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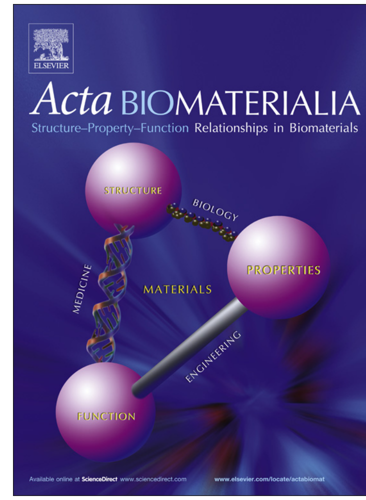

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Strain rate hardening: a hidden but critical mechanism for biological composites?

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Abstract

Natural materials such as nacre, bone, collagen or spider silk boast unusual combinations of stiffness, strength and toughness. Behind this performance is the staggered microstructure, which consists of stiff and elongated inclusions embedded in a softer and more deformable matrix. The micromechanics of deformation and failure associated with this microstructure are now well understood at the "unit cell" level, the smallest representative volume for this type of material. However, these mechanisms only translate to high performance if they propagate throughout large volumes, an important condition which is often overlooked. Here we present, for the first time, a model which captures the conditions for spreading of deformations or localization, which determines whether a staggered composite is brittle or deformable at the macroscale. The macroscopic failure strain for the material was calculated as function of the viscoplastic properties of the interfaces and the severity of the defect. As expected, larger strains at failure can be achieved when smaller defects are present within the material, or with more strain hardening at the interface. The model also shows that strain rate hardening is a powerful source of large deformations for the material as well, a result we confirmed and validated with tensile experiments on glass-PDMS nacre-like staggered composites. An important implication is that