Evaluation of Electromagnetic Heating of a Composite Material Using COMSOL Multiphysics® Software

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Abstract

Carbon fiber as filaments or as continuously reinforced composite finds application in the electronic packages, electric vehicles, and electrical machines, owing to its excellent electromagnetic (EMI) shielding and high conductivity. Carbon fiber being good conductor of electricity (in the order of 105 S/m), and the binding resin is insulating material (10-13 S/m), the response is non-linear and it is complex in electromagnetic operating environment.

This paper explains predicting the response of the CFRP structural plate to the electromagnetic condition using the multiphysics simulation. The AC/DC Module of COMSOL Multiphysics® software is used to model the electromagnetic response. The model consists of a multi-turn coil made of copper placed on top of the single strand fibers/woven mat and the carbon fiber reinforced plastic (CFRP) plate with an air gap of 12.5 mm. The model is input with 10 numbers of coil turns and an alternating coil current of 1000A. The magnetic field intensity created by the coil is evaluated first; beginning with the magnetic vector potential. A multi-turn coil domain is used to model the n-turn coil, and flux generated is solved using a quasi-static approach for zero velocity and ignoring the displacement current. Electro-magnetic field induced heat generation and subsequent heat transfer in the CFRP structure is evaluated by the heat transfer interface using the first law of thermodynamics, combined with Fourier's law which governs the heat transfer. The effect of fiber orientation/alignment (unidirectional and woven mat) and fiber content in the CFRP plate on the resistive loss, induced current density, and the electromagnetic heating is quantified. The induced current density for carbon based carbon based material is significantly different from that of the steel, due to anisotropic characteristics of the former. A significant difference in the volumetric resistive loss and electromagnetic heating pattern was observed between the steel and the CFRP. Among carbon fiber types, the unidirectional, woven mat and CFRP lamina have differences in the current density, temperature raise due to electromagnetic induction, which is attributed to the directional properties of the fibers. The results lend credence that the CFRP material properties can be fine tuned to meet the electromagnetic and structural requirements of the critical electronic and electrical application and be a potential alternate for the conventional metallic counterparts. Application builder capabilities of the COMSOL® software provided additional advantages to all the stake holders to understand the simulation with different input parameters.

Figures used in the abstract

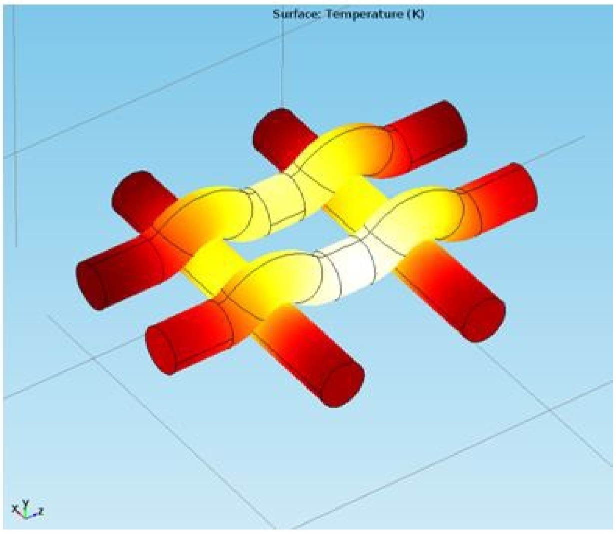

Figure 1: Electromagnetic heating in the bidirectional carbon fibers.

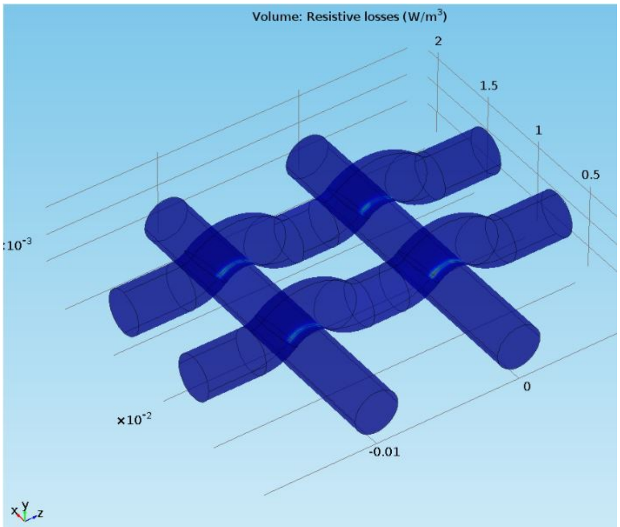

Figure 2: Resistive losses at the intersection of thebidirectionalcarbon fibers.