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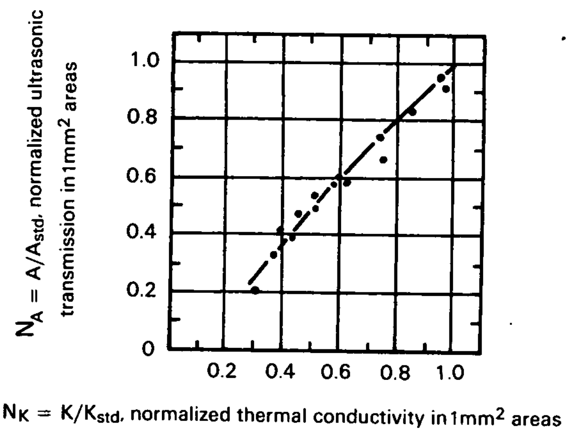
AEC-NASA TECH BRIEF

Correlation Established Between Heat Transfer and Ultrasonic Transmission Properties of Copper Braze Bonds



Normalized ultrasonic transmission at 1.0 Mc in 1 mm^2 areas versus normalized thermal conductivity in 1 mm^2 areas for copper braze bonds (f = 1.0 Mc)

The problem:

To determine whether a correlation exists between heat transfer and ultrasonic transmission through copper braze bonds. The integrity of the bond between the fuel and the cladding of nuclear fuel elements is of prime importance. Heat from the fuel must flow across the bond to react with the coolant. Therefore the bond must be capable of providing adequate heat transfer and must be free of defects that would cause localized hotspots and early corrosion failure.

Nondestructive evaluation of bonds has long been made by ultrasonic tests, in which acceptance or rejection of a bonded element is based on its ability to transmit or to reflect ultrasound. However, no correlation between thermal conductance of the bond and ultrasonic transmission has been previously established.

The solution:

A relationship was experimentally established be- heat transfer and ultrasonic transmission of brazed bonds by measuring and correlating the thermal conductivity and the ultrasonic transmission of seven hot-brazed-bonded copper plates. A typical correlation is shown. The amplitude of the transmitted ultrasonic pulse decreases with a decrease in heat transfer, and thus with bond quality. The fact that this correlation is established for copper braze bonds indicates that similar knowledge can be obtained for other types of bonds, e.g., the diffusion bonds of reactor fuel elements. For any type of bonded elements, this method will yield a definitive relationship permitting the prediction of heat transfer characteristics from the ultrasonic transmission properties. This relationship can then be used as the basis for setting

(continued overleaf)

more realistic acceptance standards for bonded reactor fuel plates.

How it's done:

To determine the thermal properties of the bonded elements, the thermal pulse method for measuring thermal diffusivity and thermal conductivity is utilized. The front surface of the specimen is uniformly irradiated by a very short pulse of radiant energy from a xenon flash tube. The temperature history of the back surface is continuously monitored by an oscilloscope, and the oscilloscope trace is photographed. The thermal conductivity, K, of the material is determined from:

$$K = \alpha Q / L T_M$$

where

- α is the thermal diffusivity, and is determined from sample thickness and half-rise time
- Q is the amount of energy falling on the front surface
- L is the thickness of the sample
- T_M is the maximum temperature rise of the back surface

To determine the ultrasonic transmission of the bonded elements, a setup that closely duplicates the typical ultrasonic nondestructive test setup for bond testing plates is utilized. Tests are made at 1.0, 2.25, and 5.0 Mc. The output is fed into a dual-trace oscilloscope, and the amplitude of the transmitted pulse is obtained from the oscilloscope.

For each specimen studied, the following values are obtained and plotted:

$$N_A = \frac{\text{amplitude of the transmitted pulse of specimen}}{\text{amplitude of the transmitted pulse of standard}}$$

$$N_K = \frac{\text{thermal conductivity of specimen}}{\text{thermal conductivity of standard}}$$

Notes:

1. The relationship between thermal conductivity and ultrasonic transmission is frequency dependent. The rate of loss of ultrasonic transmission increases as the wavelength decreases.
2. Before specimens are tested, they are examined radiographically so that a wide range of bond quality can be selected.
3. Additional details are contained in the following references:
   (a) Applied Materials Research, July 1966, pp. 162–167.
   (b) "Correlation of the Heat Transfer Properties and Ultrasonic Transmission Properties of Bonds," by R. A. DiNovi, ANL7074, February 1966. This report is available from Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151; price \$3.00 (microfiche \$0.65).
4. Inquiries concerning this innovation may be directed to:

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Patent status:

Inquiries about obtaining rights for commercial use of this innovation may be made to:

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