Announcing the Final Examination of Jinfeng Zhuge for the degree of Doctor of Philosophy

Time & Location: March 22, 2012 at 1:00 PM in Engineering 2 202
Title: Fire Retardant Polymer Nanocomposites: Materials Design and Thermal Degradation Modeling

Polymer matrix composites (PMCs) have a number of attractive properties including light weight, high stiffness-to-weight and strength-to-weight ratios, ease of installation on the field, potential to lower system-level cost, high overall durability and less susceptibility to environmental deterioration than conventional materials. However, one of the challenges facing PMCs is their vulnerability to fire. PMCs will degrade, decompose, and sometimes yield toxic gases at high temperature or subject to fire conditions. The degradation and decomposition of the composites will lead to losses in mass and that leads, in turn, to losses in mechanical strengths of the structure.

This research aims to design and optimize a fire retardant nanopaper by utilizing the synergistic effects of different kinds of nanoparticles, and to fundamentally understanding the fire retardant mechanism of the nanopaper coating by means of numerically analyzing their thermal response and post-fire mechanical behavior. Specifically, a novel paper-making technique that combined carbon nanofiber, nanoclay, exfoliated graphite nanoplatelet, and ammonium polyphosphate into a self-standing nanopaper was developed. In order to improve fire retardant performance, the nanopaper was coated onto the surface of the composites. The morphology, thermal stability, flammability, and post-fire flexural modulus of the composites coated with the nanopaper were studied. The fire retardant mechanism of the nanopaper coating was also studied.

Upon successfully improving the fire retardant performance of the nanopaper coating, a thermal degradation model that captured the decomposition reaction of the polymer matrix with second kind boundary condition (applying constant heat flux) was solved using finite element method (FEM). The weak form of the model was constructed by weighted residual method. The model quantified the thermal and post-fire flexural responses of the composites subject to continuously applied heat flux. A temperature dependent post-fire residual modulus was assigned to each element in the FEM domain. The bulk residual modulus was computed by assembling the modulus of each element. Based on the FEM model, a refined finite difference (FD) model was developed to predict the fire response of the composites coated with the nanopaper. The FD model adopted the same post-fire mechanical evaluation method. However, unlike the FE model, the flow of the decomposed gas, and permeability and porosity of the composites were taken into account in the refined FD model. The numerical analysis indicated that the thickness and porosity of the composites had profound impact on the thermal response of the composites. The funding support from Office of Naval Research (ONR) and Federal Aviation Administration Center of Excellence for Commercial Space Transportation (FAA COE AST) is acknowledged.

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Approved for distribution by Jihua Gou, Committee Chair, on February 28, 2012.

The public is welcome to attend.