Project title: Frontal Polymerization: A Revolutionary Way to Manufacture Composite Structures

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Project description
Because of their excellent specific properties, composite materials are increasingly used in aerospace engineering. One of the limitations that prevent a wider use of fiber-reinforced thermosetting-matrix composites is the complexity, duration and cost of the manufacturing process, which often involves long (8-hour-long) curing cycles under low pressure and high temperature in large autoclaves.

In this project, we investigate a radically new way to create composite parts much faster and for a much smaller cost using a self-sustaining curing process based on frontal polymerization. Unlike in conventional, autoclave-based manufacturing processes based on the bulk polymerization of the composite part, frontal polymerization uses the extra heat generated by the exothermic reaction to cure the polymer in a rapidly propagating, self-sustaining front, allowing for the manufacturing of large composite parts two orders of magnitude faster.

Before this new approach can be adopted by the aerospace industry, a set of fundamental issues need to be addressed, such as (i) how to optimize the polymer chemistry to maximize the polymerization front speed without detrimentally affecting the properties of the composite; (ii) How to optimize co-polymer system to achieve super-fast front velocity as suggested by experiments; (iii) how to extend the applications of FP in morphogenesis and pattern generation, as well as 3D printing; (iv) how to optimize the location of the front initiation sites to minimize the manufacturing time for arbitrary-shaped composite parts; (v) how to predict the propagation of the polymerization front in a composite material where the heat generated by the chemical reaction may be absorbed by the fiber tows; (vi) what is the residual strain accumulated during the FP process, and how to minimize it.

![Figure: 2D numerical modeling of frontal polymerization in a uni-directional carbon fiber-reinforced polymer composite.](a) [b]

Student background and expected research activities
Since this is a computational project, experience in numerical modeling, and of MATLAB in particular is needed. Experience in machine learning is not required but is a plus. We welcome a total of THREE students to join us since we have a list of interesting topics to investigate.

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