Influence of Topology Hybridization and Functional Grading on the Compressive Properties of TPMS-based Lattice Cores: Design and Finite Element Analysis

Chukwugozie J. Ejeh[a,b], Imad Barsoum[a,b,*] and Rashid K. Abu Al − Rub[a,b]

a. Advanced Digital & Additive Manufacturing Center, Khalifa University of Science and Technology, 127788, Abu Dhabi, United Arab Emirates.

b. Department of Mechanical Engineering, School of Engineering, Khalifa University of Science and Technology, 127788, Abu Dhabi, United Arab Emirates.

[*]Email: imad.barsoum@ku.ac.ae, Web page: https://www.ku.ac.ae/

ABSTRACT

Lattice cores are essential for achieving high strength and lightweight design of additive manufactured engineering components. The influence of topology hybridization and functional grading (i.e., cell size and relative density gradation) on the quasi-static compressive properties of lattice structures are numerically investigated in this paper. The objective is to propose an advanced meta-material design based on triply periodic minimal surfaces (TPMS) topologies with enhanced mechanical functionality. The mathematically-derived sheet-TPMS based lattices such as Schwartz diamond, F-Rhombic Dodecahedron and Scheon gyroid are considered. The base material is modelled as isotropic elastic-plastic based on the tensile data of additive manufactured AlSi10Mg specimen, evaluated in the printing direction. The finite element results such as the elastic modulus, yield strength, ultimate strength and specific energy absorption of the lattices serve as the mean of comparison. The computational results reveal that the functionally graded single TPMS topologies showed a distinctive collapse trend dominated by a layer-wise failure. The observed failure mode contributed to an increased energy absorption resulting from the increased stiffness. On the other hand, a shear-dominated deformation behaviour was observed with the uniform TPMS lattices associated with a shear-band failure causing early densification of the lattice [1]. However, an entirely different failure behaviour was noticed with the hybridized geometries, where each cell type responds differently to the compressive loading. When dissimilar TPMS topologies are combined through smooth transitioning, the failure response becomes rather complicated. Failure begins at the cells near the transition domain, followed by the cell type with the least surface area-to-volume ratio [1]. In overall, the resistance offered by the hybrid structures to compression is more pronounced than the functionally graded and uniform TPMS lattices. Also, an increase in the densification strain and energy absorption was also observed, especially for the 3D-patterned hybrid TPMS topologies.

REFERENCES

[1] Al-Ketan O., Lee D.W., Rowshan R. and Abu Al-Rub R.K. Functionally graded and multi-morphology sheet TPMS lattices: Design, manufacturing, and mechanical properties. *Journal of the mechanical behavior of biomedical materials*, 102(2020), p.103520.