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Modelling of Deformation and Damage of Fiber -Reinforced Composite under Shock Loading

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Fiber-reinforced composite (FRC) materials, due to its low density and high strength, are widely used for protecting structures from impact loads. Difficulties arise when modeling the dynamic response of FRC materials considering the mismatch of sound impedance between fibers and matrix material. Planar plate impact tests on carbon-fiber-reinforced epoxy-resin matrix (CFRE) laminates have exhibited that the epoxy resin was totally decomposed even at a low impact speed of 700m/s while the fibers remained undamaged in the post-shock recovered specimens. To represent the nonhomogeneous and local feature of FRC, a computational model is established in which the fibers and matrix materials are rebuilt, respective, according to the texture of FRC using the smoothed particle hydrodynamics (SPH). The global feature of anisotropy depends therefore on the texture of FRC, and the constitutive relations are now determined directly by those of fibers and the matrix material.

To determine the constitutive relations involving the damage evolution of fibers and matrix materials, planar plate impact tests have been performed for epoxy resin coupon and its FRC. The measured particle velocity profile using Doppler laser interferometer consists of shock wave and subsequent release waves, including the information of material compression and damage, respectively. Numerous simulations are carried out accordingly for shocked coupons with various woven-type and volume fraction from 30% to 50% for carbon fibers at impact speeds from 300m/s to 4km/s. As shown in this paper, though the epoxy resin has less density and lower modulus, it plays an important role on the shock response of the CFR coupon. Especially in the case of unloading, the integrity of the matrix material may to a great extent determine the propagation of release waves.

The validity of the computational model has been preliminarily testified when use it to sandwiched laminates resisting hyper-speed impact of a flyer. In relation to the free-surface velocity profile measured experimentally, the computational model also displayed the wave propagation and damage evolution inside a shielding laminate. Note that the interface strength between fibers and matrix has less influence on the simulation results in the case of shock loading, though it is also the next consideration in our FRC model.