8th European Solid Mechanics Conference
Gerhard A. Holzapfel and Ray W. Ogden (Eds)
Graz, Austria; July, 2012

Folding and Strain Softening of Carbon Fiber Composites with an Elastomeric Matrix

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ABSTRACT

New designs for lightweight deployable structures require materials able to undergo high curvatures without damage. A possibility is the use of carbon fiber composites with a soft elastomeric matrix, such as silicone rubber. This type of composites can be folded to very high curvatures, while it retains the high axial stiffness of traditional epoxy-based composites. The reason is that the soft matrix allows the fibers on the compression side of the material to form elastic microbuckles. Through this mechanism, the composite can be subjected to a large curvature while the strain in the fibers is relatively small [4]. In this contribution we present an experimental and numerical study of this novel composite.

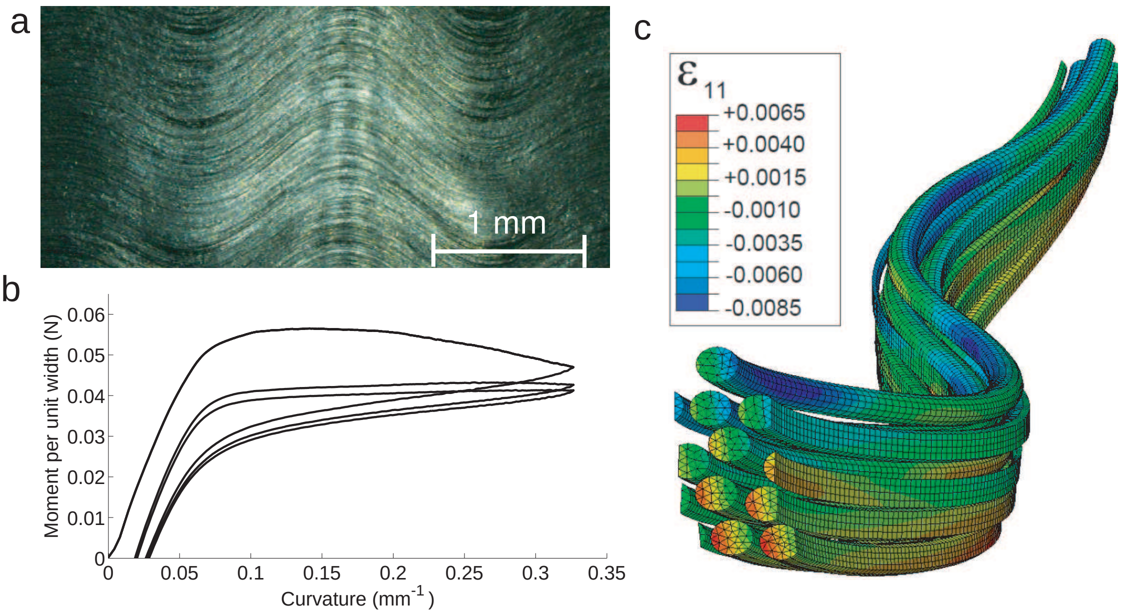

Figure 1: Folding of fiber composites with silicone rubber: (a) Micrograph of fiber microbuckling, (b) experimental moment-curvature relationship showing strain softening under cyclic loading and (c) three-dimensional simulations of the folding process, with the matrix removed to aid visualization.

Experimental testing of the folding behavior of the composite shows a highly nonlinear moment vs. curvature relationship, as well as significant strain softening, similar to the Mullins effect observed in particle-reinforced rubbers. Simulations neglecting damage sources capture the micromechanics of the microbuckling. However, the model tends to overestimate the material stiffness after buckling takes place, and is not able to capture the strain softening [1]. This shows the importance of considering a damage mechanism in the model.

In order to study the damage in the material, it is convenient to isolate its effects from those of the fiber microbuckling. In order to do so, the composite has been tested under unidirectional tensile loading perpendicular to the fiber direction. The strain softening observed in this loading case is due to the material damage, and can be modeled introducing cohesive elements at the fiber/matrix interface in a plane-strain finite element continuum model of the composite. This approach, similar to the one presented in [3], provides a good approximation of the experimental observations [2].

In the simulations two different approaches have been followed to model the arrangement of the fibers. The first one is a random hard-core process. The second is a reconstruction method based on the Random Sequential Adsortion algorithm by [6]. The goal is creating a model with a fiber distribution statistically equivalent to that observed in micrographs of the material, which is described with the second-order intensity function [5]. The results show the importance of using a realistic fiber arrangement to construct the model.

Acknowledgement. This study was supported with funding from the Keck Institute of Space Studies (KISS) at Caltech and L'Garde Inc.

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