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Strain mapping at the micro-scale in hierarchical polymer composites with aligned carbon nanotube grafted fibers

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Abstract

For the first time, micro-scale digital image correlation (μDIC) is investigated for measurement of strain fields in hierarchical fiber-reinforced composites. The methodology is developed on an exemplary alumina fiber/epoxy composite laminate with aligned carbon nanotubes (A-CNTs) grown on fibers. Utilizing environmental scanning electron microscopy and nano-scale random speckle patterns, sufficient precision is achieved to detect the influence of the A-CNTs on the deformation field around the fibers. Debonded regions at the fiber/matrix interface with openings as small as 35 nm could be detected. μDIC could identify the propagation of the debonded region based on the non-linear increase of the opening. The image correlation uncertainty in the displacement analysis is estimated to be below 5 nm. The experimental results are validated by computational analysis performed on the region of interest. For this, an advanced model with two scales of reinforcement (microscopic fibers and nanotubes) and boundary conditions taken from the experiment is used. As verified by the model, A-CNTs are found to constrain matrix deformation in their longitudinal direction.