Simulation of Composite Manufacturing with MSC Products

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ABSTRACT

PCM is a common manufacturing process used to produce thick laminate composite parts typical in rotorcraft applications such as flexbeam, blades and spars. The process involves the placement of prepeg into a mold cavity and the subsequent consolidation under heat and pressure to form the composite with two events dominating the process physics:

- Fiber Bed Consolidation: During the early part of the PCM process, the process can be mainly viewed as a viscous fluid (resin) flow through a porous medium (fiber mats) under the influence of heat and pressure. The resin pressure field is of primary importance during this stage since it is believed to control defects like marcels (fiber waviness) and voids (porosity).
- Curing and Residual Stresses: Subsequently, the PCM process can be mainly viewed as a coupled thermal-curing-mechanical analysis. The thermal and curing processes influence each other, and they in turn influence the mechanical strains and stresses. The temperatures, degree of cure and residual stresses in the composite are of importance during this stage.

Process variables causing defects are not well understood and are typically resolved using a trial-and-error approach. This often leads to long process development time and associated high manufacturing costs. Software tools that allow simulation of the physics of the coupled transport phenomena of heat, fluid and resin curing kinetics are necessary to correlate the root causes of defects with processing strategies and tool configurations. The current work describes the effort at MSC in the simulation of advanced composite manufacturing processes like PCM. The architecture of Marc is well suited for multi-physics simulations. The typical approach in these multi-physics simulations is to use a staggered approach within each increment, and simulate one particular physics type followed by passes of other physics types. Cure pass is done first where material property and other analysis options need to be modified to define a coupled analysis that includes the cure pass. Four types of cure kinetics models exist. The governing equations for cure are similar to thermal analysis with a non-linear loading term, which is a function of cure and temperatures. Once the degree of cure is determined, the thermal volume flux generated by the exothermic curing process is calculated and transferred to the thermal pass. To calculate the non-linear cure loading term accurately, an iterative scheme between each cure pass and thermal pass is used to ensure that the cure loading term is represented accurately. Once the cure and thermal passes are completed, the degree of cure and temperatures are transferred to the mechanical pass – the mechanical pass is then carried out. Two resin cure shrinkage models exist to model shrinkage effects which are incorporated in the mechanical pass. Shrinkage strains as a function of the degree of cure need to include for computing residual stresses accurately. It is found that the analysis needs robust automatic time stepping procedures since initial cure changes are significant and tend to taper off with time. Implementation of orthotropic soil properties in an existing Cam-Clay soil model and pressure film boundary conditions allows for the simulation of fiber bed consolidation analysis. Future efforts will be directed toward migrating this technology in MD Nastran product.