Introduction

Functionally graded cellular structures (FGCS) with density gradients can be obtained through optimization algorithms where an optimal density distribution is determined. Therefore, weight reduction and stiffness maximization can be achieved.

The Bio-inspired optimization [1,2] is based on the fact that, as in bone remodelling and regardless of the material law being used, applied stress will act as an optimization tool. Thus, the gyroid infill was characterized in a homogenized material law which correlates its mechanical properties with the apparent density.

The gyroid infill is based on the gyroid surface which belongs to the category of triply periodic minimal surfaces. Its highly porous and intricate shape can only be manufactured through additive manufacturing, which justifies the growing interest in these structures as AM technology and equipment develops. It should also be noted that the periodicity of the shape makes it possible to consider it isotropic.

The optimized specimens in this work were 3D printed through fused filament fabrication which is a material extrusion process, and the used material to print the specimens and characterize the gyroid infill was PLA.

Methodology

The work consists on numerical optimization and experimental validation of optimized 3D printed graded specimens.

Gyroid infill mechanical properties:

\[ E[\text{MPa}] = -492.65\rho_{\text{app}} + 538.34\rho_{\text{app}} + 27.693\rho_{\text{app}} \]

\[ a'[\text{MPa}] = -18.853\rho_{\text{app}} + 43.821\rho_{\text{app}} + 12.42\rho_{\text{app}} \]

Smoothing functions for the optimized density field were tested as a possibility for improvement of the structures, since abrupt density changes in the 3D printed parts can lead to stress concentration areas.

- FEM: finite element method;
- NNRPIM: natural neighbour radial point interpolation method [1] (meshless method);
- BESO: bi-directional evolutionary structural optimization [3].

Conclusions

1. The most stable structures were obtained with the bio-inspired optimization;
2. Smoothing functions present a positive impact when the structure itself is not efficient;
3. When the structures are highly efficient (load case 3), smoothing functions have a negative effect in stiffness;
4. The more stable and well distributed the load case is, the more efficient the obtained structures will be.

References


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