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Magnetic Field Diffusion Phenomena in Practical Shielding Applications

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Two-dimensional as well as 3-D electromagnetic calculations of transient magnetic field diffusion are compared to experimental results providing unique insight into the impact of pertinent parameters on the diffusion process. For simulation, the finite element method (FEM) is employed while a pulsed high magnetic field testbed operating at a peak current of 40 kA is utilized to generate experimental magnetic field diffusion data. The complexity of the diffusion of the transient magnetic field through the walls of conductive shielding structures is elucidated in detail. Most relevant is the diffusion condition where conductor thickness is on the order of one skin depth, a situation typical to many pulsed power systems.

Any conductive structure subject to a time-varying magnetic field gives rise to an eddy current distribution in the conductor that opposes the incident field. This current distribution decays with a characteristic time constant, similar to that of a loop with inductance L and resistance R, resulting in a finite delay and attenuation of the diffused field. For practical geometries subject to highly divergent external magnetic fields, these complex induced current distributions are at best difficult to predict analytically and shielding performance even more so.

Clearly, the magnitude and direction of the diffused field are highly dependent on a variety of geometrical and material parameters, including wall thickness, conductivity, permeability, and excitation frequency. Further, conductive loading of a shielding structure's internal volume will result in significant degradation of the shielding performance due to compression of the internal field. For instance, simulation of a cylindrical shielding geometry with a wall thickness of approximately one skin depth yielded a factor of five increase in the diffused field magnitude when the internal non-conductive volume is reduced by ninety percent. The introduction of imperfections, such as slots and holes, within the structure walls, is also considered.

Author: COLLIER, Landon (Texas Tech University)

Co-authors: BUNTIN, Tyler (Texas Tech University); DICKENS, James (Texas Tech University); MANKOWSKI, John (Texas Tech University); JAMES, Colt (Raytheon Company); NEUBER, Andreas (Texas Tech University)

Presenter: COLLIER, Landon (Texas Tech University)

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