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A shell formulation for fibrous reinforcement forming simulations

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Abstract

The fibrous nature of continuous fiber textile composite reinforcements strongly modifies their mechanical behavior, in particular for bending. The basic assumptions of classical plate and shell theories are not verified by these materials during a deformation because of the slippage between fibers. However, simulations of reinforcement forming generally use shell finite elements. A shell formulation is proposed for the forming of continuous fiber reinforcements. The large tensile stiffness leads to the quasi inextensibility in the fiber directions. The fiber bending stiffness determines the curvature of the reinforcement. The calculation of tensile and bending virtual works are based on the precise geometry of the single fiber. A simple way to consider friction between fibers is to take it into account in the flexion bending. Simulations and experiments are compared for different reinforcements. It is shown that the proposed fibrous shell approach not only correctly simulates the deflections but also the rotations of the through thickness material vectors. This is particularly interesting in the case of thick interlock reinforcements.

Keywords: A. Fabrics/textiles, C. Process Simulation C. Finite element analysis (FEA) E. Forming, Shell.

1. Introduction

The performance of composite materials with continuous fibers has been proven through recent civil aircraft programs [1,2]. However, the long production time and the high manufacturing cost act as a brake on their development. To avoid trial and error tryout procedure, process simulations enable the determination of suitable process parameters fairly rapidly. In particular, the simulation of the preform shaping in LCM processes is indispensable. This simulation allows to determine the fiber orientation after forming but also the onset and development of defects such as wrinkles [3-8]. In the context of continuous fiber reinforcement forming simulations, the objective of this article is to propose a shell approach for the reinforcements, which is consistent with the mechanical behavior of fibrous materials that are not the case of classical shell theories. The considered reinforcement is composed of continuous fibers in the warp and weft directions. It can be UD, woven, NCF or interlock. The thickness of this reinforcement can be small or large. In the case of interlock reinforcements, it can reach several centimeters (15 mm in examples shown in Fig. 1).

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