Simulation of high-velocity impact process of 3D woven orthogonal composite from meso-scale point-based model

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Abstract

Three-dimensional orthogonal woven composites (3DOWC) have received much attention in recent years owing to their outstanding properties, especially in shielding impact loading. The existence of Z-yarns sharply improves the delamination resistance when compared to uni-directional fiber-reinforced composites and two-dimensional woven composites. Constructing meso-structure model and simulating impact processes directly from the meso-structure are desirable for investigating the shielding properties of 3DOWC.

Although meso-structure models based on traditional finite element method (FEM) were developed for 3DOWC and the macro-scopic properties were successfully investigated, the mesh-based meso-structure model encountered some difficulties to reflect realistic internal structures. The section shape and the profile of yarns were severely simplified, and the discretization of the matrix material after the generation of the woven structure is difficult. The large deformation and the fracture also pose challenges for the mesh-based models.

The material point method (MPM) [1], which belongs to the category of meshfree particle methods, is much more competitive in simulating extreme events such as explosion and high-velocity impact. MPM employs both Lagrangian material points and Eulerian background mesh for the simulation. The material points carry all the physical variables and represent the movement and deformation of the material, and the uniform background mesh is used to solve momentum equations and calculate spatial derivatives. The large deformation process can be simulated accurately and efficiently by MPM. The analysis of fracture and fragmentation phenomena can be easily carried out with MPM.

Owing to the aforementioned particle feature, MPM is very suitable for investigating the role of meso-structure during high-velocity impact process. The point-based meso-structure models for aluminum foam [2] and honeycomb sandwich panel [3] were successfully constructed, and the influences of meso-structure on shielding capability for high-velocity impact were obtained with MPM simulation.

In this work, we develop a scheme to construct point-based meso-structure model for 3DOWC. The yarns are more realistic, and the matrix can be easily inserted into the woven structure with uniform discretization. Several examples with extremely large deformation, including the forming process and the high-velocity impact, are simulated with MPM and the meso-structure model. The influences of the impact velocity and the meso-structure parameters are investigated.

Keywords: Woven composite, multiscale, meso-scale model, high-velocity impact, material point method

References

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