VIRTUAL DESIGN AND MANUFACTURING OF COMPOSITE STRUCTURES USING REFINED KINEMATIC MODELS

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Space structures largely use composite materials because of their high specific properties. Carbon fiber reinforced polymers have significantly reduced weight without reducing the mechanical strength or the stiffness of structural components. Unlike metallic structures, composite manufacturing technology is not yet fully mature. The polymerization process is a source of uncertainties and leads to defects resulting in an overall reduction of structural performances. The thermal cycles required in the curing process can lead to residual deformations and residual stresses: the former may compromise the component's geometry; the latter may reduce the safety margin leading to an early failure of the structure. The use of the numerical tool could lead to a reduction by-design of the manufacturing defects, but since process-induced deformations are driven by a through-the-thickness deformation, they cannot be predicted through the classical laminate theory, that is, three-dimensional models are strictly required.

A virtual manufacturing framework is here proposed to predict the impact of the manufacturing process parameters on the structural integrity of composite components. Refined kinematic models, based on the Carrera Unified Formulation, have been adopted to overcome the limits of classical structural theories avoiding the huge computational cost of solid models. The use of refined kinematic models, and a high-fidelity representation of the laminate, has led to the fully three-dimensional solution of the problem in terms of displacement and stresses. The solution of the curing kinematic model and the ply micromechanics has been evaluated using the software RAVEN.

The results obtained considering flat and curved components demonstrate the accuracy of the present approach and its high computational efficiency. The use of higher-order finite elements is shown to be as accurate as a three-dimensional model with a fraction of the computational cost.

The present virtual manufacturing framework may impact the exhaustive understanding of the phenomenon occurring during the curing process (e.g., tool part interaction), providing a few best practices for reducing defects during composite parts manufacturing.

The large amount of data that can be produced exploiting the computational efficiency of the model could be the basis for developing future surrogate models, such as neural networks, that can play a crucial role in virtual manufacturing applications.