
Compression and shear performance of pyramidal lattice structures with I-beam struts

Mohammed Ayaz Uddin¹, Imad Barsoum^{1,2}, S Kumar³, and Andreas Schiffer^{*†1}

¹Khalifa University – United Arab Emirates

²KTH Royal Institute of Technology, Stockholm – Sweden

³University of Glasgow – United Kingdom

Abstract

Pyramidal lattice (PL) structures are widely regarded as excellent choices for core materials in sandwich structures due to their low density, high weight-specific shear strength, and the ability to absorb kinetic energy in the event of an impact or blast. However, their response is generally bend-dominated, which greatly limits their strength and stiffness under compression and shear loading, particularly at low relative densities. Since the flexural stiffness and strength of a strut in the PL depends on the size and shape of the strut cross-section, it is anticipated that modifications in the shape of the strut cross-section alone could lead to a significant improvement in mechanical performance.

To investigate potential performance enhancements resulting from the incorporation of rationally designed strut cross-sections in bend-dominated lattices, this study investigates the quasi-static mechanical response of PL sandwich cores with I-beam cross-sections. These novel PL structures are 3D printed using the Digital Light Processing (DLP) technique, allowing for precise geometrical adjustments at the sub-mm scale. The elastic modulus, strength and energy absorption of the tailored PL structures are evaluated under out-of-plane compression and shear loading and are compared to the results obtained for non-tailored PL structures with square strut cross-sections. Additionally, detailed finite element (FE) calculations are performed to examine underlying collapse mechanisms and explore the vast design space offered by the cross-sectional tailoring scheme. The experimental and numerical results reveal that the tailored PL structures with I-beam struts exhibit superior performance under both compression and shear loading compared to their non-tailored counterparts of equal relative density. In compression, the integration of I-beam struts leads to considerable enhancements in elastic modulus, strength and energy absorption of 24%, 21% and 68%, respectively. Specifically, the improvements in the collapse strength are attributed to the occurrence of an unusual lateral buckling mode, causing the I-beam struts to bend sideways and thus delaying the onset of structural collapse. It is also demonstrated numerically that specific cross-sectional designs can achieve improvements in compressive strength and energy absorption of up to 93% and 161%, respectively, as compared to a conventional pyramidal lattice with equal relative density. Under shear loading, the enhancements in modulus, strength and energy absorption are less pronounced, reporting 13%, 11% and 24%, respectively. This is because shear loading causes the PL struts to undergo unsymmetric bending which requires cross-sections with high resistance against bending in all directions. Additionally, a simple analytical model is developed to predict the stress distribution in the

*Speaker

†Corresponding author: andreas.schiffer@ku.ac.ae

lattice struts under shear loading and the onset of brittle fracture, accurately capturing the shear strength enhancements predicted by the FE models.

The findings of this study demonstrate the effectiveness of cross-sectional tailoring in enhancing the mechanical properties of truss lattices. Notably, these insights hold significance for the design of lightweight lattice-cored sandwich structures for advanced applications within the aerospace and defense sectors.