ST7 – 81 – ADDITIVE MANUFACTURING DESIGN

Dominante : CVT (Construction, City and Transportation)
Langue d'enseignement : English
Campus où le cours est proposé : Paris-Saclay

Engineering problem

Since its inception, additive manufacturing has proven to be a fundamental change in manufacturing processes, allowing total customization and artisanal quality at the cost and precision of a modern industrialized process. However, it is a young process, and therefore, not yet fully mastered. The mechanical properties of the parts produced are often unpredictable, severely limiting their use in high-end applications. This is why the development of methods (analytical and numerical) capable of predicting the final characteristics of the part by optimizing the design process seems a necessity.

The sequence focuses on the optimization of the design by additive manufacturing:
- Optimal choice of material and microstructure;
- Optimization of geometry with respect to multiphysical constraints;
- Optimization of process parameters (printing path, laser power, powder characteristics...)
- Evaluation of the economic and social stakes of FA compared to standard processes (manufacturing time, cost of materials, labor employed, environmental compatibility...)

This design presents a major challenge due to the multiphysical nature of the additive manufacturing process (thermal, mechanical, electromagnetic, metallurgical, phase change) and poses a multiscale problem both in space and in time (evolutionary nature of the process).

Advised prerequisites

It is advisable to have taken the SPI course "Mechanics of Continuous Media" and at least one of the following courses: Materials, Transfer Science, Thermodynamics.

Context and issue modules:
These modules include lectures, a study-case and a mini-project, aimed at presenting the problem, the social and economic stakes and making a simple object using 3D printing.

Specific course (60 HEE): *Multiphysics coupling*

Brief Description: This course will address the concepts and issues of multiphysics coupling in a broad sense. The following topics, among others, will be covered during the course:

- Strong - weak coupling
- Coupling of different formulations
- Coupling of different scales

Then we will focus on particular couplings, of interest for additive manufacturing:
- Laser on powder: electro-thermal coupling
- Powder bed melting: discrete-continuous, solid-fluid and thermo-mechanical coupling
- Cooling phase: aerothermal-mechanical coupling

The course will end with a reflection on the mechanics of the final part (residual stress, porosity, microstructure...).
A strong emphasis is placed on practice through tutorials and a case study on the multiphysics simulation software COMSOL. The acquired skills are evaluated by the case study.

Projects:

Brief description: The sequence is built around various projects carried out by the CVT major. The students, in groups of 5 maximum, will have to answer a problem proposed by their industrial partner around the design of a part in additive manufacturing. This may involve optimizing its geometry, thinking about its design, designing a system for a given use, analyzing the performance of the part designed by additive manufacturing, etc. Most of the topics involve finite element simulation on COMSOL or on the software of the students' choice. Some topics may involve experimental work.

All projects should follow the following steps:
- Step 1: Getting to know the subject
- Step 2: Simplified representation of the studied part to arrive at a first solution
- Step 3: Optimization of the system in a given parameter space
- Step 4: Analysis of the cost-benefit of the proposed solution compared to an initial or classical solution.

All these projects are gathered in 3 thematic groups:

Project n°1: *Optimization of aeronautical parts in metallic additive manufacturing*.
Associated partner: SafranTech - **Location:** Paris-Saclay

Project n°2: *Optimization of parts for the biomedical industry using polymer additive manufacturing*.
Associate partner: Biomodex **- Location:** Paris-Saclay

Project n°3: *Optimization of civil engineering structures using concrete additive manufacturing*.
Associate partner: XTreee **- Location:** Paris-Saclay