

Calculation of 3D internal displacement fields from 3D X-ray computer tomographic images

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We present a new method for computing the internal displacement fields associated with permanent deformations of 3D composite objects with complex internal structure for fields satisfying the small displacement gradient approximation of continuum mechanics. We compute the displacement fields from a sequence of 3D X-ray computed tomography (CT) images. By assuming that the intensity of the tomographic images represents a conserved property which is incompressible, we develop a constrained nonlinear regression model for estimation of the displacement field. Successive linear approximation is then employed and each linear subsidiary problem is solved using variational calculus. We approximate the resulting Euler–Lagrange equations using a finite set of linear equations using finite differencing methods. We solve these equations using a conjugate gradient algorithm in a multiresolution framework. We validate our method using pairs of synthetic images of plane shear flow. Finally, we determine the 3D displacement field in the interior of a cylindrical asphalt/aggregate core loaded to a state of permanent deformation.

1. Introduction

X-ray computed tomography (CT) is being increasingly used in industrial environments for non-destructive evaluation of composite material (Gordon 1985; Synolakis 1991). X-ray CT is particularly attractive in the evaluation of advanced engineering materials, such as ceramic, intermetallics, carbon–carbon, ceramic–matrix and polymer–matrix composites (Armistead and Yancey 1989). However, previous applications have concentrated on measuring the dimensions of internal structures, mass fraction calculations, mapping density distributions and precisely locating and orienting manufacturing flaws. There have been no quantitative studies of unknown internal displacements during deformation. In this paper, we will describe a novel application of X-ray CT for extracting quantitative estimates of the internal displacement fields associated with small permanent deformation of 3D objects with complex internal structure.