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Fracture toughness of two semi-regular lattices

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ABSTRACT

Lattice materials are not only light, stiff and strong, but they also have a high fracture toughness [3]. Previous studies have shown that the fracture toughness of a lattice scales with $\bar{\rho}^n$, where $\bar{\rho}$ is the relative density (*i.e.* the volume fraction of solid) and the exponent $n = 0.5$, 1, and 2 for kagome, triangular and hexagonal lattices, respectively [2]. With its low value of n, a kagome lattice is significantly tougher than other topologies, especially at low values of relative density. Whereas triangular and hexagonal lattices are regular tessellations, the kagome lattice is one of eight semi-regular tessellations [1]. The fracture toughness of these seven other semi-regular lattices has not been documented yet, and in this work, we demonstrate that some them exhibit unique characteristics.

Our investigation focused on two semi-regular lattices: the snub-square and the elongated-triangle tessellations. These two topologies were selected because they are stretching-dominated under axial loading but bending-dominated in shear [4]. Their mode I fracture toughness was obtained using finite element simulations, which relied on the boundary layer approach introduced in [2]. Predictions were obtained for both an elastic-brittle and a ductile parent material. For these two materials, the results showed that the fracture toughness of both semi-regular lattices scales with an exponent $n = 1.5$, different from all topologies previously reported. Both semi-regular lattices exhibit (i) a zone of tensile deformation along the crack plane and (ii) a zone of shear deformation perpendicular to the crack plane. The snub-square lattice has a higher fracture toughness than the elongated-triangle, and this is presumably due to its higher shear modulus.

Experiments were also conducted to confirm these numerical results. Fracture toughness tests were performed on Compact Tension (CT) specimens made from a polymer and produced by additive manufacturing. The measured fracture toughness was in a good agreement with simulations and confirmed that $n = 1.5$ for both semi-regular lattices.

Keywords: Lattice materials, Fracture mechanics, Finite Element method, Fracture toughness test.

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