22. Nondestructive Testing Techniques for LMFBR

W. O. Harms R. W. McClung

We are developing new methods, techniques, and equipment for nondestructively inspecting materials or components related to the liquid-metal fast breeder reactor (LMFBR). Among the methods studied are electromagnetic induction, ultrasonics, and penetrating radiation. Special emphasis is being given to developing techniques for measuring the degree of cold work in stainless steel tubing with a small diameter.

DEVELOPMENT OF ADVANCED NONDESTRUCTIVE TESTING

Eddy-Current Instrument

C. V. Dodd

One of the major problems with detection of defects by means of eddy currents is properly identifying signals from defects. Defects near the surface and other surface irregularities produce signals that obscure internal defects that may be in a more critical region in terms of failure of a component. Our analytical studies indicate that by measuring the phase shift of the signal we can determine the depth of the defect below the surface. We should then be able to use this information to correct the amplitude of the signal so that all defects of the same size have the same amplitude. In addition, defect signals from a noncritical region could be ignored.

We have begun design of a prototype instrument to investigate these potential benefits. Since the proposed instrument will measure phase shift, we had a modular phase-sensitive eddy-current instrument constructed, and we plan to use many of the modules in the prototype. We have constructed a scaled-up experiment consisting of a large driver coil with two pickup coils encircling a column of mercury. Various simulated defects can be placed in the mercury and moved about to selected locations. We shall use these to measure the phase and amplitude response that would be related to different depths in a solid rod.

Ultrasonic Schlieren Techniques for Inspection of Welds

H. L. Whaley, Jr. K. V. Cook

We are studying the response of ultrasound to various types of weld defects in a series of stainless steel and aluminum samples. The samples are consumable-electrode butt welds in 1-in.-thick plate. The welds contain intentional defects such as porosity, inclusions, incomplete fusion, and incomplete penetration. Initial tests[1] performed with our optical schlieren system on the series of aluminum samples confirmed the existence of defects in the intended areas of the welds and determined optimum transducer placement for detection by the schlieren technique of defects in the root and interface.

Each sample is being examined by three independent ultrasonic techniques: (1) schlieren, (2) pulse-echo, (3) delta technique. These have been described in detail elsewhere.[2]

Each technique has certain advantages that can help us to learn more about interactions between ultrasound and flaws in welds and thus, hopefully, suggest improvements in weld inspection techniques. The results from each examination are being correlated with those from the other two techniques and with radiographs of the samples. Some samples will ultimately be analyzed destructively to determine directly the exact nature of the defects.

[1] H. L. Whaley and K. V. Cook, *Fuels and Materials Development Program Quart. Progr. Rept. Sept. 30, 1969,* ORNL-4480, pp. 114–15.

[2] H. L. Whaley and K. V. Cook, "Ultrasonic Schlieren Techniques for Evaluation of Welds," *Fuels and Materials Development Program Quart. Progr. Rept. June 30, 1970,* ORNL-4600, in preparation.

DISCLAIMER

MEASUREMENT OF COLD WORK IN STAINLESS STEEL TUBING

C. V. Dodd W. A. Simpson, Jr.

We are investigating methods for nondestructively measuring the degree of cold work in small-diameter stainless steel tubing. We emphasize the use of electromagnetic induction for detecting the changes in magnetic permeability produced by cold work.

We prepared two sets of samples of type 316 stainless steel, each containing known amounts of cold work ranging from none to 50%. One set is a series of tubes 0.250 in. in diameter × 0.015 in. in wall thickness; the other is a series of sheets 0.015 in. thick. Our first efforts, with the flat sheet, were to establish quantitative instrument response relative to cold work without the problems that might be caused by the small radius of curvature on the tubes.

Cold work has been correlated with the magnetic permeability in some austenitic stainless steels.[3] An increase in relative permeability from 1.003 to 1.01 in the normal ranges of cold work and values as high as 10 for severe cold work are reported. Using the relationship we previously developed,[4] we calculated the response from a low-frequency inductance bridge circuit and determined that we could measure permeability changes between 1.003 and 1.01. We constructed on a breadboard a system for making these measurements and operated it in a "bridge unbalanced" mode, similar to many eddy-current tests, to separate the conductivity variations from the permeability variations. The permeability correlated very well with the degree of cold work. Although these preliminary measurements were very encouraging, considerable refinement is needed in both the circuitry and the technique to optimize this method.

Because of the excellent response of the eddy-current bridge system to cold-rolled flat sheets, we designed a prototype system that uses encircling coils for tubes. As part of the design study, we used our recent computer program that is a mathematical model for an impedance bridge and allows studies of variations in the components of the circuit.[5] The system finally selected was determined to be the best of a number that we analyzed on the computer. The calculations indicate that we can measure the relative permeability in the tubes to within ±50 ppm. Our work thus far indicates that a change from 19 to 21% cold work increases permeability by 150 ppm. With our computer program we determined how much variance we could allow in the components of the impedance bridge and still achieve this accuracy. While this places a rather stringent requirement on the components, the required quality is commercially available. We have obtained all the components and begun construction on the instrument.

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[3]Taylor Lyman (ed.), *Metals Handbook,* 8th ed., pp. 423, 793, vol. I, American Society for Metals, Metals Park, Novelty, Ohio, 1961.

[4]J. W. Luquire, W. E. Deeds, C. V. Dodd, and W. G. Spoeri, *Computer Programs for Some Eddy Current Problems,* ORNL-TM-2501 (August 1969).

[5]C. V. Dodd, W. G. Spoeri, W. E. Deeds and W. A. Simpson, *Fuels and Materials Development Program Quart. Progr. Rept. Dec. 31, 1969,* ORNL-4520, pp. 308–9.