroscopic mechanical properties which outperforms the bulk (dense) structure made of the same material. LM are therefore of particular interest in transport (aviation, space), implants and industry where the most stringent criteria is related to mass reduction, energy absorption (crash) and thermal management.

Even though AM gives flexibility and design freedom, these manufacturing techniques are far from perfection. One of the key problems is that there are many factors (some of them random as powder distribution) that affect the quality, behaviour and performance of printed parts [Oropallo, Bachmann]. Having such a large number of influential factors, their interaction and effects are still not completely understood. This further leads to the problems of defects which, in turn, govern the products behaviour. Second problem is related to the

specific process limits of SLM related to the minimum manufacturable feature size and inclination angle for chosen Ti and Al alloys. Not any lattice design and geometry is feasible from a manufacturing and powder cleaning point of view. In this context, **IRT St Exupery**, together with **Thales Alenia Space**, **Liebherr**, **LISI aerospace**, **AIRBUS**, **Capgemini Engineering** and the **Clement Ader Institute** (ICA), is leading a collaborative project entitled **WALLSAPP** for *thin-WALLed and Lattice Structures for Aerospace aPPlications*, which aims to better master the process-microstructure-properties chain of SLM manufactured lattices, to build predictive and efficient numerical models and to improve industrial capacity to design lightweight and multifunctional structures for aerospace.

As a part of the WALLSAPP project, this work will focus on improving the design process and additive manufacturing of the engineering product made of LM. Moreover, we will focus on the light-weight structural materials. Thus, we will prefer UC which are globally stretch-dominated aiming to achieve high specific strength. To that end, the manufacturing will concern SLM in combination with light-weight, corrosion resistant titanium (bio-compatibility) and aluminium (thermal-diffusivity) alloys.

Objective, program and outcome

The aim of this internship is to provide insight into the influence of the design parameters (mentioned above) on the deformation and failure behaviour of the engineering product made of LM. Thus, the three key aspects

- (a) manufacturing,
- (b) testing, and
- (c) modelling

will be studied on the two different scales (Fig 2.)

- (i) minimal multi-cell specimen, and
- (ii) structural (product) scale.

The key idea behind this multi-scale and multi-aspect methodology is to favour the transfer of the knowledge, related to three aspects, from the specimen to the product scale.

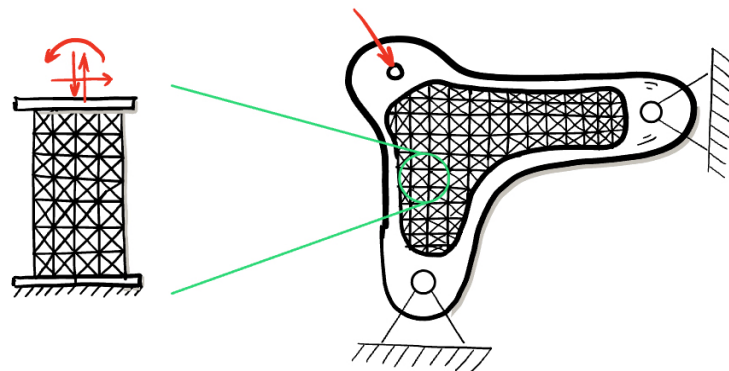


Fig 2. Scheme of the two test scales: lattice test specimen (left) and product scale (right).

To that end, for each choice of cell topology and design parameter (geometry and boundary conditions) we will have to iteratively:

1. Reestablish, from the vast literature, and complete the knowledge about manufacturing, testing and simulation on the lattice specimen scale.

2. Quantify the transferability of the knowledge gathered on the test specimen scale to the product scale (with perpetual verification and validation).

Some of the principal tasks of the intern will consider (possibly on both scales):

- Investigation of the manufacturability, characterization of manufacturing fidelity through computed tomography, classification of the defect morphology and the development of the methodology for incorporating defects into the computational models.
- Characterization of deformation and failure modes with mechanical experiments (ex- and in-situ) and investigation of the effect of the boundary conditions on the mechanical properties.
- Validation of numerical modelling performed on the beam, 3D and mixed beam-3D numerical models with and without defects by comparison with the results of the experimental modelling and observed deformation and failure modes.

Candidate profile and application

Highly motivated candidates with the applied mathematics or mechanical engineer profile and the interest for the computational mechanics are welcome to apply. Experience in finite elements and python programming is required.

The candidates should send their CV and motivation letter to the internship advisors:

Eduard MARENIC (ICA): marenic@insa-toulouse.fr

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Ludovic BARRIERE (IRT St Exupéry): ludovic.barriere@irt-saintexupery.com

Localisation:

The internship will take place at Montaudran Aerospace, Toulouse between two institutes **Institut Clément Ader** (ICA) and **IRT Saint Exupéry**.

Institut Clément Ader (ICA), Université de Toulouse, 3 Rue Caroline Aigle, 31400, Toulouse, France.

IRT Saint Exupéry, 3 Rue Tarfaya, 31400 Toulouse, France.

Duration The duration of the internship is 6 months with a start in March or April 2024.

Gratification Legal internship gratification about 600 EUR/months