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A Study of Thermal Damage of a Variety of Composite Materials Resulting in Wide Spread Delamination as a Function of Applied Thermal Load

R. Bocchieri[1], D. Dierdorf[1], K. Cozart[1], S. Wells[1], J. Hawk[2]

[1]Applied Research Associates, Inc., Albuquerque, New Mexico, USA
[2]Air Force Research Laboratory, Tyndall AFB, Tyndall, Florida, USA

Abstract

In this study, we have examined thermal damage to a series of aerospace composite materials exposed to controlled radiant fluxes over periods ranging from seconds to minutes. Three major classes of matrix resins were evaluated for comparison purposes. Three IM7 carbon fiber composites were evaluated, with epoxy 977-3, modified bismaleimide (BMI) RM3002 and condensation polyimide AFR-PE-4.

Composite plates with quasi-isotropic layup were exposed to controlled radiant heat fluxes on one face for specified time periods. Plates were thermally insulated on the back side and around the edges, to minimize edge damage. Thermal exposure was mild and the primary source of heating was radiant heating. Thermocouples were placed throughout the thickness during manufacture. After exposure, the plates were machined into 4-point bend and tensile samples and mechanically tested. Mechanical degradation in terms of reductions in tensile and flexural modulus and strength were documented as a function of exposure level. Microscopy of the machined sections was performed to document the observed damage.

In all materials and heat flux magnitudes tested, it was found that the composite plates experienced sudden and catastrophic damage, prior to any significant charring or mass loss, in the form of delaminations, sometimes throughout the entire thickness. Delaminated samples displayed little residual mechanical strength in flexure (up to 85% strength loss) and greatly reduced tensile strength (up to 40% strength loss). Samples exposed to similar heat flux and durations, but removed from heat prior to delamination, showed little reduction in mechanical strength. The time at which delamination occurred was indicated by thermocouple data and global buckling of the plate. The delamination time was affected by the water moisture content of the plate, with delamination occurring at shorter exposure times for plates with higher moisture content. High pressure gases in the plate from water vapor and resin outgassing are postulated to cause this delamination.