COMPUTER MODELLING OF EDDY CURRENT PROBES

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ABSTRACT

Computer programs have been developed for modelling impedance and transmit-receive eddy current probes in two-dimensional axis-symmetric configurations. These programs, which are based on analytic equations, simulate bobbin probes in infinitely long tubes and surface probes on plates. They calculate probe signals due to uniform variations in conductor thickness, resistivity and permeability. These signals depend on probe design and frequency.

A finite element numerical program has been procured to calculate magnetic permeability in non-linear ferromagnetic materials. Permeability values from these calculations can be incorporated into the above analytic programs to predict signals from eddy current probes with permanent magnets in ferromagnetic tubes.

These programs were used to test various probe designs for new testing applications. Measurements of magnetic permeability in magnetically biased ferromagnetic materials have been performed by superimposing experimental signals, from special laboratory ET probes, on impedance plane diagrams calculated using these programs.

1. Introduction

Eddy current testing (ET) probes are composed of coils of wire as depicted in Figure 1. Time harmonic magnetic fields are generated by AC excitation current driven through a transmit coil. The time harmonic fields interact with metallic conductors by generating electrical eddy currents in the conductors in accordance with Faraday's law of electromagnetic induction. Variations in the magnetic field pattern that may be caused by changes in the conductor geometry, permeability, or conductivity are detected by detector coils, shown in Figure 1. An eddy current impedance probe uses one coil as both transmitter and detector. In this case, the conductor may be characterized by examining the coil's impedance. Transmit-receive probes use separate transmit and detector coils.

Eddy current probe signals are typically presented on a 2-dimensional display, which plots the quadrature component of the detector coil voltage (component which is 90° out of phase with the transmitter coil current) as a function of the in-phase component. Theoretically, these components are treated with complex mathematics, where the in-phase component corresponds to a "real" value and the quadrature component corresponds to an "imaginary" value.

2. Analytic Modelling

Computer programs based on equations developed by Dodd and Deeds[1] are used to simulate impedance and transmit-receive ET probes. These equations are closed form analytic solutions to geometries such as bobbin coils with infinitely long coaxial tubes, shown in Figure 1(a), and surface coils with plates, shown in Figure 1(b). These programs also predict how coil geometry affects probe signals. These programs cannot simulate probe signals from real three-dimensional (3-D) defects. They only model probe response due to uniform wall loss.

An example of the output produced by these programs is shown in Figure 2, which is a plot of the in-phase and quadrature components of an eddy current probe signal. Signals are plotted which correspond to changes in tube wall thickness and magnetic permeability.

Programs based on analytic equations by Burrows[3], when combined with the equations of Dodd et al., can predict eddy current probe response from small spheroidal defects[1,2].

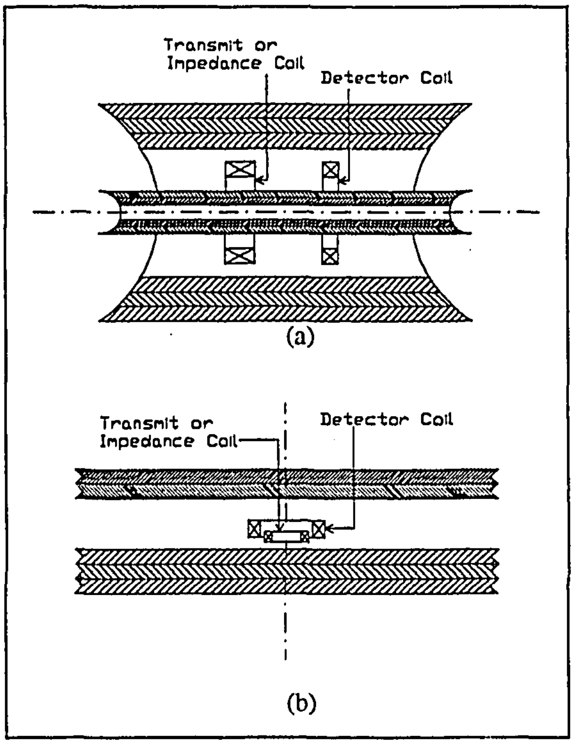

Figure 1: Eddy current probes modelled by analytic equations. (a) Bobbin coils with coaxial tube conductors. (b) Surface coils with plates.

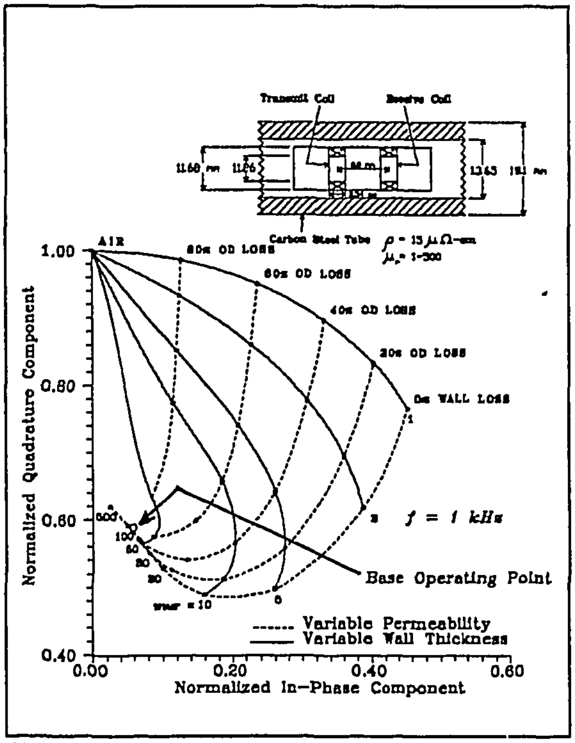

Figure 2: Normalized voltage plane display for a transmit-receive probe in a carbon steel tube with variable permeability and wall thickness.

3. Numerical Finite Element Modelling

A 2-D finite element modelling (FEM) package for IBM PC compatibles was purchased from Infolytica Corp. of Montreal. It has programs for solving nonlinear magnetostatic problems and linear low-frequency time-harmonic electromagnetic problems. So far, these programs have been used for analyzing permanent magnet configurations on magnetic biasing probes used for inspecting ferromagnetic tubes. These probes are composed of eddy current coils and permanent magnets. The field from the permanent magnets alters the permeability of the test material. With a proper permanent magnet configuration, noise from variable permeability in the test material can be significantly reduced and defect signals can be enhanced.

4. References

1. Dodd C.V. and Deeds W.E., "Analytical Solutions to Eddy-Current Probe-Coil Problems", Journal of Applied Physics, Vol.39, No.6, 1968 May, pp. 2829-2838.

2. Dodd C.V., Cheng C.C. and Deeds W.E., "Induction Coils Coaxial with an Arbitrary Number of Cylindrical Conductors", Journal of Applied Physics, Vol.45, No.2, 1974 February, pp. 638-647.

3. Burrows M.L., "A Theory of Eddy Current Flaw Detection", (University Microfilms, Inc., Ann Arbor, Michigan 1964).