17th International Conference on Experimental Mechanics (ICEM 17)

July 3-7, 2016, Rhodes, Greece

DEVELOPMENT OF A DEDICATED BENDING SET-UP FOR QUALITY CONTROL OF LIGHTWEIGHT 3D-PRINTED POLYAMIDE-12 STRUCTURES

Lammens N[1,2]., De Baere I[1]. and Van Paepegem W[1].

[1] *Mechanics of Materials and Structures, Department of Materials Science and Engineering, Faculty of Engineering and Architecture, Ghent University, Technologiepark-Zwijnaarde 903, B-9052 Zwijnaarde, Belgium*

[2] *SIM vzw., Technologiepark-Zwijnaarde 935, B-9052 Zwijnaarde, Belgium*

Abstract: This paper presents a feasibility study of a dedicated bending set-up for the mechanical characterization (Young’s modulus and flexural strength) and quality control of 3D-printed polyamide-12 struts as commonly used in lightweight lattice structures. In a first step, a series of bending tests are performed on single strut specimens using a universal testing machine and standard bending set-up. The results indicate that the material has a significant visco-elastic response and therefore a continuous, motorized drive system is necessary for repeatable test results. In addition, a significant change in Young’s modulus was observed with increasing strut diameter. As the Young’s modulus of these struts cannot be determined from bulk material properties, this justifies the development of a dedicated test set-up.

1. Introduction

Recent developments in the domain of 3D printing and additive manufacturing technology have opened the door to concepts such as rapid prototyping, rapid tooling and rapid manufacturing. However, rapid tooling and manufacturing applications require the creation of finished parts which are can provide the necessary stiffness and strength for the envisaged application. A proper knowledge of the material properties of such parts is therefore necessary.

A significant benefit of the 3D printing technology is the ability to create lightweight structures by replacing bulk material with lightweight lattice structures. These structures result in significant savings on mass and therefore material and cost of the final part. However, as the diameter of the struts making up the lattice structure is reduced, the resulting material properties (Young’s modulus and strength) are affected by the occurrence of voids and pores in the 3D printed material. As a result, material properties derived from bulk material are not representative for the behaviour of lightweight structures.

Considering the small dimensions of struts making up lattice structures (down to 1mm diameter for polyamide-12), standard universal testing machines are not well suited for mechanical characterisation of these specimens. Additionally, for quality control purposes, a smaller and more cost effective means of testing specimens is desirable. While a tensile test remains the default test procedure for determining Young’s modulus and ultimate tensile strength, several difficulties can be foreseen when testing small struts. Amongst others, clamping of the struts without damaging them is problematic, and accurately measuring strain on these small samples is challenging. Many issues can be avoided by performing a 3-point bending test rather than a tensile test. In this paper, the feasibility of performing bending tests (and developing a custom bending set-up) for the characterization and quality control of lightweight 3D-printed polyamide-12 struts is investigated.

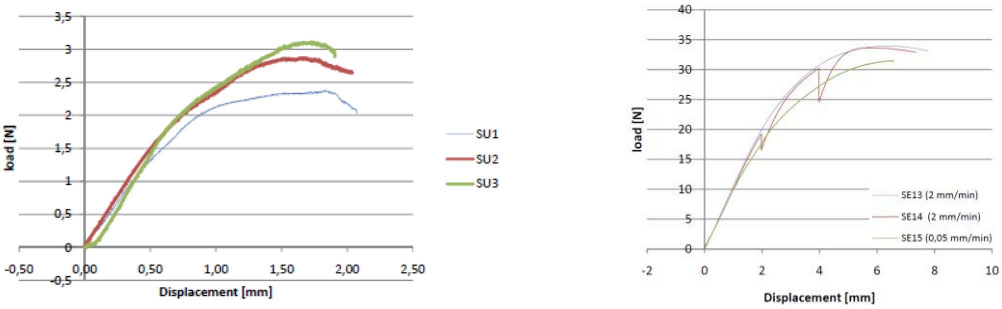
2. Preliminary results

Prior to the development of a dedicated bending set-up, a series of preliminary tests were performed on several strut samples to investigate the repeatability and usability of the test. All tests were performed on an INSTRON 5800R tensile machine with a 100N load cell. Tests were performed both on upright (strut axis perpendicular to printing plane) and flatwise (strut axis parallel to printing plane) strut samples. Samples were printed in groups of three samples (Figure 1(a)), allowing to investigate the repeatability of the test set-up. Figure 1(b) shows the loading cone and bending set-up used for testing a 1mm diameter strut.

(a) (b)

Figure 1. (a) Strut specimens (b) Preliminary bending set-up for bending of a 1mm PA-12 strut

Figure 2(a) shows the resulting load-displacement curves for a group of three specimens, showing good reproducibility of the results. Figure 2(b) shows the influence of different testing speeds and step-wise loading of the struts. These results indicate a visco-elastic behaviour of the material, necessitating an automated test set-up for accurate testing of the samples.



(a) (b)

Figure 1. (a) repeatability of a bending test on strut specimens (b) visco-elastic material response during step-wise loading

Finally, different diameters of struts were tested to investigate the change in Young's modulus with increasing strut diameter. It was found that the Young's modulus evolved from 720 MPa for 1mm diameter struts to 1670 MPa for 3mm diameter struts. The bulk material stiffness was determined to be approximately between 1850 MPa and 1970 MPa. These results suggest that porosities have a more pronounced influence on thin specimens, and thus a dedicated test set-up is justified.

3. Conclusions

The preliminary results indicate that tests on strut level specimens are repeatable and are dependent on feature dimensions. As a result a dedicated test set-up for these small specimens is justified. However, a motorized loading stage must be foreseen due to the clear visco-elastic response of the material.

Acknowledgements

The authors would like to acknowledge the financial support of the Fundamental Re-search Fund (FWO-Flanders) and of the Strategic Initiative for Materials (SIM-Flanders) through the MacroModelMat (M3) program (M3-AMCAE project) and the STREAM program (A_STREAM_AFO project).