Computational Modeling of Composite Material Fires

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Composite materials behave differently from conventional fuel sources and have the potential to smolder and burn for extended time periods. As the amount of composite materials on modern aircraft continues to increase, understanding the response of composites in fire environments becomes increasingly important. An effort is ongoing to enhance the capability to simulate composite material response in fires including the decomposition of the composite and the interaction with a fire. To adequately model composite material in a fire, two physical model development tasks are necessary; first, the decomposition model for the composite material and second, the interaction with a fire. A porous media approach for the decomposition model including a time dependent formulation with the effects of heat, mass, species, and momentum transfer of the porous solid and gas phase is being implemented in an engineering code, ARIA. ARIA is a Sandia National Laboratories multiphysics code including a range of capabilities such as incompressible Navier-Stokes equations, energy transport equations, species transport equations, non-Newtonian fluid rheology, linear elastic solid mechanics, and electro-statics. To simulate the fire, FUEGO, also a Sandia National Laboratories code, is coupled to ARIA. FUEGO represents the turbulent, buoyantly driven incompressible flow, heat transfer, mass transfer, and combustion. FUEGO and ARIA are uniquely able to solve this problem because they were designed using a common architecture (SIERRA) that enhances multiphysics coupling and both codes are capable of massively parallel calculations, enhancing performance. The decomposition reaction model is developed from small scale experimental data including thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC) in both nitrogen and air for a range of heating rates and from available data in the literature. The response of the composite material subject to a radiant heat flux boundary condition is examined to study the propagation of decomposition fronts of the epoxy and carbon fiber and their dependence on the ambient conditions such as oxygen concentration, surface flow velocity, and radiant heat flux. In addition to the computational effort, small scaled experimental efforts to attain adequate data used to validate model predictions is ongoing. The goal of this paper is to demonstrate the progress of the capability for a typical composite material and emphasize the path forward.

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