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A three-dimensional unit cell model with controllable crimped structure for investigating finite strain response of collagen fiber reinforced biological composites

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Abstract:

Composite materials reinforced by crimped fibers, such as collagen fibers, have a widely application in the advanced structures. Therefore, an effective and achievable model is significant for explicitly describing the geometry of the crimped fibers and evaluating their mechanical behaviors. Aiming at this purpose, a three-dimensional (3D) unit cell model (UCM) is developed based on the microstructure of the collagen fibers, in which a controllable modified sinusoidal waviness fiber is explicitly embedded into the soft matrix, and an effective periodic boundary condition is applied on the proposed 3D UCM by using the multi-points constraint equations. The accuracy and validity of the proposed model are verified by comparing with the existing experimental results. For investigating the influence of the geometric parameters on the mechanical responses of the crimped fiber reinforced composites, several numerical UCMs with different geometric parameters are presented. The obtained results reveal that the parameters of crimp amplitude H and waviness χ of the fibers mainly contribute to the flexibility of the materials. The parameter ω for characterizing the roughness of the fibers is associated with the size and position of largest stress region. Moreover, the fiber radius R plays an important role in determining the bearing capacity of the materials and an excellent mechanical property, e.g., not only withstands the large initial tensile load but also has a special ability to guarantee the flexibility of the materials, may be achieved by controlling the number of the fibers with big and small radii.

Keywords: Crimped fiber; Soft matrix; UCM; Periodic Boundary condition; Geometric parameter