CUF Multifield Models for Virtual Manufacturing of Composites

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Abstract. This paper uses refined structural theories to predict process-induced defects (PID) in composite parts originating from curing. PID may affect the final shape of composite parts and their mechanical properties [1]; spring-in angles, warpage, and residual stress distributions may arise during the curing process and cause significant time and economic loss. Using numerical models to predict such defects and propose countermeasures is desirable but challenging due to the multifield nature of the thermos-chemo-mechanical phenomena involved in curing [2-4].

The multifield modeling of displacement and stress fields, temperature, and degree of cure is carried out through the Carrera Unified Formulation (CUF) [5] using 1D component-wise structural theories to avoid computationally expensive 3D solid elements. The computational efficiency of the numerical models proposed allows for parametric analysis considering the influence of process parameters – e.g., curing temperatures and time – and structural features – e.g., stacking sequence – on PID. Furthermore, various structural configurations can be considered, including flat and curved parts, spars, and stiffeners.

The results show the capability of the proposed formulation to obtain the complete 3D distribution of displacement, stress, temperature, and degree of cure during the entire process and the possibility of evaluating mitigation strategies, such as using additional layers or unbalanced stacking sequences. Moreover, the possibility of coupling the formulation with machine learning is drawn.

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