Faster, Energy-Efficient Manufacturing of Composite Materials Using Frontal Polymerization

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Because of their high specific stiffness and strength properties, fiber-reinforced composite materials are being widely used in aerospace, automotive, and energy applications. However, current manufacturing techniques mainly relies on the bulk polymerization of the matrix. This makes the process expensive since substantial capital investments are needed for the large autoclaves/ovens/heated-molds. Moreover, the thermal curing process involves long and complex cycles of heat and pressure resulting in a time-consuming and energy-intensive process. Frontal Polymerization (FP) has been recently proposed by Autonomous Materials Systems research group at the University of Illinois as an alternative approach to reduce the large capital investments and make the process substantially faster and more energy efficient. FP is a process in which a localized reaction zone, driven by the heat generated through a highly exothermic reaction, propagates through the monomer by converting it into the polymer. Due to it self-sustaining nature, FP eliminates the need for autoclaves and other external source of heat during polymerization, and greatly speeds up the manufacturing process.

In this talk, I will present some of the recent experimental and modeling advances made in the manufacturing and assessment of the FP-based manufacturing of thermoset fiber-reinforced composites. I will also show how the method can be used in the printing of complex 'self-standing' 3D components. On the modeling side, the underlying physics is captured with the aid of nonlinear transient coupled thermo-chemical reaction-diffusion equations. Of particular interest is the modeling of the effects of the material and process parameters on the overall performance of the FP-based manufacturing process, including how the properties and volume fraction of the reinforcing fibers impact the speed, temperature and intrinsic length scales of the polymerization front.