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Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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A VIRTUAL MANUFACTURING TOOL FOR PROCESS-INDUCED DEFORMATIONS ANALYSIS IN THIN COMPOSITE STRUCTURES

Abstract

Composite materials are widely used in the design of space structures because of their high specific properties. Despite their outstanding mechanical properties, the manufacturing of carbon fiber reinforced polymers, CFRP, is a challenging task and should be considered from the early stage of the design. The polymerization process of high-strength composite materials must be performed at high temperatures and pressure. The thermal load and the chemical shrinkage occurring during curing may lead to large process-induced deformations and create residual stresses in the components. Residual deformations are usually undesired, and proper staking sequences must be adopted to minimize their magnitude. In some cases, residual deformations have been exploited to develop innovative deployable structures, such as tape spring structures. Regardless of the composites in hand, predicting the actual residual deformation is essential to guarantee the accuracy and integrity or provide the deployment capability. The prediction of these phenomena requires the use of refined numerical models. The three-dimensional nature of the problem and the multiple, interacting physical fields make classical models ineffective. Solid elements lead to accurate results but require very high computational costs. This work presents an advanced virtual manufacturing framework to predict process-induced deformations and residual stresses in composite components. The numerical model is based on the Carrera Unified Formulation, a numerical tool to build higher-order structural theories. The use of refined kinematic models, such as Layer-Wise, leads to the prediction of accurate stress fields, including the through-the-thickness stretching that plays an important role in the formation of residual deformations. A cure hardening instantaneously linear elastic model is used to predict the evolution of the material properties during the curing. The model is used to simulate the manufacturing process of classical and ultra-thin composite structures. The effect of the stacking sequence and the impact of curing parameters are investigated. The results show the capability and efficiency of the proposed model to deal with the process simulation of composite materials. The use of refined one-dimensional models leads to three-dimensional accuracy with a substantial reduction in computational cost compared to solid elements.