Sep 17th, 12:00 AM - Sep 19th, 12:00 AM

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IUTAM Symposium Architectured Material Mechanics,
T. Siegmund, F. Barthelat, eds
September 17-19, 2018, Chicago, IL, USA, , Chicago, IL, USA

BCC Metamaterials Composed of Tapered Beams: Stiffness and Energy Absorption

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KEYWORDS:
Metamaterials, Smooth-shell, mechanical behaviour, energy absorption

Periodic beam networks of Body-Centered Cubic (BCC) symmetry belong to the same family of cubic metamaterials as the well-known Face-Centered Cubic (FCC) octet truss lattice. Here, we present analytical closed form expressions describing their homogenized macroscopic moduli as a function of the relative density. Detailed finite element simulations are performed to confirm the analytical results. The large strain compression response of BCC lattices is also investigated numerically, showing that for any relative density, their crushing response is stable in the sense that the engineering stress-strain curve increases monotonically until densification. Both theoretical considerations and numerical simulations demonstrate that the tapering of the beam cross-sections leads to higher specific mechanical properties, with increases in the effective Young's modulus and specific energy absorption of up to 70% and 45%, respectively. To validate the specific energy absorption estimates, static compression experiments are also performed on specimens of 10%, 20% and 30% relative density and minimum beam diameter of 300□m made from stainless steel 316L through selective laser melting. In addition, dynamic compression experiments at strain rates of about 500/s are performed on a Hopkinson pressure bar system revealing a dynamic increase factor of 1.3 for the BCC metamaterials, which is comparable to that of the basis material. The comparison of the BCC and FCC lattice materials shows that the BCC Young's modulus for the stiffest material direction is higher than that for the FCC truss lattice, while the opposite holds true for the softest directions.

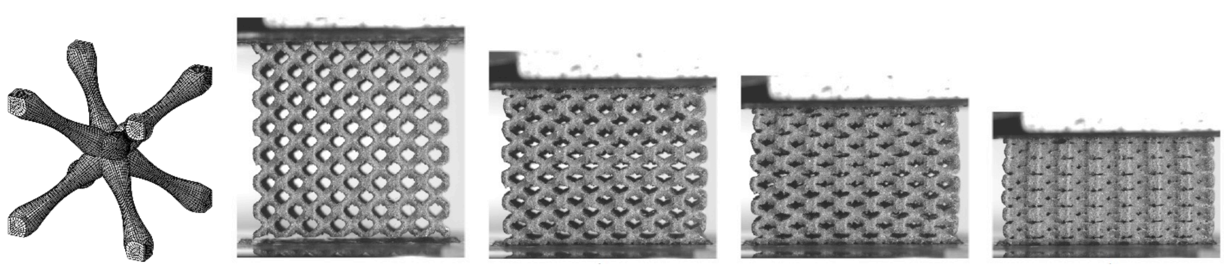

Figure 1: a) BCC unit cell composed of tapered beams, b) crushing experiment on an additively-manufactured stainless steel BCC specimen.

Acknowledgments

The authors are grateful for valuable discussions with Prof. Tomasz Wierzbicki (MIT) and Mr. Juner Zhu (MIT). Special thanks are due to Dr. Maysam Gorji (MIT) for helping in deriving the analytical model and to Ms. Marianna Diamantopoulou (ETH), Dr. Christian Roth (ETH) and Prof. Vincent Grolleau (Université Bretagne Sud) for helping in designing and performing the direct impact experiments. The partial financial support through Exxon Mobil Grant #023730-00017 and the Swiss National Science Foundation project SNF 200021-165939 is gratefully acknowledged.