EVALUATION OF A NEW APPROACH FOR THE INSPECTION OF AUSTENITIC DISSIMILAR WELDS USING ULTRASONIC PHASED ARRAY TECHNIQUES

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1 Introduction

The fundamental obstacle to accurately characterising the defects in austenitic welds is the distortion of the sound field due to the anisotropic inhomogeneous material. This paper describes the evaluation of the next generation of ultrasonic procedures which use phased array techniques and models to account for the distortion of the sound field, such that the detection, positioning and sizing of defects is improved in comparison to current capabilities.

Development of special transducers can improve signal-to-noise performance, hence detection capability. However to overcome the distortion and improve characterisation, the material condition has to be accounted for in inspection design. Electron back scatter diffraction (EBSD) techniques were used to evaluate the texture of the weld and then the microstructural information was input to a model capable of propagating ultrasonic waves through the anisotropic inhomogeneous medium. With knowledge of the distortion, a strategy was developed for improving inspection by adapting focal laws using time reversal concepts to improve sensitivity. This paper presents the methodology for the correction strategy and the demonstration of its performance. This project is funded by the UK Technology Strategy Board (www.dissimilarweld.co.uk).

This paper follows the paper given in the 7th NDE conference in relation to nuclear and pressurised components (Yokohama, 2009), where the early development of the strategy for correction was presented. This paper outlines the full development and the performance demonstration.

2 Microstructural quantification and lengthwise uniformity study

Three samples were taken from a welded specimen for EBSD characterisation. The three samples were extracted from the front, middle and end part of the weld. The surface was examined using EBSD which is a powerful tool to perform crystallographic analysis of materials in a scanning electron microscope. The orientation maps generated from EBSD contain quantitative information of the weld samples, such as crystallographic orientation, position of the grain boundaries and the grain sizes. The quantitative information obtained was used to simulate the effect of grain orientations and boundaries on the ultrasonic beam propagation using the CIVA simulation platform. The lengthwise uniformity along the weld was investigated in order to predict the variation in the sound distortion along the weld.

Major orientations of the weld were identified and it has been noted that there is no significant orientation changes from the front to the end of the weld. However, the orientation map from the middle of the weld shows a slight asymmetry of the [001] fibre. EBSD and optical micrograph results from the orthogonal direction to the weld centerline suggest that most of the orientated grains are rod-like in shape with different sizes.

In addition, the variation of the distortion along the weld was also investigated with ultrasonic measurements. The ultrasonic signal from a notch that runs the full length of the weld was monitored for a beam passing through the weld and a beam passing through the parent material. It was observed that there was good homogeneity in position along the weld when the beam passed through the weld body. The main effect of the anisotropy along the weld is on the variation in the signal amplitude.

Therefore, the results suggest that the quantification of the weld microstructure by EBSD for the definition through modeling of the correction factors to be applied during inspection can be done only once (using one weld section) and be generic for similar geometries and welding procedures.

3 Correction Strategy

The anisotropic nature of the weld causes the velocity and the magnitude of the wave propagation to vary with direction. This behaviour has to be accounted for in order to compensate for the ultrasonic beam distortion and improve the reliability of the inspection.

Phased array techniques use the principle of wave phasing in order to construct and control the sound field. The phasing of each elementary wave is directed by the delays in transmission and reception that are applied to each element. These delays are calculated as a function of the time of flight of each elementary wave to reach the target in an isotropic media. In an anisotropic media, the wave phasing is distorted due to variation of the velocity in the path of the wave. This leads to defocusing of the ultrasound at the desired position.

The strategy developed in this paper is to use modelling in order to predict the sound path for each element taking into account the anisotropic structure of the weld and adapt the delay laws. An analytical model of wave propagation (CIVA software developed by CEA, the French atomic commission) was used with input from the EBSD characterization in order to predict the effect of the anisotropy on the ultrasonic beam and generated adapted delay laws.

4 Performance demonstration

In the project a specialised probe was developed and manufactured to improve the signal to noise performance of the inspection. The probe that was developed is an immersion coupled transmit receive transducer generating a longitudinal wave.

In addition the concept of adapting laws was validated through experimental trials on a dissimilar weld specimen representing the safe-end joint of pressurised water nuclear reactors. There were a range of artificially implanted flaws representing the type of damage expected during service.

5 Conclusion

The evidence generated in this project shows potential for developing advanced ultrasonic procedures which will lead to increased confidence in specifying, manufacturing and operating austenitic welded components for the future generation of high temperature power plants.