Development of a process simulation approach for the deposition of polymeric filaments in additive manufacturing

Additive Manufacturing (EBAM) of polymers and polymeric composites combine fast and cheap manufacturing capabilities with unprecedented geometrical complexity [1]. In extrusion based AM, polymeric filaments are molten, deposited, and cooled down. Such temperature variations can cause local residual stresses in the final parts which are responsible for part warpage and distortion (see Figure 1) [2]. Being able to predict such thermal phenomena would allow designers and engineers to compensate for geometrical distortions and improve the parts 'quality.

In this thesis, a Finite Element (FE) approach will be developed to simulate the extrusion process of AM parts. Such approach will be based on the Abaqus subroutine *UEPActivationVol*, which is often used in the literature to simulate the printing path of the extruder. If necessary, Python coding can be used to enhance the performance of the subroutine or substitute it entirely. Once the extrusion process is simulated, thermal material models will be implemented either via other subroutines (e.g. *UMAT, UMATHT*, etc.) or using Python.

The following activities are thus expected to be performed:

- Write a *UEPActivationVol* subroutine to simulate the extruder's printing path
- If necessary, evaluate potential Python improvement
- Implement simple material models to simulate the material thermal and mechanical behaviour

Required skills:

- Finite element theory and modelling with Abaqus
- FORTRAN or Python coding skills (or willingness to learn)
- Basic knowledge of the mechanical behaviour of composite materials

Expected duration: 6 months
Type: full thesis, with examiner (controrelatore)
Experimental activity: no

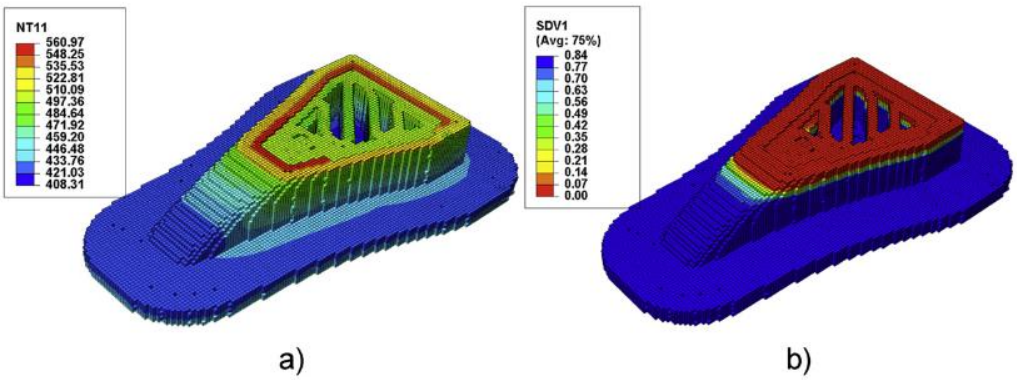

Figure 1: Printing simulation of an autoclave tool, a) Temperature distribution in Kelvin, b) Degree of crystallinity of the polymers [2].

[1] Parandoush P, Lin D. A review on additive manufacturing of polymer-fiber composites. Compos Struct 2017; 182: 36–53.

[2] Brenken B et al. Development and validation of extrusion deposition additive manufacturing process simulations. Additive Manufacturing 2019; 25: 218-226.