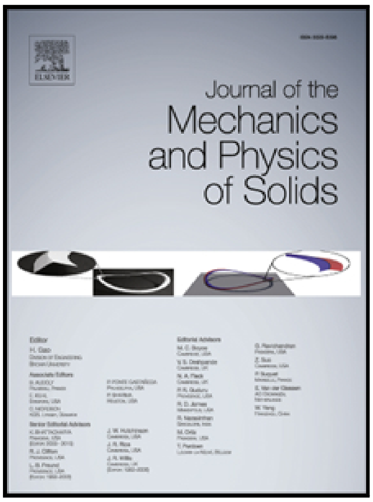

Mechanical Performance of Additively-manufactured Anisotropic and Isotropic Smooth Shell-Lattice Materials: Simulations & Experiments

Colin Bonatti , Dirk Mohr

PII: S0022-5096(17)30961-4
DOI: https://doi.org/10.1016/j.jmps.2018.08.022
Reference: MPS 3427

To appear in: *Journal of the Mechanics and Physics of Solids*

Received date: 23 October 2017
Revised date: 15 August 2018
Accepted date: 21 August 2018

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

Colin Bonatti[1,2] and Dirk Mohr[1]

[1]*Department of Mechanical and Process Engineering, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland*

[2]*Impact and Crashworthiness Laboratory, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge MA, USA*

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

---