IN SILICO – IN VITRO MECHANICAL CHARACTERIZATION OF TI6AL4V GYROID SCAFFOLDS

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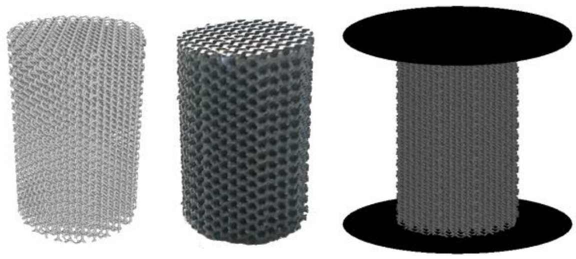
Introduction

As additive manufacturing processes have improved, so has interest in porous biomaterials increased. In the skeletal tissue engineering field, part of this interest has focused on Triply Periodic Minimal Surface (TPMS)-based scaffolds due to their ability to create biomorphic environments suitable for tissue growth [1]. Although this increase in interest has also led to an increasing amount of studies looking into the material properties of TPMS-based scaffolds, these studies use short samples, are limited to small ranges of volume fractions and usually consider volume fractions below 30% [2, 3].
In order to obtain a more complete picture of the material properties of titanium gyroid scaffolds, we are evaluating cylindrical samples of varying length for the entire range of volume fractions, both experimentally and in silico.

Methods

Cylindrical samples with gyroid unit cells of 1.5 mm and varying length to diameter ratios were created using ASLI [4] and manufactured in Ti6Al4V ELI (Grade 23) with a DMP Flex 350 (3D Systems, Leuven, Belgium) 3D printer, see Fig. 1.



(a) (b) (c)

Figure 1: Short skeletal gyroid specimen of 20% volume fraction: a) STL model, b) printed specimen and c) FE-model.

Micro-CT images were taken of the printed samples with a TESCAN UniTOM XL Micro CT (TESCAN, Brno, Czech Republic) to characterize their morphology. Subsequently, quasi-static uni-axial compression tests were carried out using an Instron 5985 Universal Material Testing Machine (Instron, Norwood, MA, USA) equipped with a 250 kN load cell to determine the offset stress, quasi-elastic gradient and plateau stress of the samples. Samples were loaded in printing direction at a constant vertical strain rate of 10^{-3} s^{-1} and displacements were tracked by means of digital image correlation. The experiments were then recreated with FE-simulations performed in Radioss (Altair Engineering Inc, Troy, MI, USA). To this end, the cylinders were placed between two rigid plates. The bottom plate was fixed while a displacement with an effective constant vertical strain rate of 10^{-3} s^{-1} was applied to the top plate. Coulomb friction was assumed between the plates and the samples while the material behavior of the titanium scaffolds was described by means of a Johnson–Cook model [5].

Results and Discussion

Preliminary data showed offset stresses, quasi-elastic gradients and plateau stresses in line with values reported in literature for lower volume fractions. The initial experimental and in silico data, see Fig 2, also highlighted the limitations of using short samples to determine the material properties of porous structures under compression. As can be seen, the quasi-elastic gradients estimated in silico and experimentally increasingly deviate from each other as volume fraction increases. This is in line with expectations since the shown experimental data was acquired using short samples and length to diameters ratios are known to be critical for accurate measurement of material properties under compression. Currently, a set of experiments with long samples are being executed that we expect will yield results in line with our in silico findings, further highlighting the importance of appropriate sample sizes.

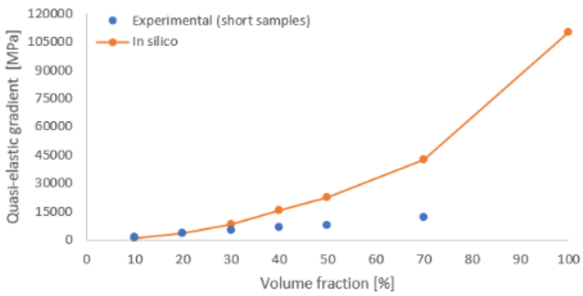


Figure 2: Summary of initial in silico and experimental results.

References

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