Pulsed Eddy Current Probe Development to Detect Inner Layer Cracks Near Ferrous Fasteners Using COMSOL Modeling Software

Vijay Babbar[1], Paul Whalen[1], Thomas Krause[1]

[1]Department of Physics, Royal Military College of Canada, Kingston, ON, Canada

Abstract

Surface breaking cracks in conductive structures can be detected by conventional eddy current techniques. However, it is very difficult to detect inner layer defects in multilayered conductive structures either by conventional eddy current or ultrasonic methods. The transient/pulsed eddy current (PEC) technology can potentially overcome these limitations and is being developed for detection of deeper defects in multilayered aluminum structures [1-2]. An earlier work [3] successfully employed COMSOL Multiphysics, the finite element (FE) modeling software, to develop and optimize a reflection type probe where the driving and pickup coils were coupled coaxially. The probe could detect defects underneath a 3.6 mm thick aluminum plate and there was good agreement with experiment. However, it was not very effective in detecting inner layer cracks that originated at a ferrous fastener, as typically found in airplane wing structures. This necessitated the development of a different probe design. The present work describes the new probe design, which consists of two pickup coils, connected in differential mode, on either side of the central driver, as shown in Figure 1. The work involves modeling of a PEC probe and its optimization by varying geometry and other circuit parameters of the driver-pickup coil combination. The modeled differential pickup signal for a crack of length 9.0 mm, width 0.25 mm, and four different crack depths are shown in Figure 2. It reveals that, although the signal decreases with increase in crack depth, the probe can potentially detect a crack at a depth of 4.0 mm below an aluminum plate. In summary, the COMSOL software proved to be useful in presenting a visualization of diffusion of magnetic flux through the ferrous fastener and its interaction with the surrounding defect region, which led to development of an optimum probe design including appropriate location of the sensing coils in the probe.

Reference

1. M. Gibbs and J. Campbess, “Pulsed Eddy Current Inspection of Cracks under Installed Fasteners,” Mater. Eval., 49, pp. 51-59 (1991).
2. Y. A. Plotnikov, et. al., “Defect Characterization in Multilayered Conductive Components with Pulsed Eddy Current,” in Review of Progress in QNDE, 21, edited by D. O. Thompson and D. E. Chimenti, AIP Conference Proceedings vol. 615, American Institute of Physics, Melville, NY, 2002, pp. 1976-1983.
3. Vijay Babbar and Thomas Krause, “Finite Element Modeling of Transient Eddy Currents in Multilayer Aluminum Structures,” in Proceedings of the COMSOL Conference, Boston, MA (2009).

Figures used in the abstract

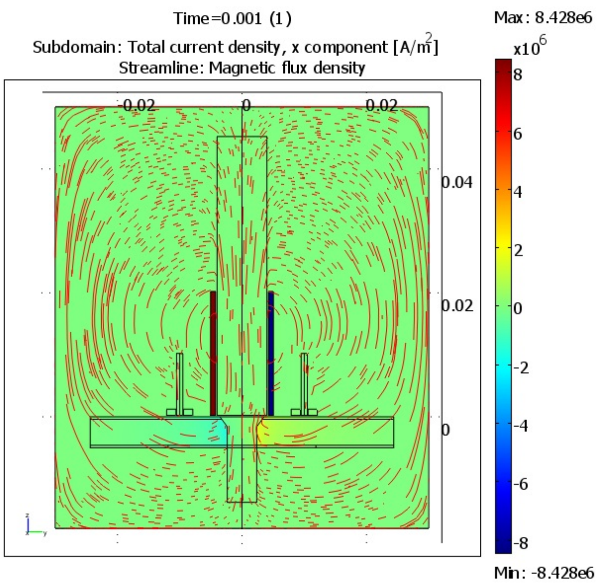

Figure 1: Finite element model of the differential probe showing surface current density (Jx) and magnetic flux density.

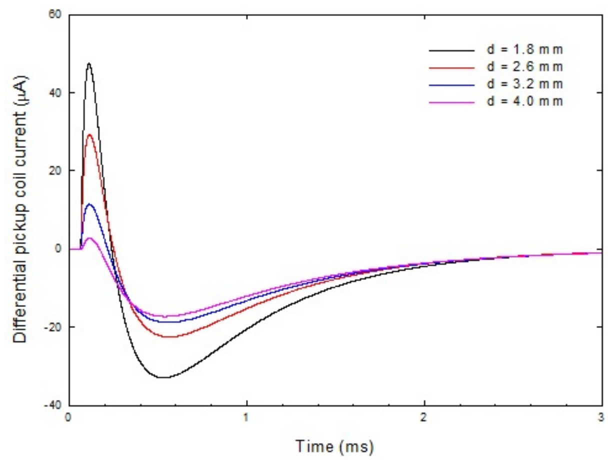

Figure 2: Variation of differential pick up current with time for different crack depths.