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Faults Detection in Metallic Tubes Using Eddy Current

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Abstract**—Faults in metallic materials can be detected by using eddy current testing system. Metallic tube passes through a pair of short solenoid coils energized by an alternating current. The rate of decrease in density of the induced eddy current from the outer surface was determined through the frequency of the energized current, electrical properties and tube design. Also the investigation shows that the distribution of eddy currents flowing circumferentially is given in general terms for non-magnetic tube.**

Keywords—eddy current, metallic tube, solenoid coils, alternating current, non – magnetic tube.

I. INTRODUCTION

Eddy – current testing may be used to detect faults, such as cracks in long metal tubes by passing the tube through a pair of short solenoid coils. The coils, which form part of balanced circuit, are energized by an alternating currents flow in a circumferential direction round the tube wall. The circuit containing the coils is balanced using a uniform tube which is free from faults. An unbalanced – condition arises when a fault appears in one side of the coils and the resulting out of balance voltage can be used to trigger automatic rejecting mechanisms [1].

The signal produced by a given small defect object under test is proportional to the product of the current density that would occur at the position of the defect and the current density that would be induced thereby a current in the sensing coil system [2].The current density below the surface is less than the surface current density so that some means is generally chosen to enhance the signals from defects below the face [2].

Eddy current testing offers several features that so welded tube may find to their liking-in particular, high through speeds and sensitive flaw detection [8].

Other advantages are, determining corrosion rate, environment condition, such as water treatment, steam and inhibitor condition it can be detect inner and outer surface corrosion and erosion cracks, and mechanical wear at support sheets.

Eddy current inspection is a safe method of testing. With the increased use of new enhanced tubes, it is critical monitor tube condition. In all cases, test data is permanently recorded for future comparison. Results of the examination can be given on the spot, allowing for a quick response, and get back on line [7].

The main thing in this type of testing is the test coil or sensor and there are different types from this test coil like weld seam probes segment test coils and encircling coils,and there is a special use for each type.

In the test object, the primary magnetic field created by the test coil is superimposed on the secondary magnetic field that is produced by the eddy currents to form the resulting field. The resulting field in a tested tube is determined by the following variables:

1. Diameter and wall thickness of the tube.
2. Field strength and frequency of the primary magnetic fields.
3. Electrical conductivity and magnetic permeability of the tube.
4. Material defects (crakes, holes, voids, etc.) and inconsistencies in the tube.
5. Relative motion between the tube and excitation system.

II. MATHEMATICAL MODLING

Consider a tube as shown in fig (1). The figure shows a section through a tube of inner radius (a) and outer radius (b), r is any point on the wall of the tube. It is subjected to a magnetic field h_b which is alternating at an angular frequency (ω).

$h_b = |H_b| \cos(\omega t) + \theta_b = \mathrm{Re}\ H_b e^{j\omega t}$ (1)

Where H_b is a complex number representing h_b in magnitude and phase (Re means real part). An alternating field of this kind would be produced by an infinitely long solenoid carrying a current i_b and $h_b = ni_b$, where n is the number of turns per meter.

The magnetic field is always in the axial direction and eddy current do not vary along the length of tube. In the inner radius of the tube there will be a magnetic field h_a, which, is smaller than h_b and be alternating at the same frequency but with a different phase.

Similarly within the tube wall there will be a purely axial magnetic field h_r ,wher

$h_r = H_r\cos(\omega t + \theta_r) = \mathrm{Re}_r e^{j\omega t}$ (2)

Using similar notion we can write S_a , S_b and S_r respectively as the current densities on the inner surface, outer surface and at general radius r and all densities will alternate at angular frequency (ω). then

$S_r = S_r\cos(\omega t + \theta_r) = \mathrm{Re}\ S_r e^{j\omega t}$ (3)

Apply Faraday's law of induction to thin ring between r and $(r + \delta_r)$.

The induced emf in this ring is

apply Ampere's law to the small rectangular cross section of length of length ℓ and width Sr

From equations (2) and (3) at high frequency (approximate solution), the eddy current beyond a small depth within surface are negligible and that the effect of curvature is therefore negligible Equation (2) becomes:

$$\frac{dS_r}{dr} = -\frac{j\omega\mu_o\mu_r H_r}{\rho}$$

Sincer r→ ∞ (semi-infinite slab) and from the last equation substituting in equation (3) yield

From last equation, the amplitude of the current is decaying exponentially as goes into the bar, and that the phase is lagging

The equation is accurate at high frequency, but now for low frequency is approximated as follows:

Assuming that the field of the eddy currents is negligible compared with the imposed field that induced them.

$H_r = H_a = H_b$ and the equation (2) becomes

$$S_r = -\left[\frac{A}{P}\right]\left[ber'\left[\frac{r}{P}\right] + jbei'\left[\frac{r}{P}\right]\right] + C\left[ker'\left[\frac{r}{P}\right] + jkei'\left[\frac{r}{P}\right]\right]$$

From last equation

$$\frac{S_r}{S_a} = \frac{\left[ber'\left[\frac{r}{P}\right] + jbei'\left[\frac{r}{P}\right]\right] + C\left[ker'\left[\frac{r}{P}\right] + jkei'\left[\frac{r}{P}\right]\right]}{\left[ber'\left[\frac{a}{P}\right] + jbei'\left[\frac{a}{P}\right]\right] + C\left[ker'\left[\frac{r}{P}\right] + jkei'\left[\frac{r}{P}\right]\right]}$$

III. RESULT AND DISCUSSION

It has been shown that most of the quantities that are needed foreddy current Testing (ECT) of tubes can be derived quickly from diagrams of plots of current density against radius of the tube. The graphs are shown for different permeabilities and different penetration depth.

And from the curves we can notice that current density and decay exponentially from the outer radius to the inner radius for different permeabilities and that is because of the inner current isless than outer current and that is because of the inductance in the inner is larger than in outer surface, that caused the resistance in radius is larger than in outer radius, therefore the current will pass in an easy way that the outer radius.

IV. CONCLUSION

The eddy current method for testing can be conducted at high throughput speeds without actual physical contact with the material.

High testing speeds help to ensure that testing always keeps up with production. Eddy current tests are reliable even at extreme temperatures. It is a clean method that doesnot contaminate tube products with other media such as oil or water. Eddycurrent testing systems are easily automated and can be readily integrated into existing production processes.

There are many ways to detect faults (cracks and corrosion…) by using (X-ray and Gamma ray), but here Eddy Current Testing is used the heart ofany eddy current test system is the test coil or sensor.

This method of testing is simple and low-cost tube testing, especially when using weld seam probes.

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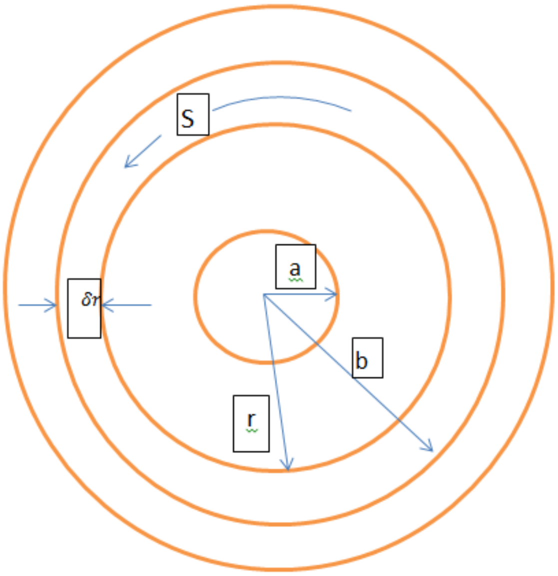

Figure (1)*a tube with inner and outer radius*

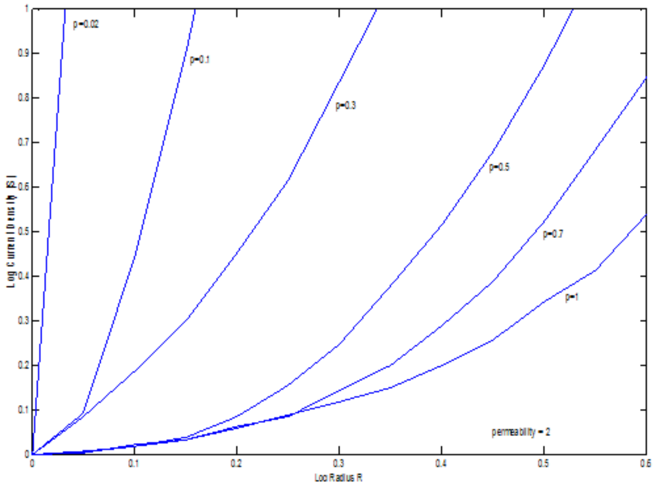

Figure (2) *Current density against radius for tube of a relative permeability of (2) and different penetration depth(p)*

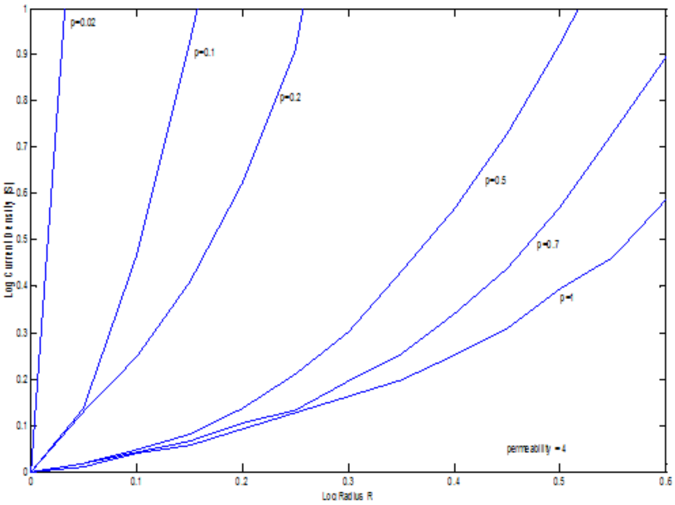

Figure (3) *Current density against radius for tube of a relative permeability of (4) and different penetration depth (p)*

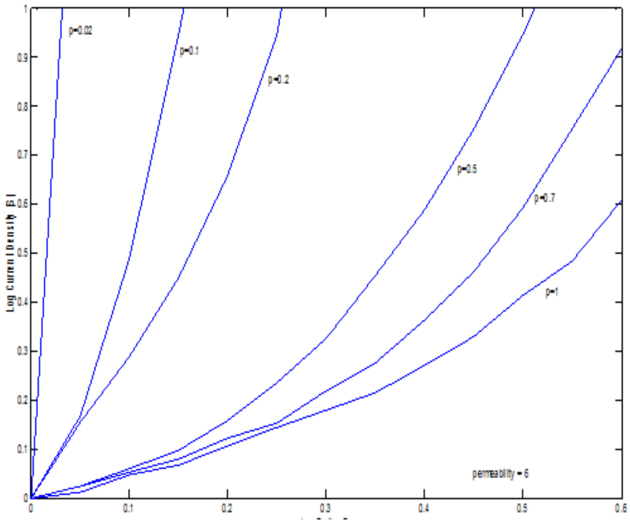

Figure (4) *Current density against radius for tube of a relative permeability of (6) and different penetration depth (p)*

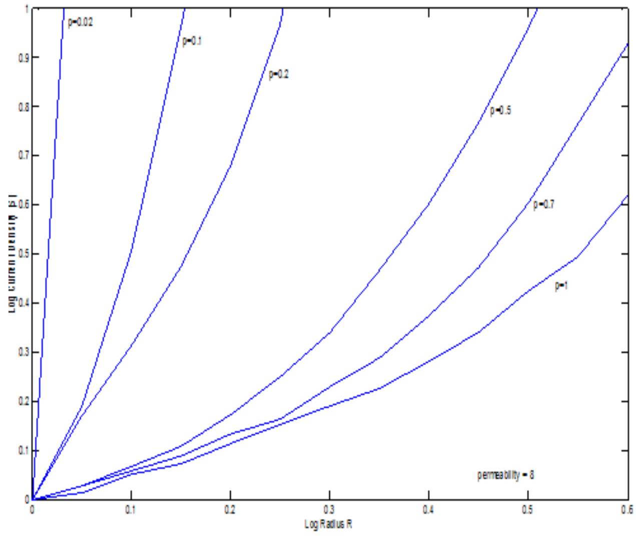

Figure (5) *Current density against radius for tube of a relative permeability of (8) and different penetration depth (p)*

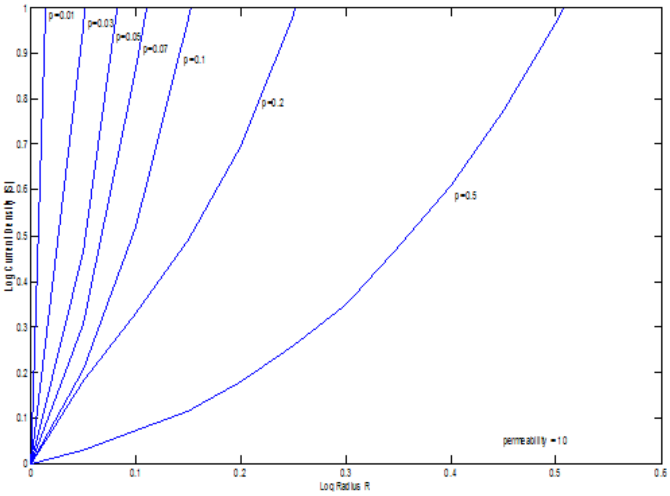

Figure (6) *Current density against radius for tube of a relative permeability of (10) and different penetration depth (p)*

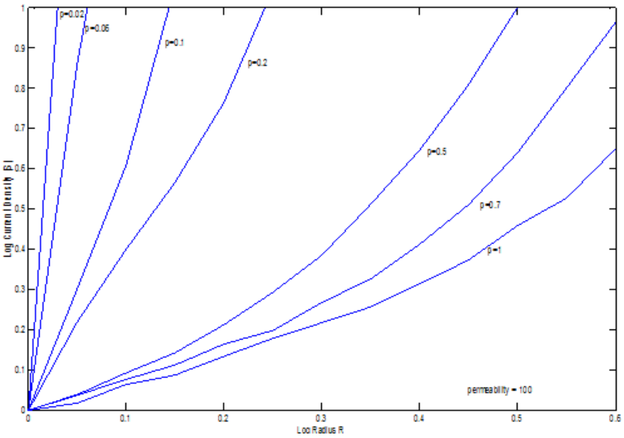

Figure (7) *Current density against radius for tube of a relative permeability of (100) and different penetration depth (p)*