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Finite element failure analysis of lattice structures

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Motivation

When modern humans build large load-bearing structures, they use dense solids, steel, concrete, glass. When nature does the same, she generally uses cellular materials; wood, bone, coral. There must be a reason for it"(Ashby 2000). The key advantage offered by cellular materials is high strength accompanied by a relatively low mass (Figure 1). Cellular materials include foams, honeycombs, lattices structure (LS), and similar constructions. Another advantages of LS over bulk samples is that by just focusing on architectural aspects (Figure 2), rather than microstructural aspects, mechanical and physical properties of materials can be tailored at elemental length scale (Figure 3).

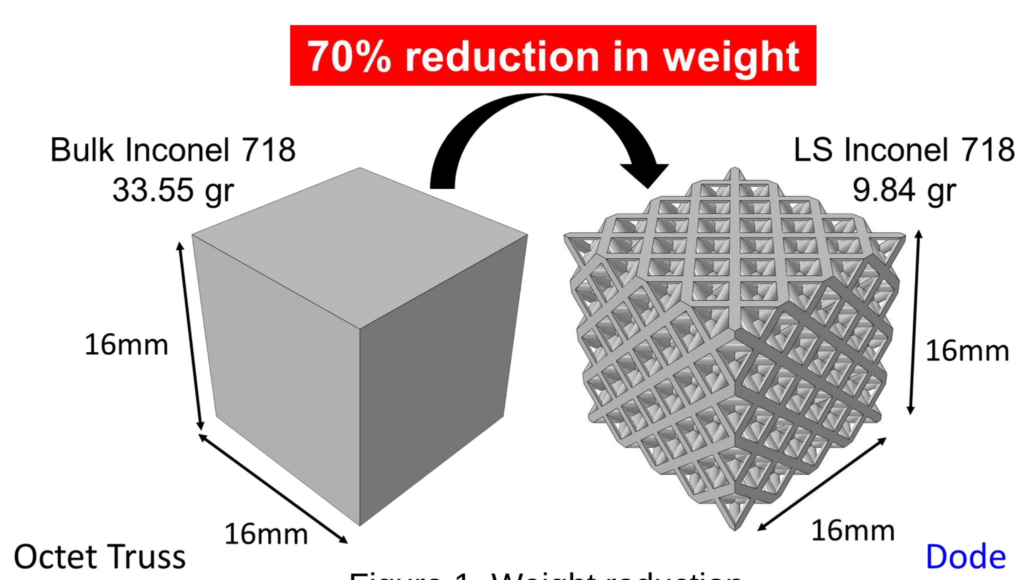

Figure 1. Weight reduction

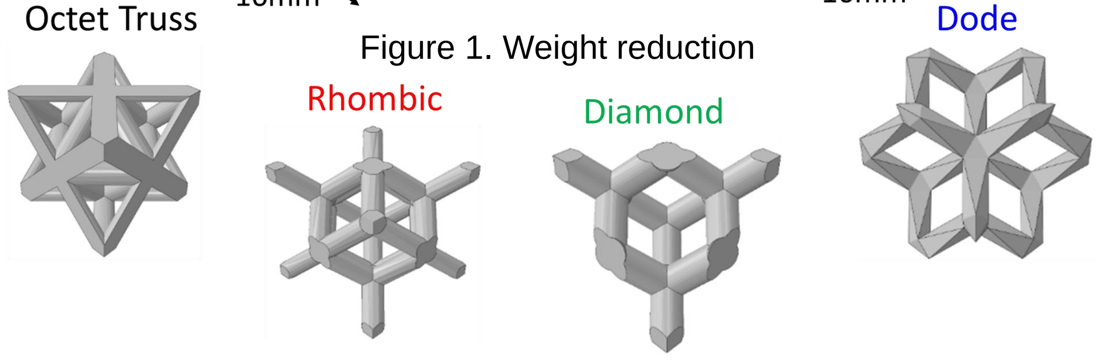

Figure 2. Different topologies

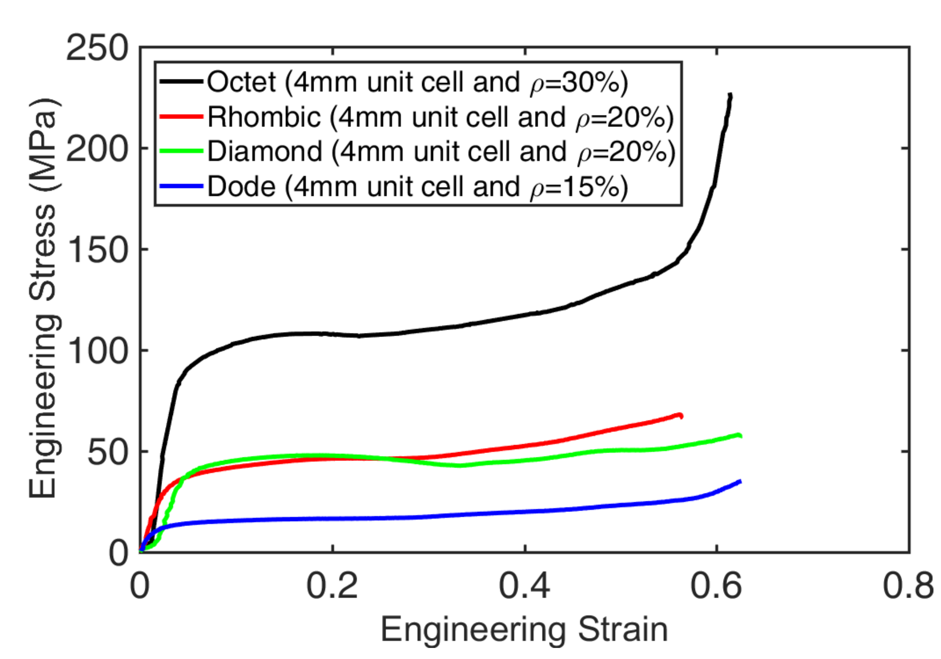

Figure 3. Different mechanical behavior of various topologies

Objective

The objectives of this study are: (1) understanding the deformation mechanisms that control the post-yielding behavior of additively manufactured LS, (2) determining where and how failure initiates and propagates.

Impact

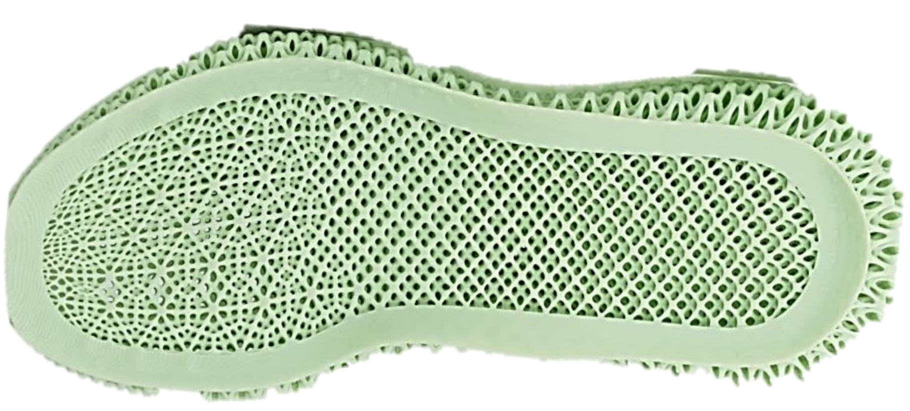

Figure 4. The lattice structure of the midsole is designed to provide the wearer with cushioning and stability. (Image courtesy of Adidas.)

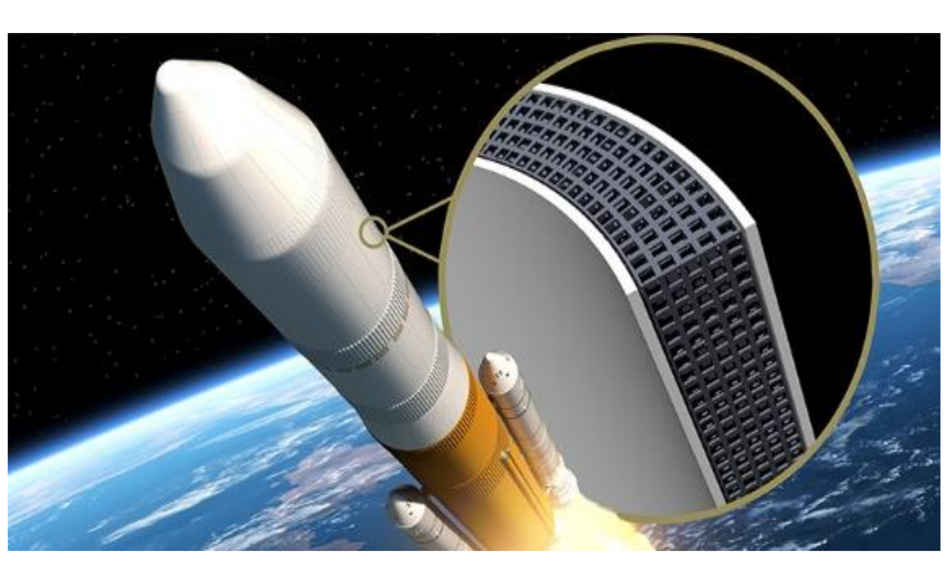

Figure 5. Potential application for LS materials in rocket's body and boosters. (Image courtesy: Jung-Chew Tse, ETH)

Methodology

A physics-based constitutive law which is able to capture the real experiment behavior (Figure 6) can lower the costs associated with testing a large number of experiments.

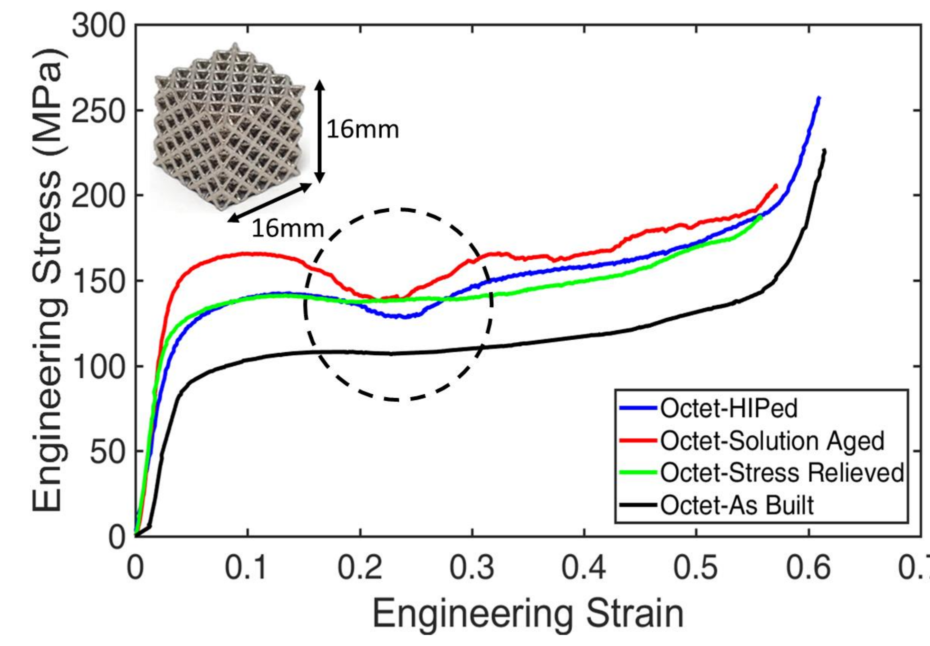

Figure 6. Different mechanical behavior of Octet with different heat treatment.

Using the Johnson-Cook failure model, simulations were able to replicate the first drop in the force-displacement curve under quasi-static loading (points A and B in Figure 7). According to the model, damage appears to be a stronger driver of energy absorbed, more than plastic dissipation.

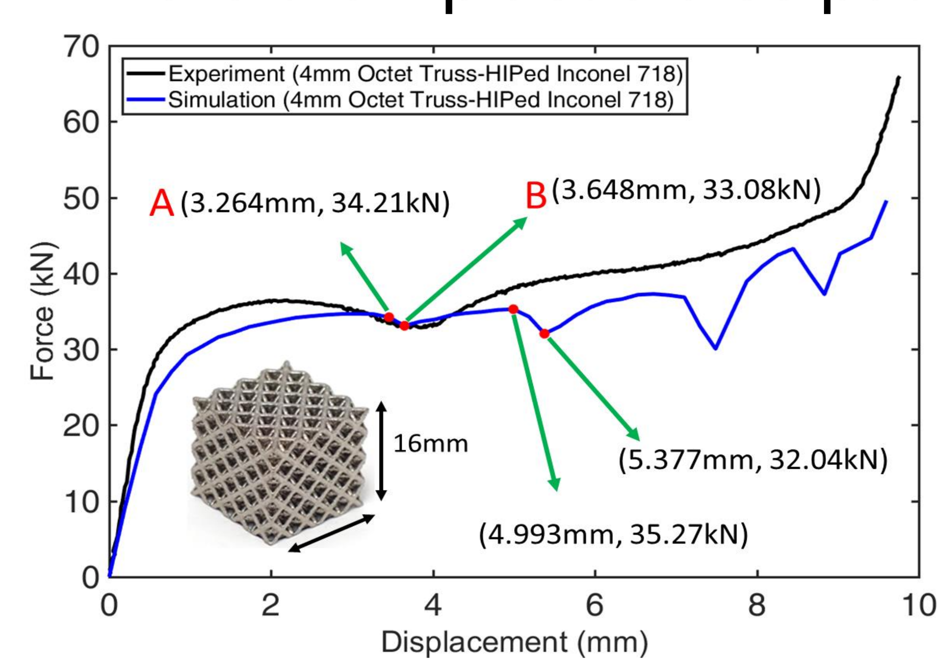

Figure 7. Force-displacement curves of HIPed Octet from experiment (black) and simulation (blue).

Key Findings

Figure 8 shows the first drop (a) and (b) evolution of damage in the structure. As can be seen damage starts internally and propagates toward the edges.

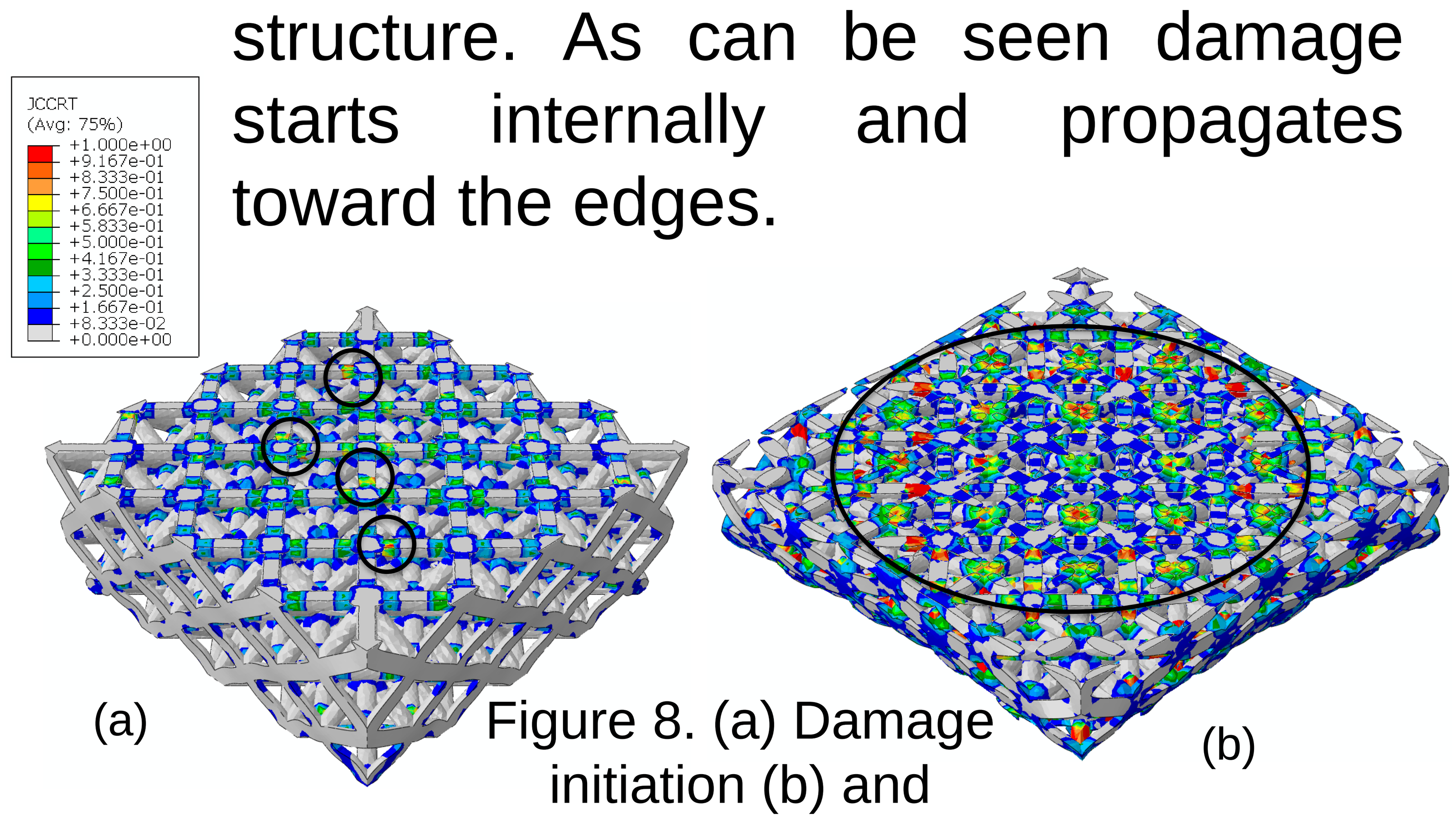

Figure 8. (a) Damage initiation (b) and damage evolution.

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