On the Relevance of Thermomechanics and Crystallization Kinetics for FE Thermoforming Simulation of Semi-Crystalline Thermoplastic Tapes

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Abstract. Thermoforming of thermoplastic pre-impregnated tapes is currently of great interest for the automotive industry due to low cycle times and recyclability. Depending on material parameters and process conditions, manufacturing defects like wrinkling, gapping or fiber fracture are possible. Finite Element (FE) forming simulation offers the possibility of a detailed analysis of the deformation behavior of multilayered thermoplastic blanks during forming, considering material behavior and process conditions by means of constitutive equations for intra- and inter-ply deformation mechanisms. Usually, thermoforming simulation is assumed to be iso-thermal, which is a reasonable assumption for temperatures above the onset of crystallization for semi-crystalline thermoplastics. Especially in a process design phase, however, the onset of crystallization cannot be excluded for a specific process strategy and geometry. In this study, a fully coupled thermomechanical approach for finite element forming simulation of thermoforming processes, predicting the evolution of temperature and crystallization of semi-crystalline thermoplastics, is presented. Based on this approach, the distinct increase of mechanical properties and thus the decreasing formability with the onset of crystallization is accurately predicted. The approach is parameterized for a thermoplastic UD-tape (PA6-CF) and successfully applied to forming simulation of a generic geometry with a very good agreement to experimental forming tests. Finally, the relevance of including thermomechanics and crystallization kinetics is analyzed by means of a virtual sensitivity study. The study reveals that only by including those effects, the influence of all process parameters on formability can be predicted.