PhD: Robust topology optimization for 3D metal printing

Within the framework of a collaboration between Inria and the Gustave Eiffel University, a PhD is proposed between the I4S team at Inria Rennes and the ENPC in Paris on robust topology optimisation for metallic 3D printing. Thus, the main objective of the thesis is to develop new mathematical and numerical tools allowing to introduce the variability of the material properties related to the manufacturing process in the topology optimisation process in order to propose mechanical components robust to the manufacturing processes, focusing here on the case of metallic 3D printing. The developments will be validated experimentally using the Navier laboratory's 3D printer.

Supervisors will be Enora Denimal (researcher at Inria Rennes) and Michael Peigney (researcher at the ENPC). TheDepending on the candidate's wishes, the thesis could be carried out at the Inria centre in Rennes or at the ENPC (Champs-sur-Marne)owever, the experimental tests will be carried out at the ENPC.

For more details, please contact Enora Denimal (enora.denimal@inria.fr)

Scientific context:

In a context where structures in the engineering world (aeroplanes, wind turbines, automobiles etc) have to be lighter and lighter and meet more and more stringent specifications, the optimisation of each component becomes a major issue to meet current societal and environmental challenges. In this context, topology optimisation directly optimises the material distribution within a predefined space for given boundary conditions and stresses. These methods have proven to be particularly effective in certain contexts for reducing the mass of mechanical components while improving their performances. As a result, these methods lead to material savings and are also more suitable for recycling, thus being part of a sustainable development approach.

These topological optimisation methods are now benefiting from a strong interest linked to the arrival of additive manufacturing, also known as 3D printing, which makes it possible to manufacture optimal geometries with complex shapes and potentially cavities within the structure. In an industrial context, metallic additive manufacturing is particularly studied. However, the variability of the material properties during the 3D-printing process is significant and therefore has a substantial impact on the quality of the final part. In the case of metallic 3D-printing, several experimental studies show that the material properties, such as the Young's modulus, the yield strength or the stress at break, present local fluctuations linked to crystallisation during printing. However, these variabilities in material properties are not currently considered in topological optimisation, even though they have a crucial impact.

PhD objectives and missions:

The main objective of this thesis is to develop mathematical and numerical methods to consider these variabilities on the material properties related to 3D printing, then to validate them experimentally.

The thesis work will be structured around the following steps:

- **Realization of a state of the art** of the different methods (LSF, SIMP, MMC etc) and identification of the most adapted method to the introduction of the variabilities related to 3D printing,
- **Modelling of the variabilities linked to 3D printing**. The aim heris to discover how to model these variabilities and translate this into mechanical modelling and topology optimisation.
- **Numerical implementation** of the topology optimisation method by introducing the previously modelled variabilities. The numerical implementation will be developed in coupling with finite element software/codes.
- **Experimental validation:** the different works will be tested and validated experimentally on an academic benchmark. Printing and testing will be done in the Navier laboratory.

Applications should be sent before mid-April and should include a CV, MSc grades' report and a letter of motivation.

We are looking for a candidate with an engineering or master's degree from a mechanical or applied mathematics background, with skills in numerical modelling.