Effect of Lode Parameter and Stress Triaxiality on the Effective Plastic Yield Properties of Triply Periodic IWP Ligament-Based Minimal Surface

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ABSTRACT

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 cellular materials, which include the mathematically-driven triply periodic minimal surfaces (TPMS). The elastic and plastic behavior has been well established for many TPMS structures [1, 2]. These structures are however rather computationally expensive to model explicitly when used in meta-materials and hence the need to develop an accurate yield function in order to model their plastic behavior in a homogenized approach. In this study, the effect of different loading conditions is numerically investigated on the effective yield strength of IWP ligament-based (IWP-L) TPMS. The simulations are based on a single unit cell of IWP-L under periodic boundary conditions, assuming an elastic-perfectly plastic material, for relative densities ranging from 7% to 28%. In order to define and account for the different loading conditions, the Lode parameter (L) [3, 4] is used. The effect of L is studied over a range of stress triaxialities (T) to understand the effect of both L and T on the effective yield strength. The results show that the effective yield surface for IWP-L should be characterized by T and L, and that the effect of these parameters is similar for the entire range of relative densities considered. In terms of T, yield strength is higher under lower T values, while in terms of L, yield strength is highest for $L = 0$ (shear loading) and is least for $L = \pm 1$. It is found that the yield strength values are similar for $L = +1$ (compression) and $L = -1$ (tension), indicating similar yielding behavior under compression and tension loading conditions, respectively. These findings will guide the development of a yield function that takes into consideration the effect of both T and L to accurately predict the yielding of TPMS based cellular meta-materials.

REFERENCES

[1] D.-W. Lee, K. A. Khan and R. K. Abu Al-Rub, "Stiffness and yield strength of architectured foams based on the Schwarz Primitive triply periodic minimal surface," International Journal of Plasticity, vol. 95, pp. 1-20, 2017.

[2] R. K. Abu Al-Rub, D.-W. Lee, K. A. Khan and A. N. Palazotto, "Effective Anisotropic Elastic and Plastic Yield Properties of Periodic Foams Derived from Triply Periodic Schoen's I-WP Minimal Surface," Journal of Engineering Mechanics, 2020.

[3] I. Barsoum and J. Faleskog, "Rupture mechanisms in combined tension and shear - Micromechanics," *International Journal of Solids and Structures,* vol. 44, pp. 5481-5498, 2007.

[4] N. Baghous and I. Barsoum, "Effect of Material Strength on Ductile Failure of Steel in Pressure Vessel Design," *Journal of Pressure Vessel Technology,* vol. 143, 2021.