INTRODUCTION

A program entitled, "Development of an Ultrasonic Imaging System for the Inspection of Nuclear Reactor Pressure Vessels", was initiated in 1976 under the sponsorship of the Electric Power Research Institute (EPRI). One objective was the development of a high-speed system capable of inspecting two lineal feet of weld per minute according to ASME Section XI code requirements. A further objective was to provide high resolution images of significant flaws.

Battelle Northwest, the contractor, determined that the only way these objectives could be met, was to use a long linear array of piezoelectric elements to take advantage of high-speed electronic scanning. The array is mechanically scanned parallel to itself to perform the required inspection.

The code requires that the weld be inspected at five different angles, typically ±60°, ±45° and 0°. That is, the weld must be examined from both sides as well as the top. This is required because flaws tend to lie along the weld line and thus may be oriented nearly vertically to the surface. Consequently, the examination of

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two lineal feet of weld requires that eight square feet of surface area be inspected (for a twelve inch thick pressure vessel).

The imaging system is designed to operate in two modes, 1) high-speed search and locate and 2) imaging of significant flaws by holography. Both were to be implemented with the linear array.

In this paper, we describe the evolution of the holographic mode, beginning with the simple substitution of electronic for mechanical scanning, to the final configuration of a line source in conjunction with a linear receiver array.

ANÁLISIS

Pulse-Echo Holography

Figure 1 is the simplified geometric arrangement as first proposed and implemented. Two linear arrays were used in this configuration, one to serve as source and the other as receiver. The elements of the source array are energized in sequence and the return echos received on an adjacent receiver. The round-trip distance from source to object to receiver is:

\[
D(x,y) = 2[(x-x_o)^2 + (y-y_o)^2 + z_o^2]^{1/2}
\]

(1)

If we set \(D(x,y)\) equal to a constant, \(K\), and square both sides of Equation 1, we obtain:

\[
(x-x_o)^2 + (y-y_o)^2 = \left(\frac{K}{2}\right)^2 - z_o^2.
\]

(2)

This is the equation of a circle centered on \((x_o,y_o)\) of radius \(\left[\left(\frac{K}{2}\right)^2 - z_o^2\right]^{1/2}\). If holography is performed by interfering the returning signals with a reference signal that is equivalent to a plane wave normal to the x-y plane, then the interference fringes record loci of equal distance \(K = (2z_o + n\lambda)\). Thus, the pattern on the x-y plane becomes a family of concentric circles of radius \([n\lambda(z_o + \frac{n\lambda}{4})]^{1/2}\). Such a family of circles constitutes a Fresnel ring system capable of focusing light and hence creating an image of the point object and is the fundamental basis of holography. Although other complicating factors arise, such as aberration and twin image overlap, these problems have been studied and adequately solved in various publications. Most of the problems, arising from the desire to use light in the image forming process, derive from the large differential in the wavelengths of sound and light. When a computer is used to form the image, it assumes the same wavelength, so that these problems do not arise.