The Impact of Pitch Angle and Porosity on the Tensile Properties Porous Bouligand Structured Polymer.

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Abstract

The study examines the effects of pitch angle and porosity on the tensile properties of bio-inspired porous Bouligand structured polymer. Bouligand structured polymers are energy-absorbent, damage-tolerant, and thermally tough materials with potential use in high-performance engineering applications. Here, we examine the impact of varying the pitch angle of the structure, using specifically 10○, 20○, 30○, 45○, and 90○ angles. We combine these pitch angles with an additional independent variable, that of fibre gap distance. The fibre gap distances we use are 0.5, 0.75, 1, and 1.25 mm, and we manufacture the materials by stereolithography (SLA) 3D printing. The 3D-printed porous Bouligand-structured polymers were subjected to tensile testing, and their properties and behaviours were corroborated by finite element analysis (FEA). We demonstrate that tailoring the pitch angle and porosity can substantially influence the mechanical performance of Bouligand structured polymers. A pitch angle of 30○ resulted in the highest tensile strength, and we consider that this is because the fibres were oriented optimally for stress transfer and crack deflection. Smaller fibre spacings, particularly at 0.5 mm, were consistently superior gap distances for mechanical performance, and this is at least partly because there is more material available to redistribute stress. Comparison of the strength and density of the 3D-printed porous Bouligand-structured polymer to other structural materials suggests that these designed polymers achieve strength-to-density values comparable with natural, polymer and elastomeric materials, whilst showing superior over other porous materials such as foams. Our work demonstrates how complex helicoidal structures with varied porosities and pitch angles, can be designed to create light and efficient mechanical materials.

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