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# Mechanical Performance of Additively-manufactured Anisotropic and Isotropic Smooth Shell-Lattice Materials: Simulations & Experiments

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**Abstract.** A novel family of smooth-shell structures is introduced as mechanical metamaterials of exceptional specific energy absorption capacity. The proposed shell structures respect all symmetries of the face-centered cubic crystal. To obtain a smooth curvature shell structure, the exact shape of the shell mid-plane is determined through the minimization of a bending-energy based measure of the overall curvature. Among the members of this new family, the mechanical properties of a Triply Periodic Minimal Surface (TPMS) -like architecture and an elastically-isotropic derivate are investigated in detail. The TPMS-like structures showed important anisotropy in both its small and large strain responses, with loading-direction dependent differences in stiffness of more than 100%. The mechanical properties of the elastically-isotropic shell-lattice turned out to be close to the mean value for all directions of loading for the TPMS-like structures. For relative densities ranging from 1% to 50%, the shell-lattices always exhibited a higher mechanical performance than truss-lattices of equal density. For relative densities greater than 20%, the mechanical response of the shell-lattices is more stable than that of truss-lattices which makes them particularly suitable as higher order structures in hierarchical metamaterial design. The computational results are partially confirmed through compression experiments on additively-manufactured stainless steel specimens. A direct comparison of the stress-strain curve of additively-manufactured stainless steel 316L with that of sheets made from the same alloy revealed an increase in yield strength of about 30% related to the selective laser melting process.

*Keywords:* Mechanical metamaterials, architected materials, unit cell analysis, shell-lattices, stiffness, energy absorption

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