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A PROTOTYPE ULTRASONIC TEST SET FOR STEEL TUBING, USING ELECTRONICALLY-FOCUSSED ACOUSTIC ARRAYS

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1. INTRODUCTION

Previous papers by the author et al[1,2,3,4] have discussed the on-line ultrasonic inspection of steel tubes, with particular reference to the possibility of using arrays of transducers to produce focussed, electronically-steerable beams of ultrasound.

A prototype tube-testing equipment working on this principle has now been built. The present paper describes the principles of operation, and the construction of this equipment and discusses the results achieved with it.

2. PRINCIPLES OF OPERATION

The way in which the directional properties of a pulsed beam of ultrasound from an array of transducers may be altered by scanning techniques may be summarised briefly as follows :-

If each transducer in an array is regarded as a point source, an expanding spherical wavefront will propagate from it when the transducer is excited. The shape of the beam from the array as a whole will be determined by the interference pattern produced by the intersection of these individual wavefronts, and for transducers grouped closely together and energised simultaneously, the resultant beam pattern will approximate to that from a single transducer with the same outline. Also, to a first approximation, the wavefront from the array as a whole in the near field may be regarded as the envelope of the intersection of the wavefronts from the individual transducers, provided short pulse trains are considered. The effect of increasing the pulse length is to produce additional side-lobes; for most ultrasonic testing applications short pulses are desirable both from this point of view, and in order to improve resolution.

By delaying the excitation of some transducers relative to others in the array, the shape of the wavefront may be changed. Linear time delays and uniformly spaced co-planar transducer arrays are usually used, resulting in a plane wave-front inclined at an angle to the array.

If an array is used whose cross-section is a circular arc, a focus will be produced at the centre of curvature if the transducers are excited simultaneously. Delaying the excitation of consecutive transducers in a linear manner will still produce an (approximately) circular concave wavefront converging to a focus, but the focal point will be shifted to one side or other of its original position. Arrays of this type, by the nature of their geometry, are particularly suited to the non-destructive testing of tubes, and are considered further in the following sections. Arrays may be used in a receiving, as well as a transmitting mode, by delaying the received signals in the same way before feeding them to an amplifier.

3. THE PROTOTYPE EQUIPMENT

The prototype test equipment is designed to cover a tube size range 12.5 mm to 75 mm diameter and is intended to detect longitudinal, radial defects in the internal or external tube wall.

The test frequency is 5 MHz, with a pulse repetition rate of 5 KHz. It is intended that tube should be fed through without rotation at speeds up to 200ft/min. Adjustment for change of tube size, apart from changing bushes, is by a single electronic beam-angle control, together with facilities for setting position and widths of strobes on the time base to pick out signals of interest.

The test head comprises a water jacket through which the tube passes, in which are mounted 90 small piezo-electric transducers, rigidly fixed at 150 mm pcd on a tungsten-loaded araldite backing ring. Flat lead-zirconate-titanate transducers 3.25 mm wide by 10 mm long are used, giving a beam-angle of 5° at the 3 dB points from each transducer. The transducers are excited in groups of ten, with a predetermined time delay in the range 0.1 to 1μsecond between the firing of successive transducers in the group. The path of the emergent wavefront from the group will be angled with respect to the array, by an amount dependent on the inter-transducer time delay, which is chosen to suit the size of tube to be tested. The object is to achieve maximum conversion of incident energy to shear waves in the tube wall, and an optimum concentration of energy in the tube wall for detection of defects.

One transducer out of the selected group of ten is used for receiving. After each group has been fired and an echo received, a new group is selected, displaced by one transducer pitch (4°). Thus, the circumference of the tube to be tested is examined in 90 steps, taking a total of 20 mSec.

The energy content of the signal received by each transducer in turn during a selected time period is displayed as one of 90 vertical lines on a C.R.T. ("Histogram" display).

3. TEST RESULTS

The equipment has been tested under laboratory conditions with the tube stationary. As a next step tests will be undertaken under more realistic conditions with the tubes moving longitudinally. Although it has been found possible to receive signals from defects ranging from 0.01 mm to 0.1 mm in depth on most sizes of tube, a wide variation has been found in the strength of the signals received by the 90 transducers. This has made interpretation of the histogram display difficult when examining smaller defects, since the noise level from a sensitive transducer can exceed the signal level from a less sensitive one. These variations are attributed to variation in the batches of material from which the transducers were made, and to initial difficulties in mounting, polarising and connecting to the transducers. These difficulties have now been largely overcome using improved techniques, and in making a second transducer ring it is anticipated that variations will not exceed 3dB. This can be further improved by the application of averaging techniques to the signals from the individual transducers.

A study has been made of the relation between the settings of the instrument (particularly choice of delay time and selection of the gating period for the received signal) and the signal amplitudes received from various defects. In particular, it is advantageous (a) to equalise received signal amplitudes from artificial defects of the same depth in the inside and outside wall of the tube, and (b) to achieve a linear relationship between defect depth and signal amplitude. The work to date has pinpointed the problems involved in doing this and indicated that, while it is possible to satisfy these criteria independently by a suitable choice of instrument settings, the two requirements may not be compatible. This is not a feature of this equipment alone but can also apply to conventional NDT equipment.

CONCLUSIONS

Promising results have been obtained with the prototype equipment on a variety of tube sizes. It is anticipated that with the construction of an improved transducer ring, initial difficulties with transducer sensitivity variations will be overcome.

The electronic beam-angle adjustment technique has shown itself to be a versatile tool for the investigation of defect depth/signal amplitude relationships, and for determining the optimum criteria for equalising signals for bore and O.D. defects.

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