THE UNIVERSITY OF MISSOURI

Bulletin

ENGINEERING REPRINT SERIES
Reprint Number 22

❖ ❖ ❖

Engineering Experiment Station
Columbia, Missouri

PULSED EDDY CURRENTS GAGE PLATING THICKNESS

Donald L. Waidelich
Associate Director
Engineering Experiment Station

Reprinted from
Electronics
vol. 28, page 146, November, 1955

COLLEGE OF ENGINEERING
THE ENGINEERING EXPERIMENT STATION

The Engineering Experiment Station was organized in 1909 as a part of the College of Engineering. The staff of the Station includes all members of the Faculty of the College of Engineering, together with Research Assistants supported by the Station Funds.

The Station is primarily an engineering research institution engaged in the investigation of fundamental engineering problems of general interest, in the improvement of engineering design, and in the development of new industrial processes.

The Station desires particularly to co-operate with industries of Missouri in the solution of such problems. For this purpose, there is available not only the special equipment belonging to the Station but all of the equipment and facilities of the College of Engineering not in immediate use for class instruction.

Inquiries regarding these matters should be addressed to

The Director,
Engineering Experiment Station
University of Missouri
Columbia, Missouri

THE UNIVERSITY OF MISSOURI BULLETIN

VOL. 57, NO. 9 ENGINEERING EXPERIMENT STATION REPRINT SERIES, NO. 22

Published by the University of Missouri at Room 102, Building T-3, Columbia, Missouri. Entered as second-class matter, January 2, 1914, at post office at Columbia, Missouri, under Act of Congress of August 24, 1912. Issued four times monthly October through May, three times monthly June through September.

500
March 1, 1956

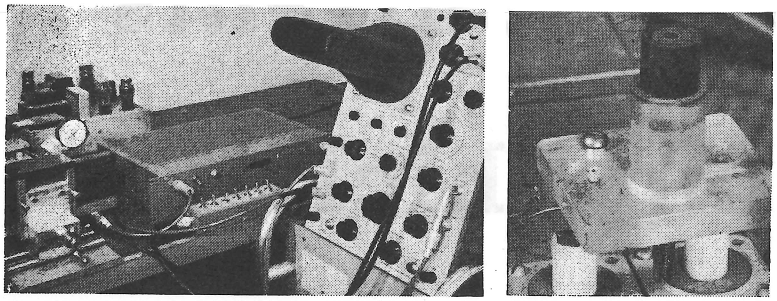
Pulsed Eddy Currents Gage Plating Thickness

By DONALD L. WAIDELICH*

Argonne National Laboratory
Lemont, Illinois

Reprinted from ELECTRONICS, November 1955

Pulsed Eddy Currents



Experimental setup using crt oscilloscope, left; and closeup of probe, right

Table I—Values of T in Microseconds

Coating Metal	Distance 5 mils	25 mils
Aluminum	0.75	18.8
Zirconium	0.045	1.12
347 Stainless Steel	28.1	702.0

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[1] 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[2] 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

$$T = d^2 \mu_1 \sigma_1$$

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-$\mu\mu$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

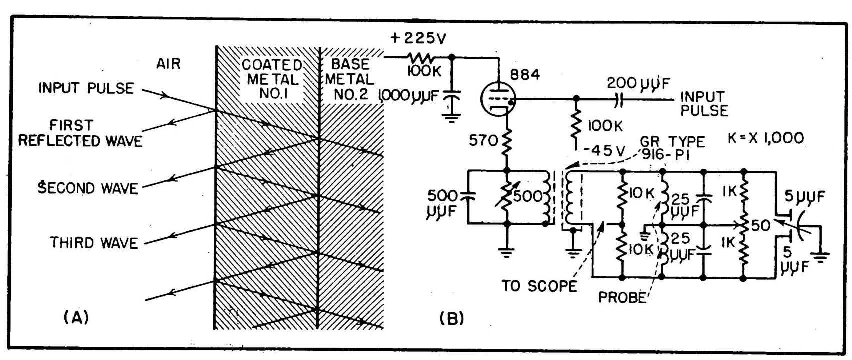


FIG. 1—Wave reflection at metallic interface (A) and pulsing circuit (B)

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

By DONALD L. WAIDELICH* *Argonne National Laboratory Lemont, Illinois*

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.

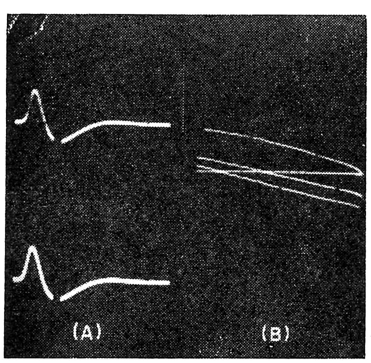
Measurement

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.



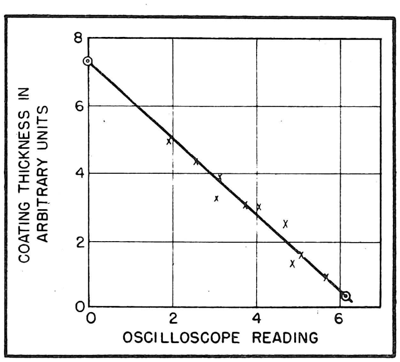


FIG. 2—Output waveform on crt (A), expanded trace (B) and coating thickness as a function of crt reading, right. Crosses indicate optical measurements

REFERENCES

(1) R. Hochschild, Eddy Current Testing by Impedance Analysis, *Nondestructive Testing*, 12, p 35, May-June 1954.
(2) D. L. Waidelich, Coating Thickness Measurements Using Pulsed Eddy Currents, *Proc NEC*, 12, Feb. 1955.

*Now at University of Missouri, Columbia, Mo.

PUBLICATIONS OF THE ENGINEERING REPRINT SERIES

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

Reprint No.

8. Use of the Centrifugal Governor Mechanism as a Torsional Vibration Absorber, by O. A. Pringle, Assistant Professor of Mechanical Engineering. Reprinted from the Transactions of the A.S.M.E., Vol. 75, p. 59, January 1953.

*9. How to Plan for the Safe and Adequate Highways We Need, by Harry Rubey, Professor and Chairman of Civil Engineering. Reprinted from the General Motors "Better Highways Awards", 1953.

*10. A Dynamic Analogy of Foundation - Soil Systems, by Adrian Pauw, Associate Professor of Civil Engineering. Reprinted from Symposium on Dynamic Testing of Soils, Special Technical Publication No. 156, American Society for Testing Materials, 1953.

11. Ternary System Ethyl Alcohol--n--Heptane-Water at 30°C, by Joseph L. Schweppe, Research Engineer, C. F. Braun and Co. and James R. Lorah, Associate Professor Chemical Engineering. Reprinted from Industrial and Engineering Chemistry, Vol. 26, p. 2391, November 1954.
The Rectifying Property of Polarized Barium Titanate, by Donald L. Waidelich, Associate Director, Engineering Experiment Station and Professor of Electrical Engineering. Reprinted from Journal of the Acoustical Society of America, Vol. 25, p. 796, July 1953.

12. Chip Breakers Studies 1, Design and Performance of Ground Chip Breakers, Erik K. Henriksen, Associate Professor of Mechanical Engineering

    Balanced Design Will Fit the Chip Breaker to the Job, from American Machinist, April 26, 1954, pp. 117-124, Special Report No. 360

    How to Select Chip Breakers I, II, III, from American Machinist, May 10, 1954, pp. 179, 181, 183, Reference Book Sheets

    Chip Breaking-A Study of Three-Dimensional Chip Flow, from page No. 53-5-9, presented at the A.S.M.E. Spring Meeting, Columbus, Ohio, April 28-30, 1953

    Economical Chip Breakers for Machining Steel, from Technical Aids to Small Business, May 1954, pp. 1-8

13. The Design of Sampled-Data Feedback Systems by Gladwyn V. Lago, Associate Professor of Electrical Engineering and John G. Truxal, Polytechnic Institute of Brooklyn. Reprinted from Transactions of the A.I.E.E., Vol. 73, Part 2, p. 247, 1954.

14. Selection of Personnel by George W. Elliott, Assistant Professor of Mechanical Engineering. Reprinted from the 1954 Transcript of the Midwest Feed Production School.

15. Lightweight Aggregates for Structural Concrete by Adrain Pauw, Associate Professor of Civil Engineering. Reprinted from the Preceedings of the A.S.C.E., Vol. 81, Separate No. 584, January 1955.

16. Coating Thickness Measurements Using Pulsed Eddy Currents by Donald L. Waidelich, Associate Director, Engineering Experiment Station. Reprinted from the Proceedings of the National Electronics Conference, Vol. 10, February 1955.

17. Additions to Sample-Data Theory by G. V. Lago, Associate Professor of Electrical Engineering. Reprinted from the Proceedings of the National Electronics Conference, Vol. 10, February 1955.

18. Additions to Z-Transformation Theory for Sample-Data Systems by Gladwyn V. Lago, Associate Professor of Electrical Engineering. Reprinted from Transactions of the American Institute of Electrical Engineers, Vol. 74, January, 1955.

19. Tension Control for High Strength Structural Bolts by Adrian Pauw, Professor of Civil Engineering and Leonard L. Howard, Lakeland Engineering Associates, Inc., with a discussion on the Turn-of-the-Nut Method by E. J. Ruble, Association of American Railroads. Reprinted from the Proceedings of the American Institute of Steel Construction, National Engineering Conference, April 18-19, 1955.

20. Autotransformer Betters Motor Phase Conversion by Joseph C. Hogan, Associate Professor of Electrical Engineering. Reprinted from Electrical World, Vol 144, page 120, October 17, 1955.

21. Sequence Summation Factors by Adrain Pauw, Professor of Civil Engineering. Reprinted from the Proceedings of the American Society of Civil Engineers. Vol. 81, Paper No. 763, August, 1955.

22. Pulsed Eddy Currents Gage Plating Thickness by Donald L. Waidelich, Associate Director, Engineering Experiment Station. Reprinted from Electronics, Vol. 28, Page 146, November, 1955.

*Out of Print