PhD position

Development of numerical methods for the simulation the machining process of a part produced by additive manufacturing

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The use of additive manufacturing (AM) is becoming very popular in many industries. There are many different technologies today that fall into the category of AM, and they all share a common characteristic: their ability to create parts with highly complex geometries, which is not always possible with conventional processes. Despite this considerable advantage, some applications have surface quality requirements that are not met by the additive manufacturing process.

In these cases, a machining process is required to produce the final part. In this context, Labomap/ENSAM, LEM3/Université de Lorraine and CEMEF/Mines Paris have joined forces to study the machining process for parts manufactured by AM, thanks to the ANR-funded CENTURION project. The CENTURION project focuses on AM using laser powder melting (L-PBF) and machining, without heat treatment, to produce high-quality parts in Inconel 718 (IN718).

Proposed PhD project

The aim of the thesis is to develop a version of the industrial software Forge®, which allows the modeling of the machining process. To achieve this, the PhD student will **develop and implement**:

- An explicit formulation of the software's mechanical and thermal resolutions. This will involve ensuring the compatibility of the approaches with the use of tetrahedral finite elements needed to manage automatic remeshing.
- The coupling of the new formulation with the use of the field method and intensive remeshing to propagate cracks.
- The anisotropic behavior law identified by the other project partners.
- The friction conditions will be studied by the project partners and must be correctly introduced in the explicit version of the software.

Numerical modeling

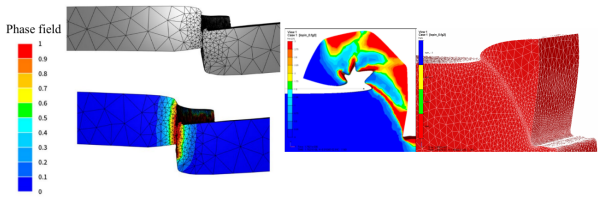
Machining processes induce significant plastic deformation at high strain rates. Simulating this process is a challenge because, in addition to the non-linearities associated with plastic deformation at high strain rates, it involves the complexities induced by contact and friction at the interface of material and tool.

All numerical simulations will be carried out using Forge®software, which can handle problems involving large deformations and complex contacts. **Forge® is the world's leading software** for the simulation of material forming processes. The solver currently available is implicit and not suited to the study of machining processes.

The first task of this project is to develop an explicit solver to simulate the machining process in more reasonable computation times. The anisotropic behavior law identified by the other project partners will be implemented in Forge®and coupled with the existing damage and cracking modeling framework.

This damage modeling framework is based on the use of the Phase-Field method and intensive remeshing to propagate cracks (see figure below, left) [Eldahshan *et al.*, 2022]. Friction conditions will be studied by the project partners and will have to be correctly introduced in the explicit version of the software.

The coupling between the explicit version of Forge®and the phase-field damage and fracture simulation framework will enable the machining process to be simulated. Simulation results will be validated against experimental tests carried out by other project partners.



Approach proposed in the study: Left: Phase-field damage to fracture framework [Eldahshan et al., 2022] ; right: 3D modeling of machining with adaptive mesh (PhD Thesis F. Delalondre, 2008)

Candidate profile

The candidate must have a keen interest in numerical methods and the numerical modeling of complex systems. Knowledge of solid mechanics, Fortran programming skills and materials testing are undeniable assets.

Partners

The CENTURION project is funded by the ANR (ANR-22-CE08-0028), and close collaboration is expected between the various PhD students who will be working simultaneously on the project.