ENGINEERING/TECHNOLOGY

Computationally Efficient Spring-Based Element Model for Cellular Solids, Metal Foams, and Reticulated Structures

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Cellular solids, metal foams, and reticulated structures are used for a variety of applications, including but not limited to lightweight construction, impact absorption, acoustics, and heat transfer. To evaluate the mechanical properties of metal foams and reticulated structures, engineers usually conduct physical tests and/or computational finite element analyses of material samples and structural systems. Physical tests can be expensive, while finite element analysis requires high computational power and might not reproduce results with the desired accuracy.

In this study, we develop a simplified computational model using spring-based elements to represent individual ligaments in the microstructure of open-cell foams that can capture the mechanical behavior of these foams over a wide range of deformations. The model leads to highly non-linear systems of equations that are solved

with Newton's method. It was found that this model was able to capture the expected response of a representative volumetric element (RVE) of a typical open-cell cellular solid under moderately large deformations. However, the behavior of these open-cell foams changes dramatically upon extremely large deformations when the ligaments come into contact with each other and the foam material exhibits crushing. In order to model crushing of cellular solids, the computational model was enhanced with the capability to detect and resolve contact between ligaments using an augmented Lagrangian method in an energy-based approach. The performance of this simplified spring-based element computational tool is verified with several numerical examples by comparing the solutions with existing studies.

Research advisor Arun Prakash notes, "With growing emphasis on the development of advanced high-performance materials, cellular solids, which are both stiff and lightweight, have attracted much attention. This research facilitates realistic computational modeling of the behavior of such materials in different real-life applications, such as their use for structural fuses, blast mitigation, and impact absorption."

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