Materials and Design 32 (2011) 885–891

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Automatic generation of random distribution of fibers in long-fiber-reinforced composites and mesomechanical simulation

Zhenqing Wang [a], Xiaoqiang Wang [a,*], Jifeng Zhang [a], Wenyan Liang [a], Limin Zhou [b]

[a] *Smart Structures and Advanced Composites Laboratory, College of Aerospace and Civil Engineering, Harbin Engineering University, Harbin 150001, China*
[b] *Department of Mechanical Engineering, The Hong Kong Polytechnic University, Hong Kong*

ARTICLE INFO

Article history:
Received 26 March 2010
Accepted 2 July 2010
Available online 7 July 2010

Keywords:
A. Composites
F. Elastic behavior
H. Failure analysis

ABSTRACT

An algorithm for the automatic generation of 2D representative volume element (RVE) of unidirectional long-fiber-reinforced composites (LFRCs) is presented in this paper. Both high fiber volume fraction and random fiber distribution are considered in the RVE. Two procedures which are named as global criss-crossing and local disturbing are included in this algorithm. Based on the model generated, mesomechanical analysis is carried out by using general finite element method (FEM) software ABAQUS. Firstly, the effect of the randomness of fiber distribution on the transverse modulus is investigated. Secondly, user subroutine to redefine field variables at a material point (USDFLD) in ABAQUS is used to simulate the damage behavior. A series of computational experiments are performed to evaluate the influence of mesh size on the ultimate load of the composites. The obtained results prove that the algorithm is capable of capturing the random distribution nature of these materials and the RVE produced could be used for predicting the damage onset and propagation of LFRCs.

1. Introduction

Amount of efforts have been devoted toward the use of light-weight structures in order to increase energy efficiencies in various industries [1–4]. Fiber-reinforced composites used in these structures have been found numerous applications in aerospace industry for their high specific strength and specific stiffness [5]. The increasing use of these materials in the industries requires efficient technologies to predict the mechanical behaviors of such composites from the properties of their constituents. Traditionally, full-experiment method is used to confirm the characters of composite materials. In fact, this method needs a considerable amount of human and financial resources. Recent research, based on mesomechanics, could satisfy the requirement of decreasing the dependency on experimental work. For instance, the use of new numerical and/or analytical technologies provides a quick and helpful way to establish the basis of composites research. In order to analyze the mechanical behaviors and properties of composites, taking into account their microstructures, an appropriate RVE model of composites should be defined firstly.

Many methods have been developed for the generation of RVE models of composites. Pyrz [6] produced a RVE using the Poisson point distribution, where the points are the centers of fibers. This is called the hard-core model. However, Buryachenko et al. [7] found that this method hardly generates distributions with fiber volume fraction larger than 50%. This phenomenon is called as "Jamming" [8]. Recently, Böhm and Rammerstorfer [9], Wongsto and Li [10] and Gusev et al. [11] presented a scheme for the generation of fiber distribution with high fiber volume fraction by disturbing an initially regular fiber distribution randomly. Melro et al. [12] developed a model which can generate random distribution cross-section model with high fiber volume fraction. Additionally, image processing and reconstruction method [13] can give a good reflect of the material microstructure, though it requires specific software and hardware, meanwhile it would be extremely time and resource consuming.

In this paper, an algorithm and program code for the automatic generation of 2D RVE model of unidirectional LFRC is presented. Meanwhile, both high fiber volume fraction and random fiber distribution are considered in the RVE. The fibers in the transverse cross-section are generated by moving them from their initially square arrangement randomly. Additionally, a series of mesomechanical analytical experiments on the RVE are performed to study the elastic and damage properties of the LFRC microstructure.

2. Procedure to generate RVE

In this section, a two-step procedure is illustrated for the automatic generation of RVE models with random distribution of fibers (see Fig. 1). These models could be used for LFRC mesomechanical analysis. The program code is developed in Python language. Then

* Corresponding author. Tel./fax: +86 451 82589364.
E-mail address: wangxiaoqiang@hrbeu.edu.cn (X. Wang).

0261-3069/$ - see front matter Crown Copyright © 2010 Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2010.07.002