Contribution ID: **134**

Type: **Oral Presentation**

Initial Yield Surface of Cellular Sheet TPMS Lattices

Wednesday, 1 June 2022 11:30 (15 minutes)

Due to the advancements in additive manufacturing and increased applications of additive manufactured structures, it is essential to fully understand both the elastic and plastic behavior of bio-inspired cellular materials, which include the mathematically-driven sheet/shell lattices based on triply periodic minimal surface (TPMS) that have received significant attention recently. The compressive elastic and plastic behaviors have been well established for many TPMS latticed structures, but not under multiaxial loading. Furthermore, TPMS lattices are computationally expensive to model explicitly (i.e., micromechanical) when used in latticing various structures for enhanced multi-functionality, and hence the need to develop an accurate yield surface function or criterion in order to model their plastic behavior in a homogenized approach. The majority of previous yield surfaces developed for cellular materials were developed for cellular foams [1, 2], and very few attempts has been made to develop a yield surface based on cellular lattices [3]. Furthermore, some of the few studies [4] that used the yield surfaces developed for foams to predict the yielding of cellular lattices, have found that such yield surfaces do not predict well the yielding of lattice structures under various multiaxial loading conditions. In this study, an initial yield surface is developed for sheet TPMS cellular lattices, which to our-best knowledge has never been attempted before, and is compared to the major yield surfaces that have been developed for cellular materials.

The effect of different loading conditions on the effective yield strength of IWP sheet-based (IWP-S) TPMS lattice is numerically investigated. The simulations are based on a single unit cell of IWP-S under periodic boundary conditions, assuming an elastic-perfectly plastic behavior of the base material, for relative densities ($\bar{\rho}$) ranging from 7% to 28%. In order to account for the different loading conditions, the Lode parameter (L) is used [5]. The effect of L is studied over a range of mean stress values (σ_m) to understand the effect of both L and σ_m on the effective yield strength.

In the plane of the von Mises equivalent stress σ_{VM} verses σ_m, σ_{VM} is maximum at $\sigma_m = 0$ and reduces in a parabolic and almost symmetric manner with $\pm\ \sigma_m$ values. On the other hand, in the plane of σ_{VM} verses L, σ_{VM} is minimum at $L = 0$ and increases in a parabolic and almost symmetric manner with $\pm\ L$ values. Using these relationships, the effective yield surface for IWP-S is characterized by σ_{VM}, the mean stress σ_m, L and $\bar{\rho}$. In the 3D space of the principal stresses, this yield surface is best described as a cocoa pod. The current developed framework can be adapted for generating yield surfaces for other lattice topologies. As future work, tests on additively manufactured IWP-S lattices, under different loading conditions, will be conducted to validate the proposed yield surface.

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Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

In person

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Session Classification: MS22

Track Classification: (MS22) Manufactured Porous Materials for Industrial Applications