Simulations of 3D Textile Composite Reinforcements Forming. Specificities and possible modeling of the mechanical behavior

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The present work concerns the analysis of the mechanical behavior of 3D textile preforms (interlock) during the forming process. Forming 2D (i.e. thin) composite reinforcements has been thoroughly studied with the development of efficient draping software packages. In draping simulations, the 2D reinforcements are generally modeled by shell finite elements. The thick reinforcement fabrics analyzed in the present paper need to be modeled by 3D finite elements and 3D constitutive models. Their mechanical behavior is specific: because of the absence of a matrix during the forming process, the fibers that constitute the preform can slide transversely against each other. This behavior has a significant influence on the constitutive model and its resulting rigidities. Beyond this, it will be shown that a 3D modeling based on Cauchy hypothesis is not sufficient to describe certain aspects of the deformation of thick fibrous reinforcements. In particular, the absence of the fiber local bending stiffness in the model leads to discrepancies between simulations and experiments. Such phenomena are observed with three point bending tests, tetrahedral forming, and hemispherical shaping performed on thick interlock reinforcement. To overcome this difficulty, two approaches are considered. First we propose to use a second gradient, 3D orthotropic model for the characterization of the mechanical behavior of thick woven composite interlocks [1, 2]. Such second-gradient theory is seen to directly account for the out-of-plane bending rigidity of the fibers at the microscopic scale which is, in turn, related to the bending stiffness of the fibers composing the yarns themselves. In the second approach, the local bending stiffness is taken into account in the finite element formulation [3, 4]. A local curvature is determined from the position of the nodes of the neighboring elements using an approach based on rotation free shell elements. It will be shown in the three point bending test, and the hemispherical and tetrahedral shapings, that taking into account the local curvature stiffness avoids the problems highlighted with the 3D finite elements.

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