Semi-analytical simulation of aligned discontinuous composites

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Semi-analytical simulation of aligned discontinuous composites

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Abstract

Aligned-discontinuous-fibre reinforced polymers have the potential to combine (i) the high specific stiffness and strength and light weight of conventional continuous-fibre composites with (ii) increased damage tolerance, improved manufacturability, and the ability to close the life-cycle loop of composites by using recycled fibres. However, predicting the mechanical response of discontinuous composites is a challenge for which no universally accepted and computationally-efficient solution exists yet. This paper presents a model for aligned discontinuous-fibre reinforced composites considering (i) a generic constitutive law for the matrix, (ii) stochastic fibre failure under non-uniform stress fields due to the presence of fibre-ends, and (iii) unstable final failure from a critical cluster of damage. Results show good agreement with experiments from the literature, and the model also stresses the importance of considering the stochastic nature of both the fibre-end locations and the fibre-strengths to model aligned discontinuous composites. Parametric studies suggest that failure of aligned discontinuous composites depends on (i) the *overlap length* between fibres for short-fibre composites, and (ii) the *fibre strength* for long-fibre composites; intermediate-length fibres would result in discontinuous composites with maximum stiffness, strength, and failure strain simultaneously.

Keywords: A. Short-fibre composites, B. Stress/strain curves, C. Failure criterion, C. Modelling, C. Statistics

1. Introduction

Continuous-fibre reinforced composites are remarkably stiff, strong and light, but tend to fail in a brittle manner that cannot be tolerated in most applications. Natural composites overcome this flaw through discontinuous microstructures, achieving stiffness and strength comparable to those of continuous-fibre materials, but increasing significantly their tolerance to damage [1, 2]. Nacre, for instance, composed of 95% of stiff mineral platelets embedded in 5% of a soft organic phase, has a 3000-fold increase in toughness compared to the platelets, while maintaining reasonable stiffness and strength [3]. Experiments with man-made discontinuous composites have been successful in showing increased non-linearity and toughness, and also the potential of tailoring the discontinuous architecture to achieve different failure mechanisms [3–6].

Discontinuous composites also have better manufacturability than continuous-fibre composites, as the fibres are able to flow in the matrix during curing; this allows discontinuous composites to be manufactured through automated processes, it reduces the manufacturing time, and it allows for more complex-shaped components to be manufactured [7]. Moreover, recycled composites – which will become essential as composite production keeps increasing – have inherently discontinuous fibres [8, 9].

Many problems arise when modelling discontinuous composites. The first one, also present in continuous-fibre composites, is the stochastic variability of the fibre strength, which can be captured

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