EXPERIMENTAL MEASUREMENTS OF THE EDDY CURRENT SIGNAL DUE TO A FLAWED, CONDUCTING HALF SPACE

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INTRODUCTION

The eddy current method of nondestructive evaluation involves the induction of eddy currents in a conductive test object by a time-varying field produced by a suitable distribution of impressed currents and the detection of the resultant field. The method is ordinarily used at frequencies sufficiently low to neglect effects due to displacement current; hence a theoretical analysis entails calculating the self-impedance of the coil in the presence of the test object. In practice, one often needs only the change in impedance produced by the test object or by changes in the nominal properties of the test object (e.g., changes in its geometry or position with respect to the test coil or coils, or distributed or localized changes in the resistivity of the test object).

One of the more useful geometrical configurations is that of an eddy current coil located above and parallel to a conducting plane (see figure 1). This problem has been addressed theoretically by Cheng(1) and by Dodd and Deeds(2) in which numerical solutions were found. Later Zaman, Long, and Gardner(3) produced an analytical solution, valid over a restricted range of parameters, for the same coil and test sample geometry.

In this paper an experimental investigation is reported in which the change in impedance of a practical multi-turn eddy current coil near a conducting half space has been measured as a function of the conductivity and the lift-off distance. These results are then compared in a qualitative fashion with the previously mentioned analytical results for a single-turn coil(3). Measurements were also

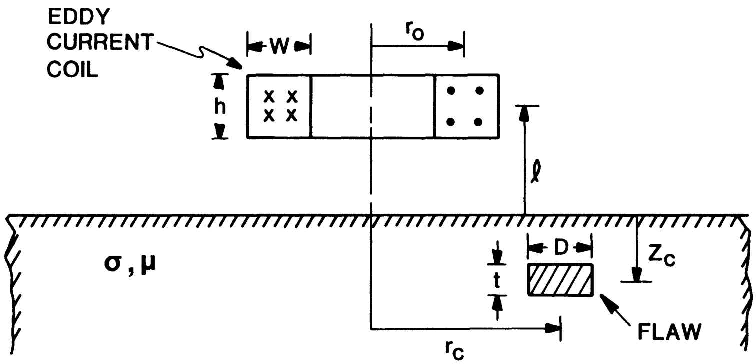

Figure 1 Eddy-current coil and test sample geometry.

made of the change in impedance due to a small void in the conducting half space as a function of both its depth and radial position. These results are then compared with the analytical solution for a single-turn coil near a flaw in the conductor found by Zaman, Gardner, and Long(4).

EXPERIMENTAL MEASUREMENTS

Both the magnitude and phase of the impedance of a multi-turn coil were measured at an operating frequency of 1.0 KHz for various lift-off distances for two different conducting planes (aluminum and brass). Afterward an artificial void was introduced into the conducting half space and the resulting change in impedance measured as a function of depth and radial location of the flaw relative to the position of the coil. A shallow hole was drilled in the plane and then covered with plates of different thicknesses to simulate changing depths of the flaw. Since the induced eddy currents are all parallel to the interface formed by the two sheets, any perturbations in the currents, and therefore in the resulting changes in impedance, should be minor.

The eddy current coil had a mean radius of $r_0 = 1.136$ cm, a width w = 0.635 cm, height h = 0.635 cm, and was made with 2520 turns of AWG #38 wire (diameter = 0.003965"). The lift-off distance could be varied between $0.5 \text{ cm} < \ell < 2.0 \text{ cm}$ above the conductor and the depth of the flaw could be adjusted between $.0965 \text{ cm} < z_c < 0.5 \text{ cm}$. The void tested was cylindrical in shape with a diameter of D = 0.71 cm and a height of t = 0.193 cm.

RESULTS

During the first phase of the experimental investigation, the change in the complex impedance of the coil was measured as a function of the lift-off distance ℓ. The imaginary portion of this change is proportional to the change in inductance ΔL, and that quantity is shown in figure 2 for a coil located above ground planes made of aluminum, brass and iron. The main emphasis of the work was concerned with aluminum so the previously derived analytical expression for the change in inductance was also calculated for this case. Since that theory only applies to a single-turn coil the theoretical curve was arbitrarily normalized to the experimental data at the point $\ell = 1.0$ cm. Quite good agreement is found over the range of lift-off distances considered. Similar measurements were also made

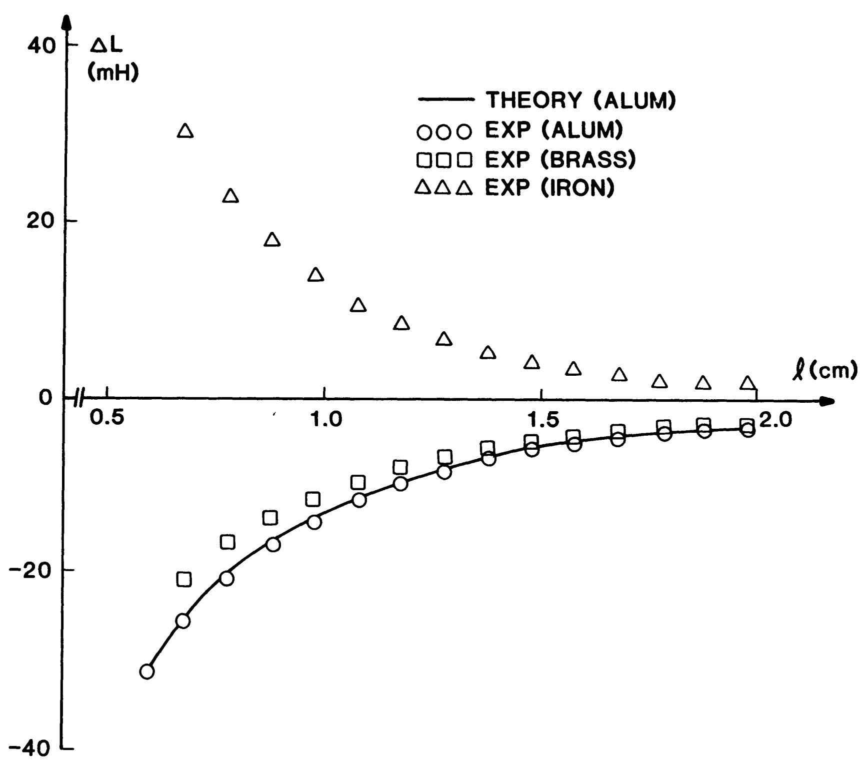

Figure 2 Change in inductance versus lift-off distance.

for the real portion of the changes in complex impedance (ΔR) and are shown in figure 3. Once again the theoretical curve is shown normalized at ℓ = 1.0 cm with reasonable agreement found.

In a second phase of the investigation the change in the inductance was measured as the coil was moved parallel to the aluminum plane at a constant lift-off distance in the vicinity of a sub-surface void. A representative set of experimental data is shown in figure 4 for the case of the centroid of the void located at a depth z_c = 0.145 cm and a constant coil lift-off distance ℓ = 0.58 cm. The previously derived analytical solution [4] normalized at $r_c = r_0$ is also shown for comparison. Quite similar behavior was found. The change in inductance reached a maximum near the point where the windings of the coil are directly over the center of the flaw and approaches zero both as the coil moves away from the void and as the coil is precisely centered over it.

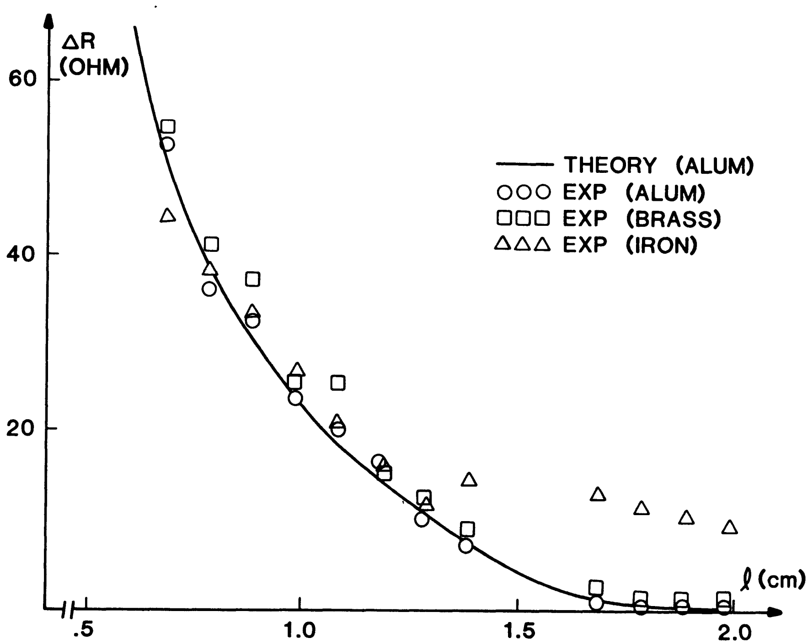

Figure 3 Change in resistance versus lift-off distance.

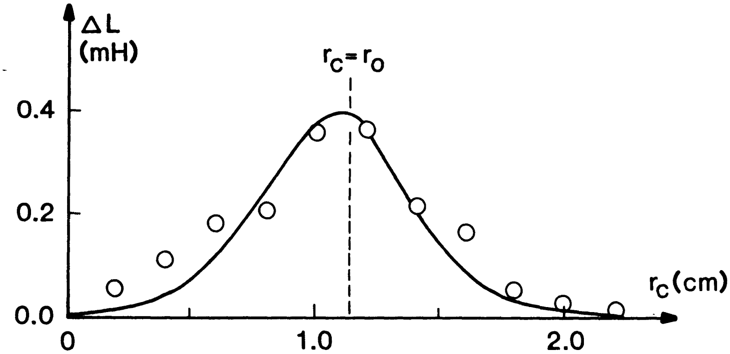

Figure 4 Change in inductance versus radial position of void (z_c = 0.145 cm; ℓ = 0.58 cm).

CONCLUSIONS

The experimental investigation has shown, at least in a qualitative fashion, that the precisely derived analytical solutions adequately predict the general behavior of the change in complex impedance of an eddy current coil above a conducting ground plane as a function of lift-off distance. The effect of a sub-surface void on the change in inductance of the test coil was also measured and seen to correlate well with theoretical calculations.

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