EXPERIMENT AND SIMULATION STUDY OF THE ENERGY ABSORBTION IN BIOMIMETIC SCAFFOLD LATTICES

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Introduction

Architectured materials have been recently attracting attention due to their high stiffness-to-density ratio, tailored mechanical properties and high energy absorption, for multifunctional applications in aerospace, biomedicine such as implants and scaffolds, etc. To enhance energy absorption capacity of the conventional structures, new lattices are introduced and studied, some based on biological samples such as bone, to enable biomimetic architectured materials [1].
In this study, we investigated two gyroid and dual-lattice [2] structures, in terms of their mechanical response under large strains and energy absorption capacity, through finite element analysis (FEA). Model predictions were validated through 3D printing and experimental compression testing.

Materials and Methods

Gyroid and dual-lattice models with 10% volume fractions were 3D printed using a FormLab3 elastic resin printer (SLA technology). Samples were testing under uniaxial quasi-static deformation-controlled compression loading of 85% strain, using a Zwick mechanical tester (Zwick Roell, GmbH & Co., Germany) as shown in Fig. 1.
FE models generated to replicate uniaxial compression test, for the gyroid and dual-lattice structures, with 10% and 20% of volume fraction each. Models were meshed using tetrahedral (C3D10M) elements and the material properties was calibrated for the elastic resin shown in Table 1. The ABAQUS/Explicit solver was used analyze their mechanical response and energy absorption capacity for the four categories of lattices under 85% uniaxial compression deformation.

	Neo-Hookean Model		
Resin	C10	D1	Density
Elastic 50A	0.60 (Mpa)	0.25	1.20 g/cm^3

Table 1: Physical and calibrated mechanical properties of elastic resin.

The energy absorption per unit volume, W, for a lattice structure under compression with the strain up to ε, is calculated by Eq. 1 [3].

$$W = \int_0^{\varepsilon} \sigma(\varepsilon) d\varepsilon \qquad (1)$$

Results

The stress strain curve of the two experiments and the fitted finite element model for the 10% volume fraction of the dual-lattice structure is shown in Fig. 1.

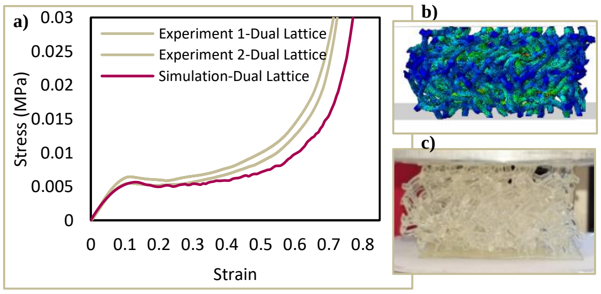

Figure 1: Stress strain curve (a) for the two compression experiments (b) and fitted FE simulation (c) results for 10% volume fraction of dual-lattice structure.

Fig. 2 shows the stress strain curves for all four categories of lattices studied via FEA. Stresses of all the curves increase with the strain increasing in the initial of compression and then pass into a stress plateau that is without stress collapses. At last, the stresses increase dramatically at around 55% strain for 20% volume fractions and around 65% for 10% volume fractions, reaching densification stage. The W of the cellular structure with 20% volume fraction is nearly larger around 5 times than that of with 10% volume fraction.

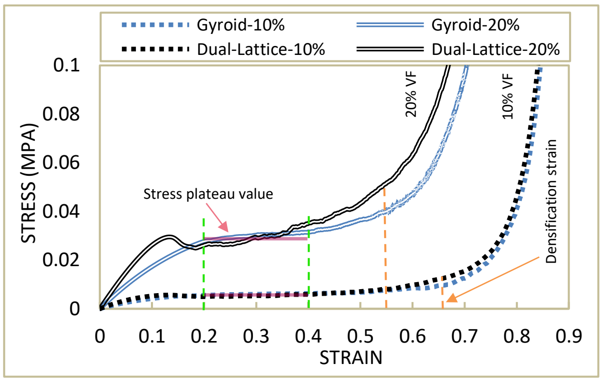

Figure 2: Stress strain curve of gyroid and dual-lattice 10% and 20% volume fraction each.

Conclusions

We studied the mechanical response of two gyroid and dual-lattice lattices, as candidates for biomedical scaffolds. In the same volume fraction, dual-lattice shows higher stiffness, yield strength and energy absorption. As the volume fraction increases, the energy absorption capacity increases, the plateau region decreases, therefore, densification starts at lower strain.

References

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2. M. Vafaeefar, et al., JMBBM, 138, 2023.
3. F. N. Habib, et al., Mat. & Design, 155:86-98, 2018.