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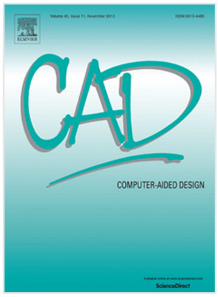

3D woven composite design using a flattening simulation

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Kotaro Morioka[a,*], Yutaka Ohtake[a], Hiromasa Suzuki[a], Yukie Nagai[a], Hiroyuki Hishida[b], Koichi Inagaki[b], Takeshi Nakamura[b], Fumiaki Watanabe[b]

[a] *The University of Tokyo, Japan*
[b] *IHI Corporation, Japan*

Abstract

Fiber composite materials have unique, advantageous mechanical properties that have made them highly desirable in a range of industries. In particular, 3D woven-fiber composites are highly resistant to delamination compared with laminated 2D woven-fiber composites and have been adopted in various advanced products. This paper focuses on the design of 3D woven-fiber composite products and proposes a flattening simulation method for designed 3D models with constant thickness. The proposed method estimates the shape of a flat material and the fiber directions in the 3D model design; deformation phenomena of 3D woven-fiber materials are also considered in order to improve the accuracy of the proposed method. CT images are used to compare the simulation results with the actual defromation of 3D woven-fiber materials and confirm the ability of our method to effectively design the fiber direction base on the 3D model and to estimate the shape of flat materials.

Keywords:
fiber material, 3D woven fabrics, flattening, forming

1. Introduction

Fiber composite materials, which are made of fibers and matrix materials, have attracted considerable attention from various industries because of their unique, advantageous mechanical properties [1]. For example, carbon fiber composite materials are lightweight and have high stiffness compared with alloys and are thus widely adopted in both the aircraft and automobile industries. However, the design and manufacturing of fiber composite products is difficult, resulting in high production costs. The reduction of these costs necesitates an imprvement in both the design and manufactureing technologies that are used. To that end, this study focuses on developing a design support method for fiber composite products.

When designing fiber composite materials, two points have to be considered:

1. Fiber direction design
   Fiber materials have strong anisotropic mechanical properties depending on the fiber direction; this, in turn, affects the strength of the final product. These anisotropic properties are most noticeable in materials with long continuous fibers, which means that designers using such materials have to pay special attention to the fiber directions. Because these long-fiber materials are advantageous in terms of stiffness, almost all advanced products are manufactured from these materials implying that fiber direction is a concern for most designers.
2. Large deformation of thick fiber materials
   To create products with complex shapes, it is necessary to deform fiber composite materials prior to using matrix materials to shape the products. However, thick fiber composite materials are necessary to achieve product stiffness (this is done by either accumulating several planar woven-fiber laminates or using 3D woven-fiber materials), and using thick fiber composite materials to obtain products with complex shapes is difficult.

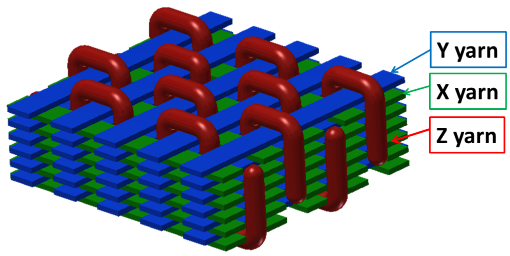

Figure 1: Fiber structure of 3D woven-fiber composite materials

Thus, the chosen design method has to overcome the problems associated with both fiber direction design and large deformation of thick materials.

Our method focuses on designing advanced products from fiber composite materials and assumes that these fiber composite materials consist of long continuous fibers and are made by weaving fiber yarns in a 3D manner. We evaluated the results of our method by adopting ceramic matrix composite (CMC) materials with high specific strength and heat resistance [2].

The general process for producing products using 3D woven-fiber composite materials consists of three steps: first, planar-shaped materials are made by weaving fiber yarns; second, ma-

*Corresponding author