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Impact of Joule Heating on the Electrical Conduction Behavior of Carbon Composite Laminates under Simulated Lightning Strike

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Abstract : Increasing demands for high strength and lightweight materials in aircraft industry prompted the wide use of carbon composites in recent decades. Carbon composite laminates used on aircraft structures are subject to lightning strikes. Unlike its metal/alloy counterparts, carbon fiber reinforced composites demonstrate smaller electrical conductivity, yielding more severe damages due to Joule heating. The anisotropic nature of composite laminates makes the electrical and thermal conduction within carbon composite laminates even more complicated. Good understanding of the electrical conduction behavior of carbon composites is the key to effective lightning protection design. The goal of this study is to numerically and experimentally investigate the impact of ultra-high temperature induced by simulated lightning strike on the electrical conduction of carbon composites. A lightning simulator is designed to apply standard lightning current waveform to composite laminates. Multiple carbon composite laminates made from IM7 and AS4 carbon fiber are tested and the transient resistance data is recorded. A microstructure based resistor network model is developed to describe the electrical and thermal conduction behavior, with consideration of temperature dependent material properties. Material degradations such as thermal and electrical breakdown are also modeled to include the effect of high current and high temperature induced by lightning strikes. Good match between the simulation results and experimental data indicates that the developed model captures the major conduction mechanisms. A parametric study is then conducted using the validated model to investigate the effect of system parameters such as fiber volume fraction, inter-ply interface quality, and lightning current waveforms.

Keywords : carbon composite, joule heating, lightning strike, resistor network
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