1.3.18. QUANTITAVE CHARACTERISATION OF COMPLEX DEFECTS USING TWO-DIMENSIONAL ULTRASONIC ARRAYS

Velichko A., Wilcox P.D., University of Bristol, Bristol, UK

Introduction. Recent years have seen a rapid increase in the interest in arrays for NDE. However, current NDE systems utilise mainly 1D arrays and so are limited to obtaining a 2D image. 2D arrays offer the potential to image in 3-dimensions. This has clear benefits as real defects and engineering structures are 3D – for example defects such as cracking and inclusions in welds are of arbitrary shape and can occur in arbitrary orientations. The 3D steering and focusing ability of 2D arrays enables both improved defect characterisation due to the increased range of inspection angles and increased volumetric coverage from a single inspection location.

However there are a number of obstacles currently restricting the application of 2D arrays to NDE. The fundamental challenge associated with truly 2D arrays, capable of full 3D imaging, is due to the number of elements required to produce an aperture of sufficient size to allow adequate beam-forming. Also, special signal-processing techniques for dealing with 2D array data to generate high quality images in 'real-time' are required. Moreover, in many cases detection alone is not enough and quantitative information about defect shape, size and orientation is needed. This information helps to estimate how a defect affects the structural integrity. For defects with size greater than the wavelength this information can be obtained directly from the image. However, sub-wavelength defect characterization is still a major challenge for nondestructive evaluation. In this case in order to get defect size estimation more advanced processing methods are needed.

In this paper different techniques for optimisation of 2D array element layouts and possible 2D array inspection strategies are presented. Results are shown that illustrate the application of the proposed techniques to modelling and experimental data.

Basic results. The strategy of imaging using an ultrasonic array that is considered here consists of collecting signals from each transmitter-receiver pair in the array. Such an approach is called Full Matrix Capture and the acquired data contains all information about the test sample that could possibly be obtained by the array at a particular test position.

The next question is how to process this transmit-receive data in order to extract information about each defect. The imaging algorithms transform the array data into an image, which indicates the location of the defects in the sample. According to the distance between an array and the testing area it is possible to distinguish between two cases: near field imaging and far field imaging.

Mathematically an imaging algorithm can be expressed in the frequency domain as a summation of contributions from the spectra of all time-traces with phase and amplitude coefficients chosen to maximise the signal at the focal point. If imaging in the far-field of an array, the number of elements required in the array can be significantly reduced by using the special method of calculating the phase coefficients, which is based on the effective aperture concept. Theoretically, there is no loss of information or degradation of image quality associated with this reduction in number of array elements.

In the near-field of an array the aperture must be fully sampled in order to preserve all possible information. The optimum regular sampling scheme with the lowest density of array elements is hexagonal sampling. The limiting factor for regular array element layouts is that element spacing must be small enough to prevent the grating lobes appearance in the image. On the other hand, an irregular distribution of the array elements suppresses grating lobes but at the expense of increased uniform noise throughout image. In this case the limiting factor is how high a uniform noise level can be tolerated in the image.

The general 2D array processing strategy proposed is to use fast far-field imaging algorithms to provide rapid volumetric coverage and qualitative detection and then to only use full resolution techniques for defect characterisation on small volumes where defects are indicated. Any defect can be characterized by its angular reflectivity pattern. A signal processing technique for reconstructing the 3D angular reflectivity pattern of a defect is described. This enables the characterisation of arbitrarily oriented defects without a priori information about their nature.

Summary. It has been shown that in the case of far-field imaging the performance of fully populated array can be achieved by using sparse array. For near-field imaging and regular array pattern hexagonal elements on a triangular grid is optimum (about 20% more efficient than square elements on square grid). Increasing the separation distance between array elements leads to grating lobes in the image. However, a random distribution of array elements suppresses localized grating lobes but at the expense of increased uniform noise throughout the image. A 2D array processing strategy has been developed that allows detection and quantitative characterization of defects to be achieved.