PULSED EDDY CURRENTS
GAGE PLATING THICKNESS

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Pulsed Eddy Currents
Gage Plating Thickness

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SEVERAL methods may be used to measure the thickness of metal coating on a base metal such as: ultrasonics, back-scattering of beta or gamma rays and eddy currents. Eddy currents appear to offer the best chance of success.

If one of the metals is ferromagnetic the problem is simple, but for two nonmagnetic metals the problem is more difficult. Several investigators have used sinusoidal eddy currents of a single frequency but this method presents difficulties such as low sensitivity and high harmonic content. Echo sounding by pulsed eddy currents seems to have promise.

Theory

An electromagnetic field is applied to the surface of the coated metal and echoes from the metallic layers received. These echoes are caused by reflection from the metal-to-metal interface separating metals of different electrical properties.

A small single-layer probe coil with its axis perpendicular to the surface of the metal projects the electromagnetic field into the metal and receives the echoes. This helps make point-by-point depth measurements.

The input pulse is shaped like the positive loop of a sinusoidal wave. The path of the waves in the metal is shown in Fig. 1A. The first reflected wave contains information about the surface metal but nothing about the thickness of the coating. If the primary object is to measure the thickness of the coating, the first reflected wave will not be useful and must be balanced out by a bridge circuit. The second reflected wave contains information about the thickness of the coating and it will be the strongest of the remaining waves.

Pulse Width

The length of the pulses needed is directly related to the basic time

\[ T = \frac{d}{\mu \rho} \]

where \( d \) is the thickness of the coating. Representative values of \( T \) in microseconds are given in Table I.

For best results, the input pulse should be approximately five times \( T \). From Table I this would necessitate an extreme range of length of pulses. Some compromise on pulse length is necessary unless only one coating metal and thickness \( d \) is to be used. A pulse length of 3 microseconds was used.

The rate generator of an oscilloscope (Tektronix Model 517) is used to trigger a thyratron which sends identical pulses through both the standard and the test probes. The circuit is shown in Fig. 1B. The responses of the probes are balanced against each other and the difference voltage amplified and reproduced by the oscilloscope. Proper interpretation of the oscilloscope trace will yield the depth of the coating thickness.

When the input pulse from the oscilloscope triggers the thyratron the 1,000-\( \mu \)F capacitor discharges through the thyratron and the primary of the transformer. The resistor in series with the thyratron and the capacitor and resistor shunting the primary of the transformer aid in shaping the pulse. The secondary of the transformer is loosely coupled to the primary and shielded from the primary. The secondary is balanced to ground and the output voltage applied to a bridge. Two of the arms of the bridge are the two probes. The probes are shunted by variable capacitors and resistors which permit

<table>
<thead>
<tr>
<th>Coating Metal</th>
<th>Distance</th>
<th>( T ) in Microseconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>5 mils</td>
<td>0.75</td>
</tr>
<tr>
<td>Aluminum</td>
<td>25 mils</td>
<td>18.8</td>
</tr>
<tr>
<td>Zirconium</td>
<td>0.045</td>
<td>1.12</td>
</tr>
<tr>
<td>347 Stainless Steel</td>
<td>28.1</td>
<td>702.0</td>
</tr>
</tbody>
</table>

FIG. 1—Wave reflection at metallic interface (A) and pulsing circuit (B)
Gage Plating Thickness

SUMMARY — Echo-sounding technique making use of pulsed eddy currents determines thickness of one metal coated on a base metal. System takes advantage of electrical dissimilarities and is effective even when both metals are nonmagnetic

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a closer balance. The other two arms of the bridge are 10,000-ohm resistors whose midconnection serves as the output terminal to the oscilloscope.

Operation

If the bridge were perfectly balanced, when the ungrounded end of one probe is driven positively in voltage, the corresponding end of the other probe is driven negatively to the same extent and the output voltage to the oscilloscope would be zero. If a slight unbalance is present, an unbalanced voltage will exist at the terminals of the oscilloscope.

For adequate deflection of the oscilloscope under less sensitive conditions, an additional wide-band amplifier employing distributed amplification is useful.

The probes, shown in the photograph, are about ½ inch in diameter and have a core and outside shell of ferrite (Croloy 70). A single-layer coil of wire is wound on an insulating tube encasing the core. The resulting coil has an inductance of approximately 250 µh. Part of the core is movable so that a variable air gap can be introduced in the core to help in balancing the probes. If sufficient sensitivity were available, only the inner core would be used. This would materially reduce the effective area of the probe. The probe is held in plastic and a screw at the bottom adjusts the length of the air gap. An insulating spacer centers the core.

Measurement

The standard sample of metal is placed on the standard probe while another sample of metal is placed on the test probe. The balancing adjustments on the bridge and the probe are made so that the pulse output is nearly zero. A slight unbalance is added by changing the test probe air gap. The result is a wave similar to that of Fig. 2A, left. The gap in the wave is caused by a marker on the oscilloscope screen. The crossing point of the pulse wave is singled out and the time axis about this point expanded. The resulting wave is shown in Fig. 2B. As the thickness of the coating increases the crossing point moves toward the left. The position of the crossing point may be calibrated in thickness of coating.

One difficulty was the variation of the crossing point with the probe spacing. It was found experimentally that the slope of the oscilloscope trace varied also with this probe spacing. If the distance between the probe and the plate were varied until the slope of the trace had some fixed value, then the probe spacing would always be the same and the crossing point would measure coating thickness.

The results are shown in Fig. 2, right. The solid line is the calibration curve of the oscilloscope. The two encircled points are those of standard samples used for calibration.

The test sample was tested by the oscilloscope method and then was sectioned for optical measurements. The crosses are the results of optical measurements. They indicate good agreement between the nondestructive and destructive tests.

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Copies of the complete list of publications may be secured from the Director of the Engineering Experiment Station, University of Missouri

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