High Current and Multiphysics Modeling of Carbon Fiber Reinforced Polymers (CFRP) plates and Joints under Lightning Strike Conditions

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INTRODUCTION: Coupled thermal and electrical behavior of joints formed by two carbon-fiber reinforced polymers (CFRP) panels, but separated by intentional dielectric barriers such as adhesive is modeled to demonstrate the physics impacting high current conduction across the joints under lightning strike condition.

MULTI-PHYSICS MODEL:

The time-varying joule heating source couples the electrical and thermal problem. The carbon-fiber composite materials have fully anisotropic, inhomogeneous, time and temperature dependent electrical and thermal conductivity. Model ignores the structural damage and magnetic effects.

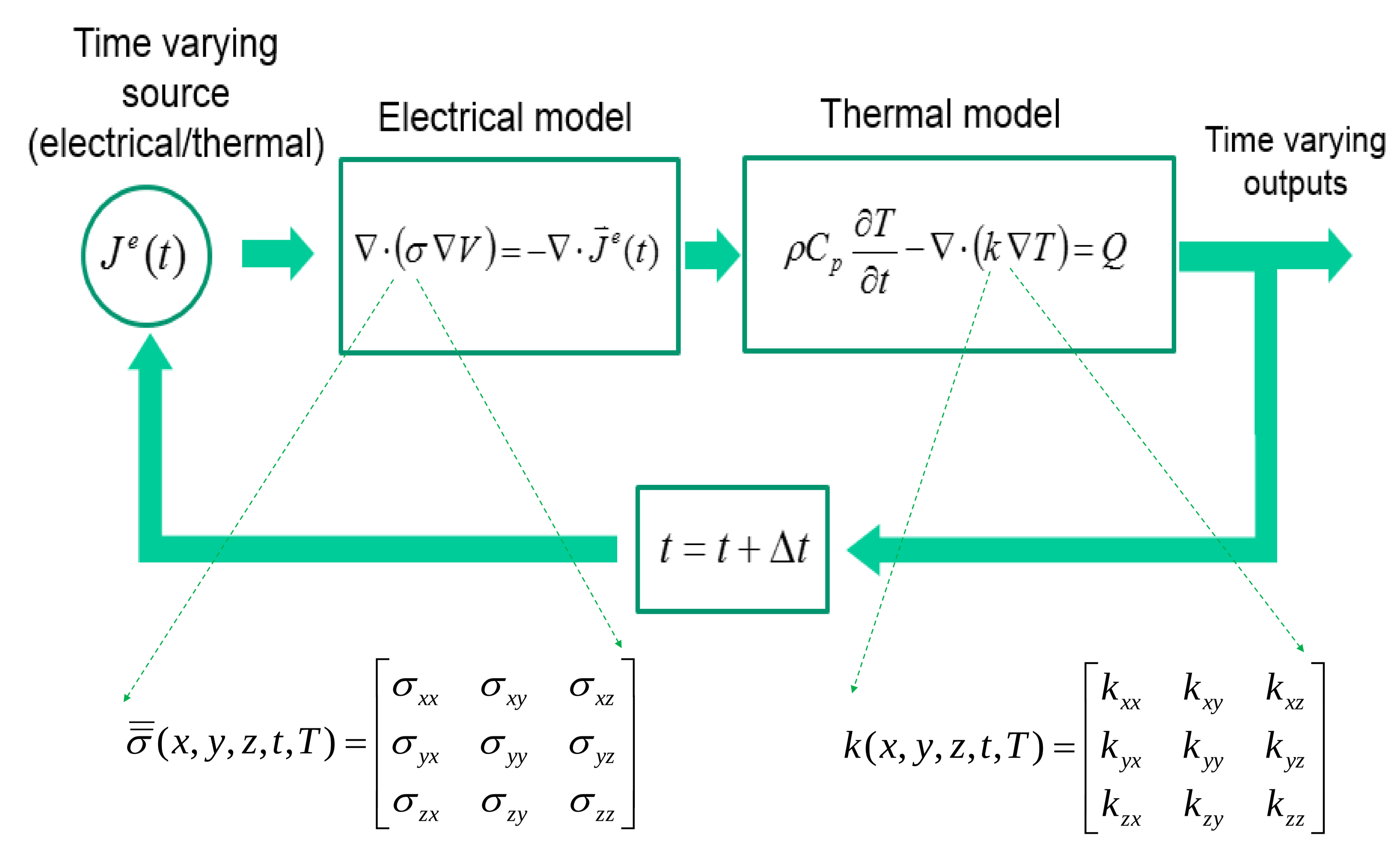
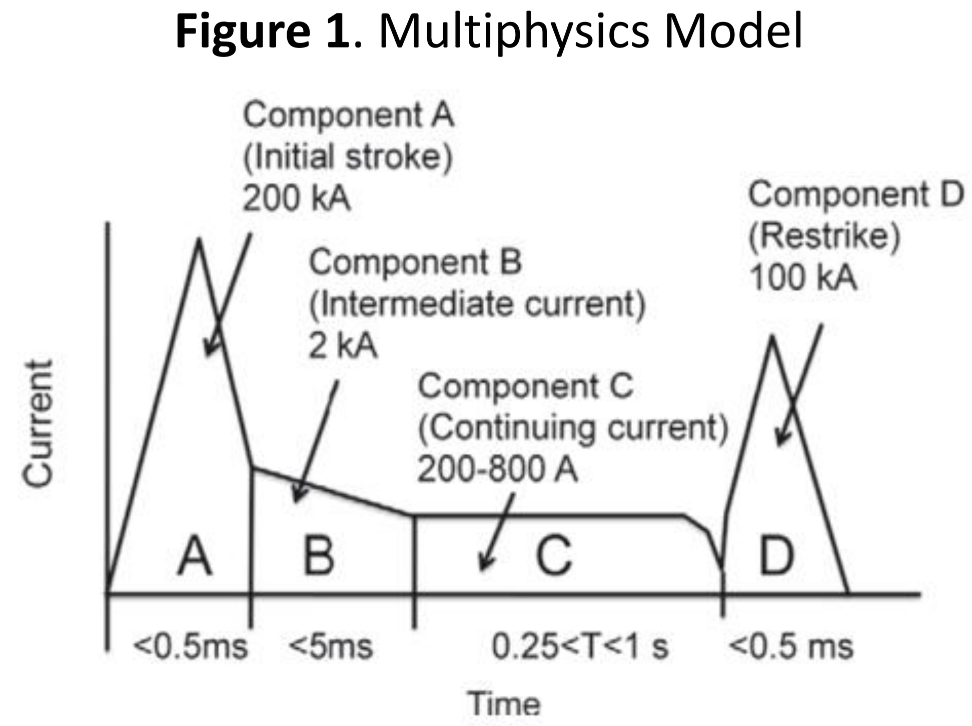


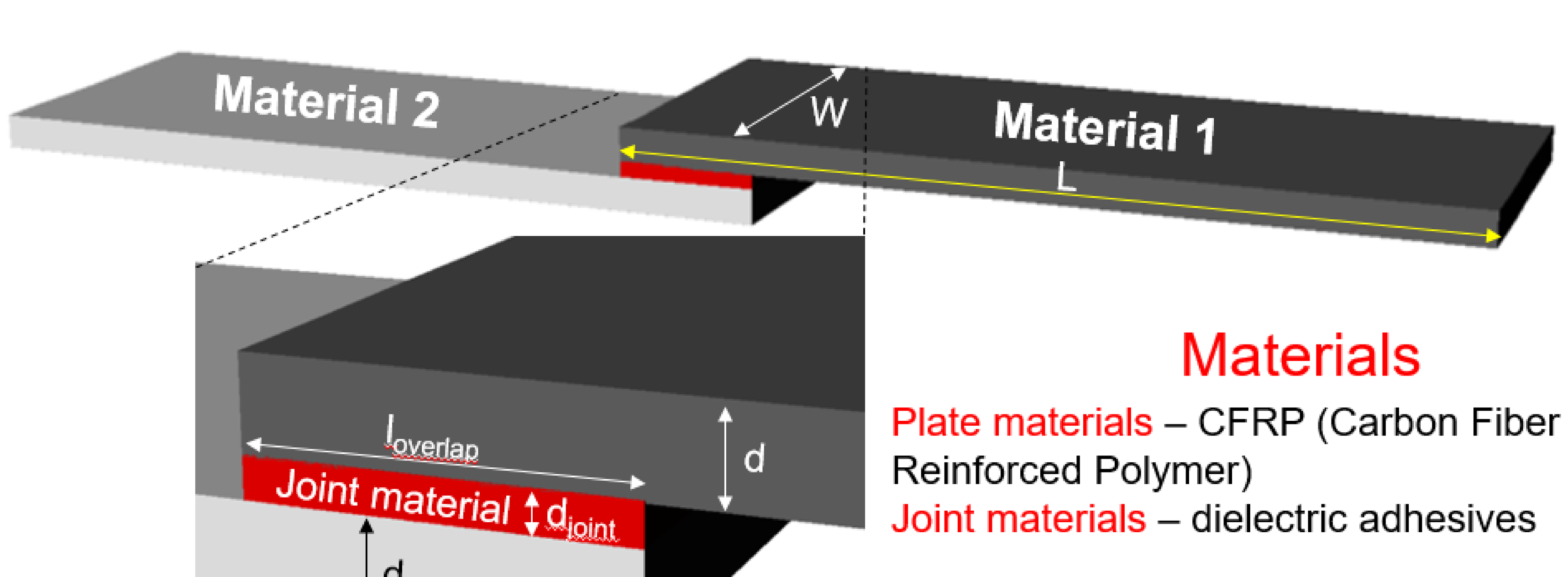
Figure 1. Multiphysics Model



$$I(t) = 43762.0\left(e^{-22708\,t} - e^{-1294530\,t}\right)$$

Figure 2. Lightning strike waveform

FINITE ELEMENT MODEL SETUP: The multiphysics modeling of joints formed by two carbon-fiber reinforced polymer (CFRP) plates, but separated by intentional dielectric barriers was modeled using COMSOL solver. The joints can be formed in any direction of the carbon fiber composite panel.



W (mm)	L (mm)	d (mm)	d_{joint} (mm)	$l_{overlap}$ (mm)
75	150	4	0.5	50

Figure 3. Joint configuration

JOINT STUDY:

Case I: Voltage sources at the edges

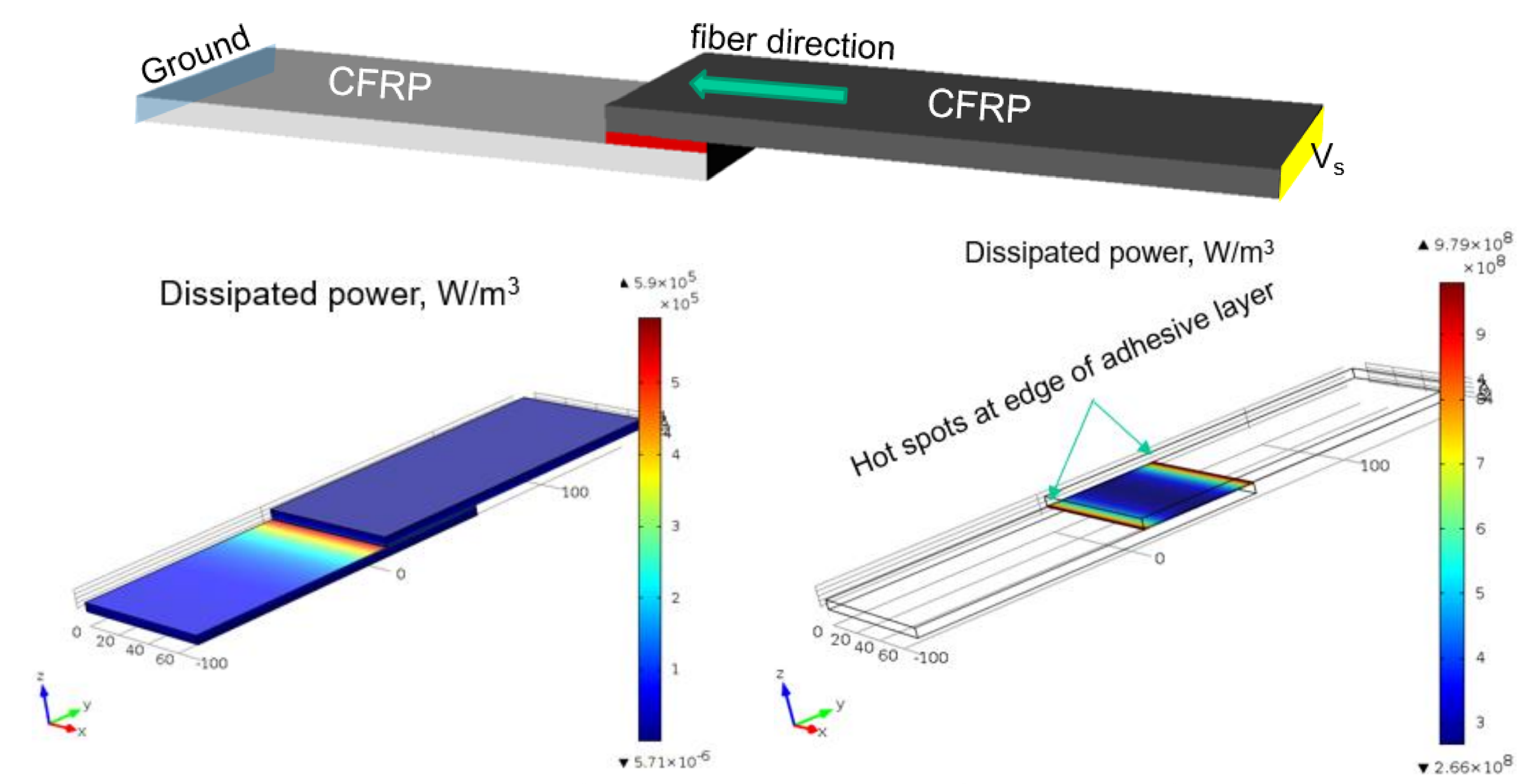


Figure 4. Power dissipation across the joint edges

Case II: time-varying current source via cylindrical hole

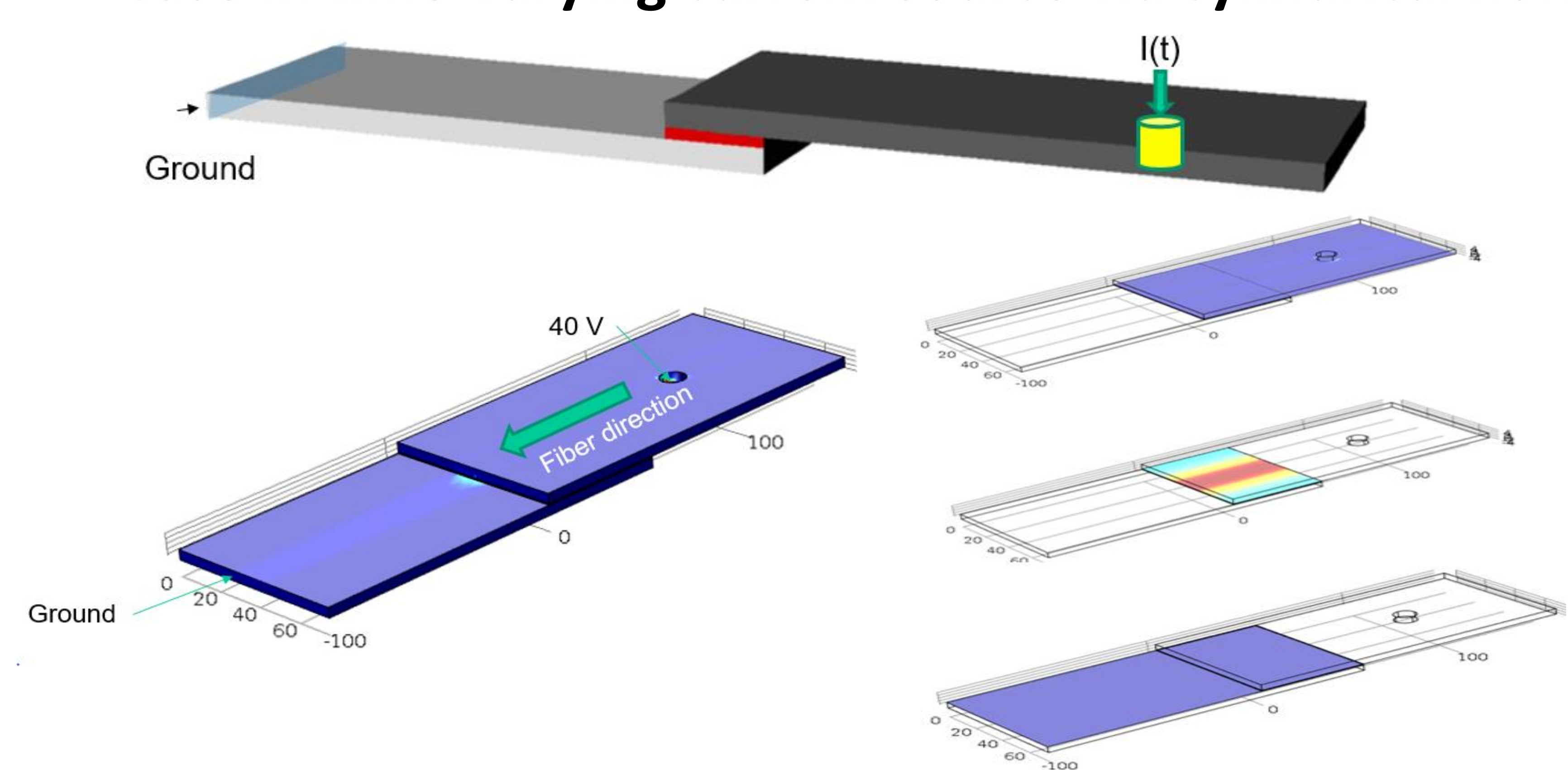


Figure 5. Power dissipation across the joint with through hole source

Case III: Carbon-fiber Joint with metallic fastener

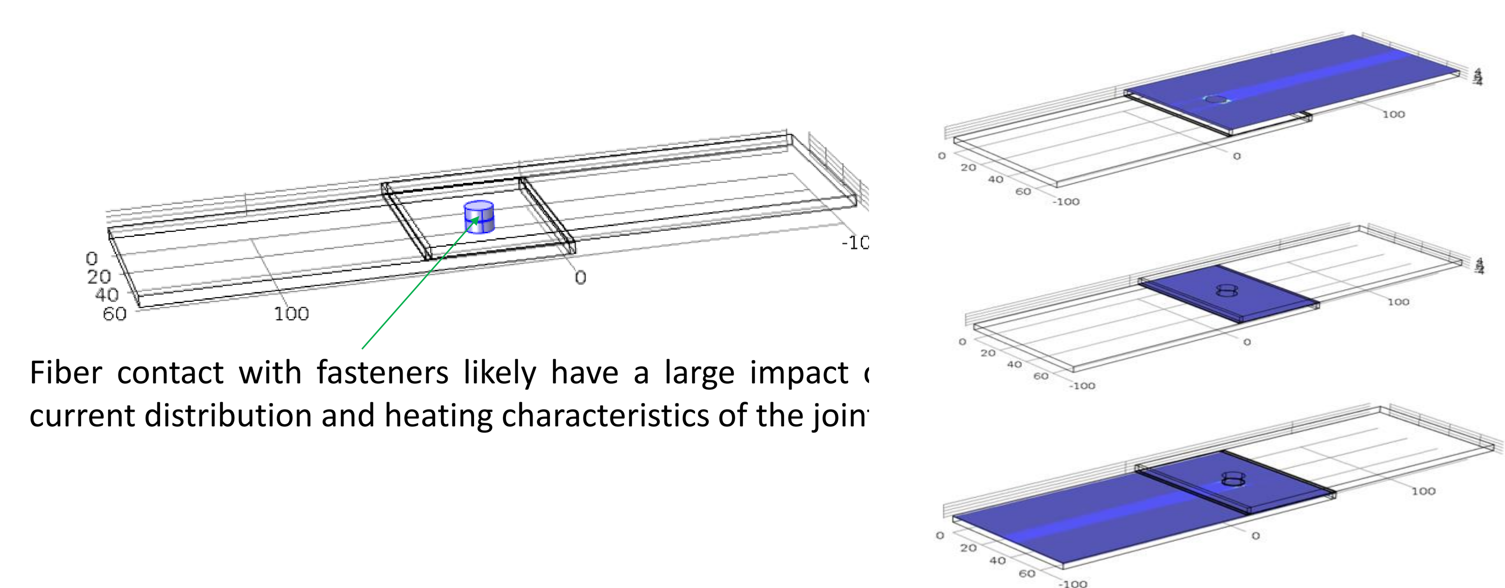


Figure 6. Power dissipation across the joint with metallic fastener

Case IV: Carbon-fiber joint with metallic fastener and edge conductor

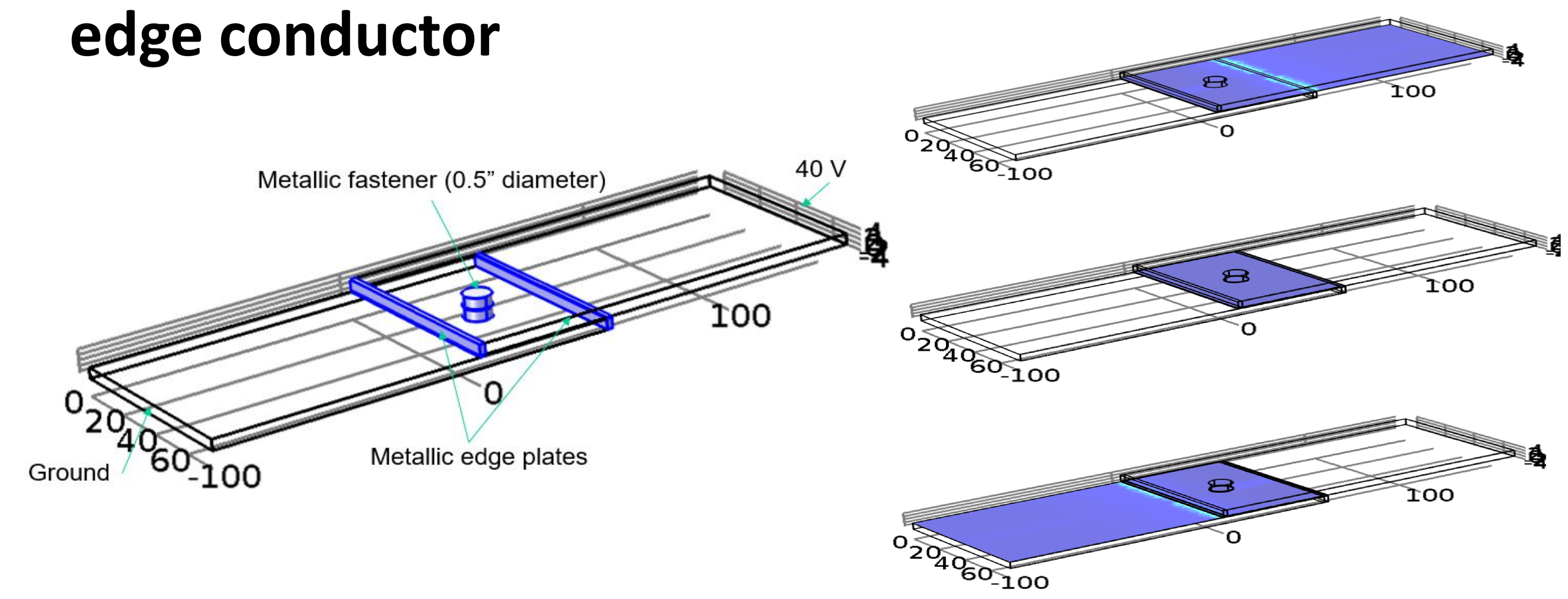


Figure 7. Power dissipation with metallic fastener and edge conductor

CONCLUSIONS: A finite element based thermal-electrical multi-physics modeling of carbon-fiber joints is demonstrated to show the current distribution and heat dissipation across the joints for different configurations. The model was evaluated under lightning strike conditions to predict the non linear effects impacting current transfer across the joints.

REFERENCES:

1. G. Abdelal, A. Murphy, “Nonlinear numerical modelling of lightning strike effect on composite panels with temperature dependent material properties,” Composite Structures 109(2014) 268-278.
2. T. Ogasawara, Y. Hirano, A. Yoshimura, “Coupled thermal-electrical analysis for carbon fiber/epoxy composites exposed to simulated lightning current,” composites: Part A41 (2010) 973-981.