Microstructure, deformation and microcracking of a 3D printed composite

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Abstract —Glass fiber composites are preferred as 3D printed materials for aerospace applications for their improved stiffness, strength and toughness. However, the effects of the anisotropy of printed material's microstructure on their mechanical properties are still not fully understood. The microstructure of a printed material is first quantitatively investigated via X-ray computed tomography, in terms of porosity and fibers size and orientation distributions. The DIC and DVC analysis of a complex ex situ compression test is then presented. Several fracture mechanisms are observed.

Keywords — Glass fiber composite, microstructure, mechanical behavior, DVC/DIC.

Introduction

Selective Laser Sintering (SLS) is being widely considered in the aeronautics to manufacture light objects with complex geometries based on layer-by-layer deposition [1]. The anisotropic mechanical behavior of printed short glass fiber reinforced composites is strongly influenced by layer and fiber orientations as well as residual porosity. Such information is first quantified by X-ray computed tomography (XRCT) and image processing. A cylindrical sample is then compressed along a direction parallel to the impression plane, which generates a bending zone and two shearing zones with intense deformation, in which micro-cracks are initiated and propagate.

Material and test procedure

Figure 1a shows a cross section parallel to printing plane through an XRCT image of a printed composite sample provided by the PRISMADD company, composed of a polymer matrix (PA12), glass fibers, pores and additives. Image processing gives access to fiber orientation distribution as illustrated in Figure 1b, which shows that fibers are preferably orthogonal to the impression direction (here Y axis). A 30mm long cylindrical sample with a diameter of 10mm was submitted to a compression along a direction parallel to the printing plane at a rate of is 0.15 mm/min. Surface deformation was recorded continuously by two cameras perpendicular to each other while XRCT scans of the whole sample were realized at the end of several loading increments to measure residual deformation by volume correlation.

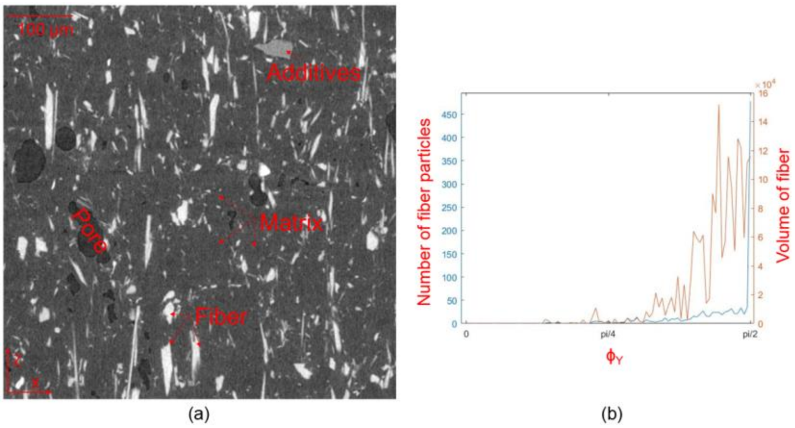
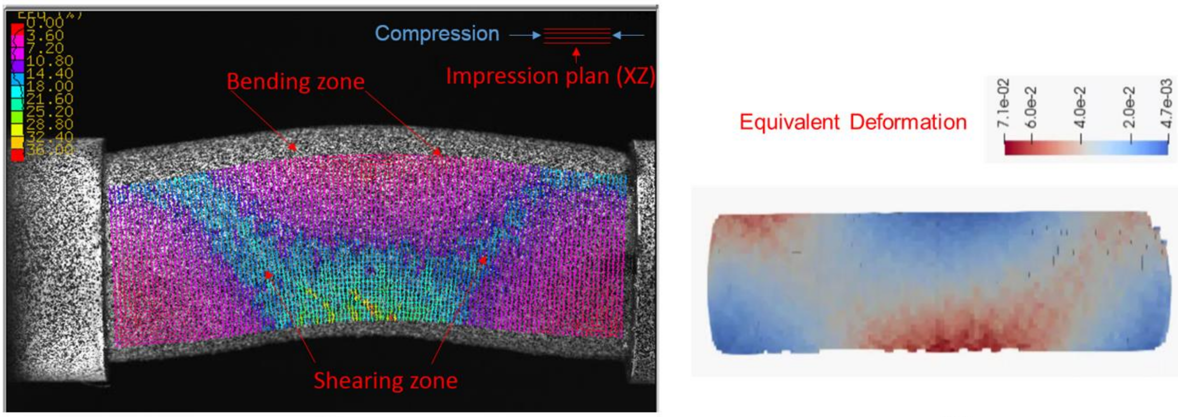


Figure 1: Cross-section along impression plane and fiber orientation distribution.

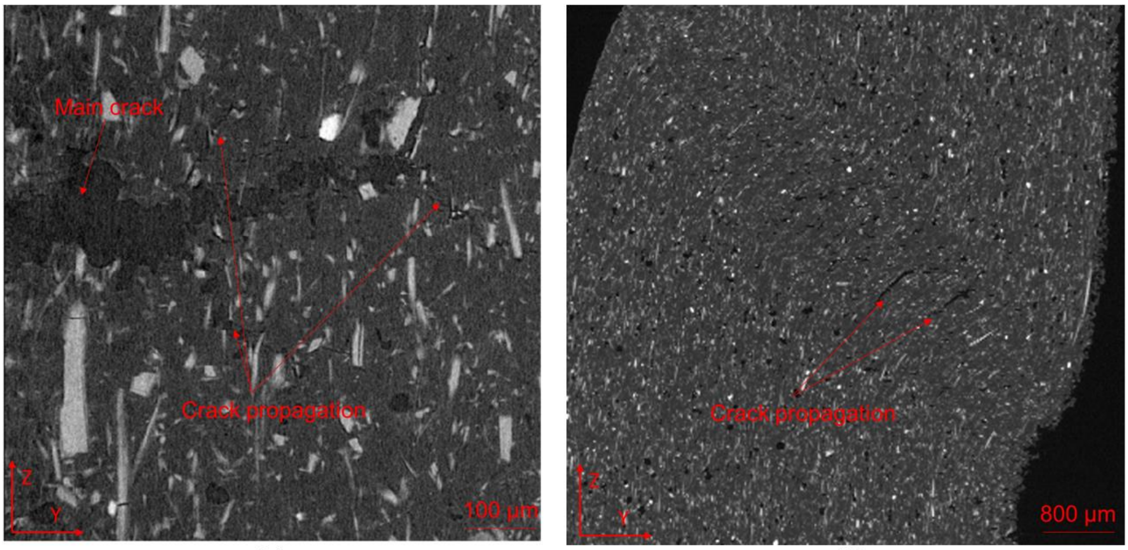
Results

The sample buckled almost from the beginning of the test along directions governed by its anisotropy creating a central bending zone and two symmetric shearing zones, as shown in Figure 2. The deformation turned out to be almost plane so that the surface observations (Figure 2a, 2D DIC) closely reflect well what happened in the bulk of the sample (Figure 2b, 3D DVC). As the sample continued to be compacted, a major crack appeared in the bending zone together with several other smaller ones in the shearing zone. They progressively propagated during the following loading steps and could be observed by local tomography (Figure 3). In the bending zone, the main crack propagates through the printing planes, with complex local features governed by local pores and fibers distribution, while in the shearing zone, the cracks are much more planar and propagate along printing plane in between layers.



(a) (b)

Figure 2: Equivalent strain field measured by 2D (a) and 3D image correlation (b).



(a) (b)

Figure 3: Cracks propagation in the bending zone (a) and in a shearing zone (b).

Conclusion

The anisotropy of the microstructure of a printed composite has been first investigated by XR computed tomography. The mechanical behavior of the studied material has then been observed via a compression test instrumented by both 2D and 3D image correlation. The strong anisotropy of the printed composites influences both the deformation mode and micro-cracking mechanisms.

References

[1] Y. T. Kao, T. Dressen, D. S. D Kim, S. Ahmadizadyekta, B. L. Tai. Experimental investigation of mechanical properties of 3D-Printing built composite material. *SFF Symposium*, pages 904-913, 2015.