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POINT-BASED MESO-SCALE MODELING FOR WOVEN COMPOSITES

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ABSTRACT

A point-based method to construct meso-structure model of the woven composites is proposed. The point-based models can demonstrate more realistic details than the traditional mesh-based models because it is much more convenient to discretize only with points than to connect point into elements. After the reinforced structures are generated, the matrix points can be easily inserted in a uniform manner. The macroscopic responses of the composite material under extreme loading can be well predicted by the point-based model owing to the advantages of the material point method for problems of large deformation and fracture. Examples of calculating the elastic modulus, the forming process, and the perforation process of woven composites are simulated. Numerical results of meso-structure models agree well with experimental results.

Keywords: multiscale modelling and simulation, woven composites, the material point method, large deformation, dynamic fracture.

INTRODUCTION

The woven composites have attracted wide attention (Tong, 2002) owing to their outstanding mechanical properties, which can be attributed to the complex meso-structure of the reinforced phase. It is not easy for the traditional mesh-based methods to discretize the woven meso-structure, and the existence of matrix material makes the discretization much more complicated. Even if the meso-structure is discretized, the large deformation or the fracture process of the woven composites when subjected to impact loading cannot be well simulated due to numerical difficulties aroused by mesh such as mesh distortion.

The material point method (MPM) is one kind of meshfree particle methods (Zhang, 2016). The MPM does not encounter mesh distortion even with extremely large deformation, and the failure and fracture process can be easily simulated with the MPM. The efficiency of MPM is very high in the large deformation stage. Because the simulated object is discretized by a group of points, the discretization of complex structure is simple and straightforward.

Owing to the aforementioned advantages, the MPM has been successfully applied in the impact problems, the explosion problems, the fluid-structure interaction problems, and the multiscale analysis (Zhang, 2016). Liu et al. (Liu, 2014) constructed the complex meso-structure of the aluminum foam material based on CT images, and they successfully simulated the hyper-velocity impact process of the aluminum foam.

A point-based modeling method to construct the meso-structure of the woven composites is proposed in this work. The shape of yarns is determined by observations from realistic specimen, and the woven structure can be discretized with uniformly distributed points because no connection between points is required. After the structure of the reinforced phase is discretized, the matrix points can also be easily inserted. The generated point-based meso-structure model can be used to calculate the macroscopic properties of the composite. The responses of the composite under extreme loading can be well simulated with the meso-structure model and the MPM.

RESULTS AND CONCLUSIONS

Several examples, which include calculating the elastic modulus of the woven composite, the forming process, the perforation of 2D plain woven fabrics, and the perforation of 3D woven composite plate, are simulated with the meso-structure model. The simulated results agree well with experimental results. Fig. 1 demonstrates the residual velocities of the projectiles after perforating the composite plate.

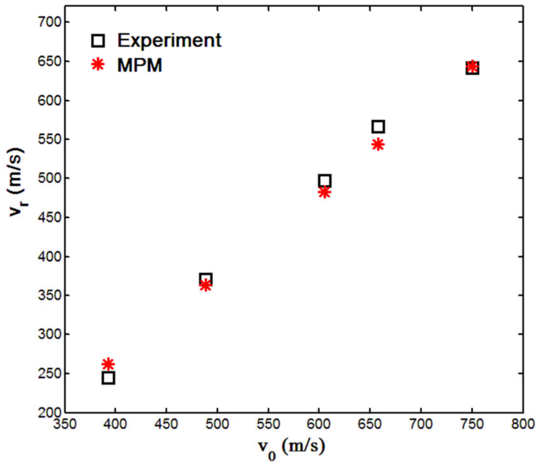

Fig. 1 - Residual velocities of the projectiles versus the initial velocities

This study proposed a point-based meso-scale modeling and simulating method for woven composites. More details of the meso-structure, such as initial defects and the interface effect, may be incorporated in the future study.

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