Quantitative Ultrasonic Holographic Defect Characterization

J. W. Brophy, A. E. Holt, J. H. Flora
Nondestructive Methods and Instruments Section
Babcock & Wilcox Company
Lynchburg Research Center
P. O. Box 1260
Lynchburg, Virginia 24505

Abstract

Ultrasonic holography has proven to be a useful and accurate tool for defect imaging and sizing in thick wall materials. The optical image formation gives a true two-dimensional cross-section of the flaw as a function of the angle at which the flaw is inspected. Recently Babcock & Wilcox participated in Oak Ridge Laboratories thermal shock program of HSST test vessels, under an EPRI contract, to attempt to define cracks induced into the vessels. The defects induced were "natural" cracks running the length of the vessel.

The purpose of the holographic inspection was to map the extent of the crack propagation extending from the inside diameter towards the outside diameter of the vessel. The crack propagation map provided by the holography inspection was compared to destructive analysis and found to be within 10 percent of the area of maximum crack propagation.

The potential of ultrasonic holography as a quantitative tool for characterizing defects has long been recognized. For large primary containment vessels used in nuclear power stations or other heavy section materials, time-gated pulse-echo holography has been demonstrated to be a fieldworthy technique. The basic technique of data acquisition and the production of a visual image whose dimensions are directly proportional to the defect dimensions are outlined.

For the specific data reported here, schematics of the Oak Ridge Laboratory test vessels are shown, as well as the basic geometry of the inspection procedure. The data being reported here is the holographic mapping of a thermal shock induced crack in a Heavy Section Steel Technology (HSST) test vessel. The BW holography field units are shown in use at Oak Ridge as well as one of the two test vessels that was examined.

The reduced data and available destructive results are presented with the holographic and destructive analysis of prominent features tabulated. The holographic map of the through-wall dimension of the crack can be viewed directly in its through-wall extent on the reduced data plots.

All the defect images in this study were produced by optical reconstruction of the holograms. Future efforts by BW are to implement direct computer data acquisition and image reconstruction into a field compatible unit. We show here some results of the computer technique of data acquisition and reconstruction and the corresponding optical hologram. The proposed computerized ultrasonic field unit would use a rugged minicomputer and would provide enhanced imaging techniques and displays with no loss in the time from data acquisition to image display.

References


Fig. 1. Basic pulse-echo time-gated ultrasonic holography volume tested
Fig. 2 Hardware Schematics

Fig. 3 Optical Processor Field Unit Configuration

Fig. 4 Artist Illustration of HSST #1 Showing Machined Notch, EB Weld Zone and Trepans.

Fig. 5 End and Side Views Showing Scanned Region Geometry and Transducer Angle
Fig. 6 Field Unit Electronic Hardware
a. Signal processor
b. Oscillator and power amplifier
c. Oscilloscope display units

Fig. 7 Field Unit and Operators HSST Test Vessel Inspection at Oak Ridge Site

Fig. 8 HSST Vessel #2 Setup Scanner, Mounting Fixture and Camera Light Pipe. Scribe Marks on the Vessel Outline Relative Coordinate System Used
Fig. 9 Destructive Results for HSST #1
a. Maximum crack extent
b. Average crack extent
c. EB weld and machined notch

Fig. 10 Comparison of Destructive and Holographic Results
I) maximum crack extent
   holographic: 1.55"
   destructive: 1.7"
II) EB weld and notch extent
    holographic: 0.5"
    destructive: 0.5"
III) trepan diameters
     holographic: 0.95"
     destructive: 1.0"
HSST VESSEL #2
HOLOGRAPHIC DETERMINATION OF THROUGH WALL CRACK

Fig. 11 Comparison of Destructive and Holographic Results

I) average crack extent
   holographic: 0.5"
   destructive: 0.5"

II) EB weld zone extent
    holographic: 0.5"
    destructive: 0.5"

Fig. 12 Core Samples Removed from HSST #2 Arrows
Point to Extent of EB Weld Area (a) and Extent of Crack Area (b)
Bottom view photo of "Y" test block.

Schematic of "Y" block dimensions.

Fig. 13 Test Block Used to Evaluate Results Between
Optical Image Reconstruction and Computer
Image Reconstruction

Fig. 14 Optical media acoustic hologram of "Y" block.

Fig. 15 Optical reconstruction of "Y" block image
Fig. 16 Computer reconstructions of "Y" block image