NUMERICAL INVESTIGATION OF THE INFLUENCE OF THE SHAPE OF THE CAVITIES ON THE RIGIDITY AND THE ANISOTROPY OF FFF PRINTED MATERIAL BASED ON X-RAY TOMOGRAPHY RESULTS

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The Fused Filament Fabrication (FFF) process induces the presence of cylindrical cavities in the printed material (Figure 1), leading to an anisotropic mechanical behaviour [1]. While *a priori* prediction of the elastic properties have been proposed assuming geometrical hypothesis on the geometry of the cavities [2], few works investigate the influence of the actual shape of the cavities on the macroscopic mechanical behaviour. Yet, the process variabilities induce fluctuations in the microstructure of the printed material which may affect its macroscopic properties. In this work, we exploit X-Ray tomographic images for the prediction of the macroscopic elastic tensor of the FFF material based on the actual shape of the cavities in the printed material.

To determine a representative volume element (RVE) of the printed material, tomographic images are extracted for several printing strategies. Several printing directions (0°, 45°, 90°) and a cross-printed structures (0°/90°) are considered. A methodologic study of the porosity distribution in the structures is established. Interestingly, the analysis of porosities inside the structure shows a repeating pattern of porosity. Then, exploiting this periodic distribution of porosity, one determines a RVE made of one oscillation of the microstructure. This method generates reduced RVE as shown in Figure 1. The obtained reduction of size of the RVE and the periodic nature of the microstructure makes it very suitable for numerical simulation with the Fast Fourier Transform (FFT) method [3].

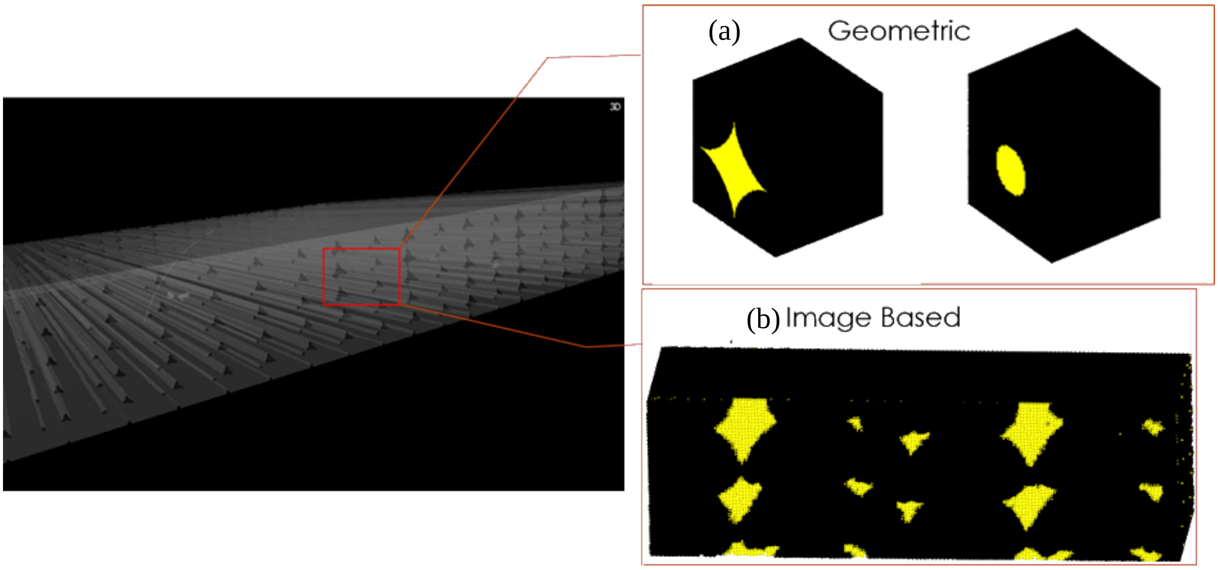

Figure 1 RVE created from original volume (on the left), (a) classical simplified geometries (top), (b) RVE extracted from tomographic images (Bottom)

Then, we perform numerical simulations on the obtained periodic RVE to determine the macroscopic response of the printed material. Using the FFT method [3], one derives the macroscopic elastic tensor. Numerical simulations on classical simplified geometries (circle and hypotrochoid, see Figure 1) are also performed to investigate the influence of the shape of the cavities on the macroscopic elastic properties.

For each RVE considered, the directional Young's moduli classically determined through tensile tests [1] are studied. The anisotropic behaviour of the printed material is reproduced. Comparisons of the results for different RVE (Figure 2) show that, while the shapes of these porosities do not affect the directional Young's modulus of the structure in the printing direction (0° angle between printing direction and tensile direction), there is considerable differences in the transverse direction (90° angle between printing direction and tensile direction), highlighting the necessity to take the actual shape of the porosity into consideration to model the printed material behaviour. Furthermore, printing parameters strongly influence the porosity and the shape of the cavities, and then the macroscopic elastic properties.

Conclusions

i. Porosity in FFF structure exhibits periodic fluctuations.
ii. The fluctuation of the shape of the cavities strongly affects the directional Young's modulus in the transverse direction. It must be considered to model the material's behaviour.
iii. The printing quality affect the porosity and the fluctuation of the porosity, then the mechanical behaviour of the printed material.

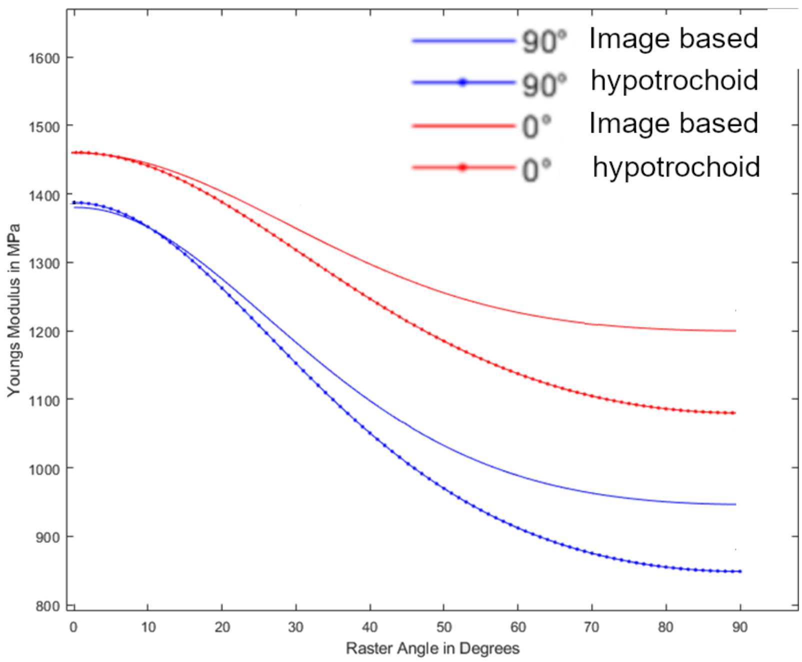

Figure 2 - Directional Young's moduli for two printing directions (0° in red and 90° in blue) and two types of RVE: hypotrochoid RVE and image based RVE.

References

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