Thermo-Mechanical Analysis of Composite Material Exposed to Fire

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Abstract

Polymer matrix composites have long been plagued by the problem of high flammability and poor fire resistance. This problem is a major concern when composite materials are used in applications where fire can occur, such as aircraft cabins, ships and rail carriages. Many types of polymer composites are highly flammable and pose a serious fire hazard due to the released heat, smoke and toxic fumes when they burn [1]. Furthermore, thermal softening and pyrolysis of the matrix and softening of the fiber reinforcement causes composites to distort, weaken and eventually fail when supporting an external load. A large amount of research has been performed to characterize the fire properties and reduce the flammability of composite materials, although less is known about the structural behavior of composites in fire. Several studies have examined the effect of high temperature or fire on the load-bearing properties of polymer laminates and sandwich composites. This paper presents thermo-mechanical models for predicting the strength of polymer laminates loaded in tension or compression and exposed to one-sided radiant heating by fire. The models predict the temperature rise and through-thickness temperature profile in a hot decomposing laminate exposed to fire. The models assume that one side of a laminate beam is evenly heated at a constant radiant heat flux, as shown schematically in Figure 1 [2]. Calculation of the fire resistance demands apposite determination of temperature distribution in the cross-section (heat-exposure model) and analysis of mechanical responses of the structure exposed to increased temperature (structural-response model). Space division of temperatures, which rises in probable fire, could be expressed through computational fluid dynamics (CFD) model of fire-driven fluid flow or FDS (Fire Dynamics Simulator) [3,4]. The Temperature field of the laminate was calculated by COMSOL's Heat Transfer Module. The surface recession rate is specified with a moving mesh boundary condition enabled through the "Moving Mesh" interface of the COMSOL Multiphysics software. The program has a pre-packaged feature described as the Arbitrary Lagrangian-Eulerian (ALE) method. It permits moving boundaries without the need for the mesh movement to follow the material.

Reference

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3. McGRATTAN, K. Fire Dynamics Simulator (Version 5) - Technical Reference Guide. NIST Special Publication 1018, NIST, (2010).
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Figures used in the abstract

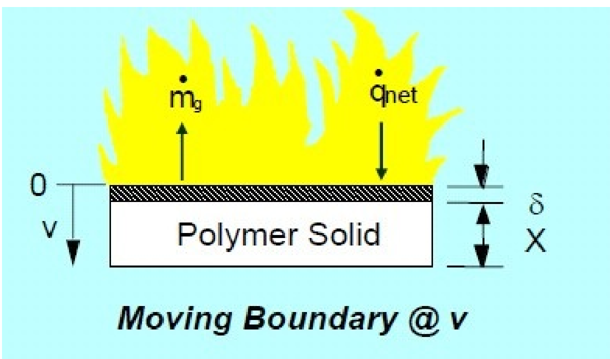

Figure 1: Schematics of composite burning process.