SAND2014-18844C

Implementation of a Finite Deformation Hyperelastic Composite Material Model within a Shock Physics Hydrocode

Christopher T. Key[1], Bryan M. Love[2], and Shane C. Schumacher[3]

[1]*HI-TEST laboratories, Applied Technologies Group, 32 Murphys Drive, Groton CT 06340*
[2]*U.S. Army Research Laboratory, ATTN: RDRL-WMM-B, Aberdeen Proving Ground, MD 21005-5069*
[3]*Sandia National Laboratories, P.O. Box 5800 MS-0836, Albuquerque NM 87015*

Keywords:

Hyperelastic, Finite Deformation, Hydrocode, Impact

Abstract:

Fiber reinforced composite materials are often used in vehicle and personnel armor applications due to their low density and unique abilities to absorb energy. These materials have intrinsic microstructural and fabrication features, which allow for large amounts of energy absorption through high strains to failure, nonlinearity, delamination and fracture. The most efficient of these composite materials exhibit highly non-linear stress-strain responses combined with significant fiber rotations, which allow for membrane like large deformations and increased energy absorption. The problem is that traditional composite material models often fall short in capturing these unique kinematic and constitutive behaviors under finite deformations.

This work details the implementation and application of a finite deformation hyperelastic composite material model with novel kinematics [1] for capturing the composite material's response under high velocity impact. The model is implemented into material point method (MPM) hydrocode framework [2] to accurately capture the large deformations, wave propagation and high pressures associated with these impact conditions.

The material model defines six scalar strain attributes, which have direct physical interpretations, and when cast into a hyperelastic framework result in kinematic stress tensors that are mutually orthogonal. The orthogonality of these stress tensors allows for the material constants to be directly extracted from traditional composite material experimental test methods. This formulation offers a distinct advantage over other orthotropic hyperelastic material models where the normal and shear responses are coupled and material constant fitting can be very difficult. Finally, the kinematics of the model utilizes a fiber bisector method to calculate the evolution of the fiber orientations during the deformation process.

For this paper, we demonstrate the kinematics and deformation response of the hyperelastic model (Figure 1) as they relate to composite materials under high

velocity impact. The model results are compared against a traditional elastic-plastic transversely isotropic composite material model [3] that is currently available in the hydrocode to highlight the increased energy absorption capability of the model.

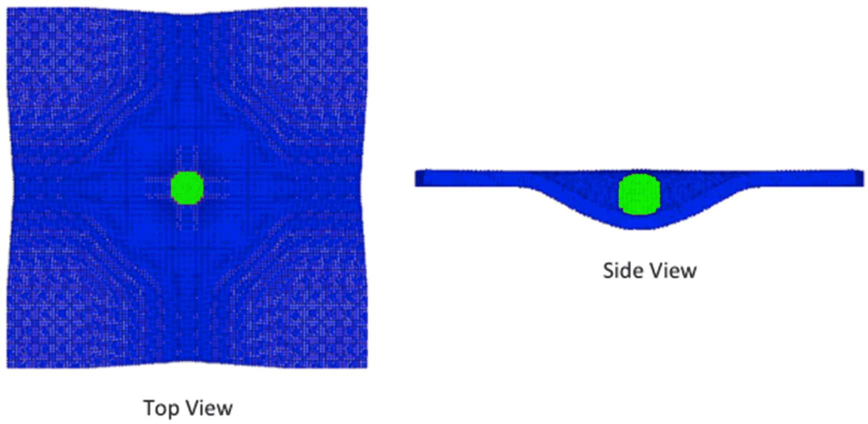

Figure 1. Predicted composite deformation pattern under impact loading.

[1] *Criscione, J.C. and W.C. Hunter, "Kinematics and elasticity framework for materials with two fiber families," Continuum Mech. Thermodyn. (2003) 15: 613-628.*

[2] *Schumacher, S.C. and K.P. Ruggirello, "CTH Reference Manual: Marker Technologies," SAND2013-1675, March 2013.*

[3] *Taylor, P.A., "CTH Reference Manual: The Transverse Isotropic (TI) Model," SAND95-2750, 1995.*