Simulations of the stamping, compaction and consolidation of thermoplastic composites based on solid-shell finite elements

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Abstract

During thermoforming process, the consolidation deformation mode of thermoplastic prepregs is one of the key deformation modes especially in the consolidation step, where the two resin flow phenomena: resin percolation and transverse squeeze flow, play an important role. This occurs a viscosity behavior for consolidation mode. Based on a visco-hyper-elastic model for the characterization of thermoplastic prepregs proposed by Guzman, which involves different independent modes of deformation: elongation mode, bending mode with thermo-dependent, and viscoelastic in-plan shearing mode with thermo-dependent, a viscoelastic model completed with consolidation behavior will be presented in this paper. A completed three-dimensional mechanical behavior with compaction effect for thermoplastic pre-impregnated composites is constituted, and the associated parameters are identified by compaction test. Moreover, a seven-node prismatic solid-shell finite element approach is used for the forming simulation. To subdue transverse shear locking, an intermediate material frame related to the element sides is introduced in order to fix nodal transverse shear strain components. Indeed, the enhanced assumed strain method and a reduced integration scheme are combined offering a linear varying strain field along the thickness direction to circumvent thickness locking, and an hourglass stabilization procedure is employed in order to correct the element's rank deficiency for pinching. An additional node is added at the center providing a quadratic interpolation of the displacement in the thickness direction. The predominance of this element is the ability of three-dimensional analysis, especially for the transverse stress existence through the thickness of material, which is essential for the consolidation modelling. Finally, an intimate contact model is employed to predict the evolution of the consolidation, which permits the microstructure prediction of void presented through the prepreg. Several tests including a thermoforming test are launched to evaluate the consolidation model and the accuracy of the proposed element.