Maximizing the Fatigue Crack Response in Surface Eddy Current Inspections of Aircraft Structures

C. Mandache[1], T. Theodoulidis[2]

[1]National Research Council Canada, Ottawa, ON, Canada
[2]University of Western Macedonia, Kozani, Western Macedonia, Greece

Abstract

Abstract
In-service detection of fatigue cracking in metallic aerospace structures relies on capable and efficient eddy current inspection procedures. For best results, inspections with surface scanning eddy current techniques are following rigorous procedures that indicate the instrument settings, probe type and configuration. Parametric numerical simulations are representing great tools for optimizing these types of inspections, can considerably decrease the resources dedicated to procedure development and enhance the visual interpretation of the scans. In this study, the crack length with respect to the coil diameter, the crack orientation along the scanning direction, as well as the crack depth are investigated in order to observe the optimal eddy current inspection arrangement. Through limited empirical investigations, agreement between experimental findings and COMSOL Multiphysics® software simulations is sought.

Background
The problem analyzed represents a case frequently encountered in surface scanning eddy current nondestructive testing for fatigue cracks. Since in the vast majority of cases, the inspections are performed on airframes, the fatigue cracks are starting from the fastener holes, due to local stress concentrations or inhomogeneities in the structure, as due to the riveting or hole drilling processes. In this work, only the crack (in the absence of the hole) interaction with an absolute eddy current coil is discussed. This provides a better understanding of the underlying physics, help with the coil/probe design, and provide insight for data interpretation.

Problem Setup
The simulations are performed in COMSOL® software, employing the AC/DC Module and a Frequency-Domain study. An absolute coil is driven by a harmonic current and it is moved above a defect (i.e. crack) present in a conductive test piece, such as a thin aluminum plate [1]. Changes in the coil inductance and resistance are indicative of the defect presence [2]. The model looks at the crack orientation with respect to the coil scanning direction (90o, 45o, and 0o), the crack length with respect to the coil diameter, as well as the crack height with respect to the conductive plate thickness. For demonstration purposes, Figure 1 shows the crack-containing plate, with the coil moving longitudinally to the crack, and with the crack length larger than the coil outer diameter.

Partial Results
The inductance of the coil is sensitive to the number of magnetic flux lines intersecting the coil area, and it is one of the parameters normally used in eddy current nondestructive testing for data interpretation. In Figure 2, the coil's inductance is plotted against the scanning position (posx) as the coil is scanning along the crack length. As seen, the peak values are located close to the crack edges, but not exactly at the same positions, since the crack extends from x=15 mm to x=25 mm. In the same plot, it is noted that the inductance increases as the coil gets closer to the edge of the plate, a phenomenon known in the trade as "edge effect".

Figure 3 shows the eddy current distribution around the crack for three different positions of the coil, as centered on the crack edge (a), symmetrical on the center of the crack (c), and at an intermediate position, at 1.25 mm away from the crack edge.

Conclusion
Laboratory-based empirical data collection is currently underway. Potential agreement between the empirical data and COMSOL simulations is believed to help in eddy current testing optimization for detection of cracking in thin conductive parts, as is the case in the inspection of airframes, but also in many other metallic components used in different industries.

Reference

1. COMSOL Multiphysics model, “Multi-turn coil above an asymmetric conductor”, https://www.comsol.com/model/multi-turn-coil-above-an-asymmetric-conductor-plate-13777

2. J. Martinos, T.Theodoulidis, N. Poulakis, and A. Tamburrino, “A benchmark problem for eddy current nondestructive evaluation”, IEEE Transactions on Magnetics, Vol. 50, No. 2, 2014.

Figures used in the abstract

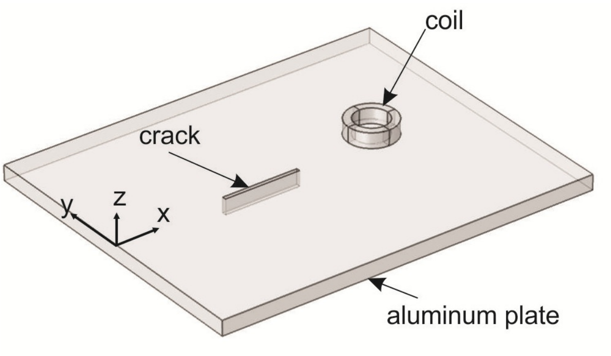

Figure 1: Schematic representation of one of the testing arrangements.

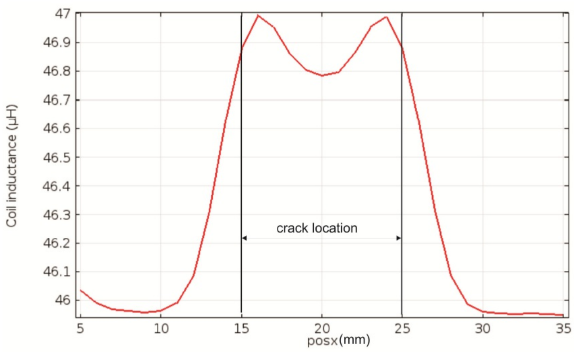

Figure 2: Changes in the coil inductance as it is moved along the crack length (coordinates corresponding to the ones indicated Figure 1).

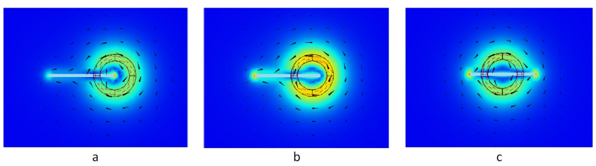

Figure 3: The coil-crack electromagnetic interaction when: (a) the coil is centered on the edge of the crack, (b) coil is centered at an intermediate position along crack, and (c) the coil is symmetrically positioned above the crack.