46th Annual Review of Progress
in Quantitative Nondestructive Evaluation
QNDE2019
July 14-19, 2019, Portland, OR, USA

QNDE2019-1234

ON THE SUITABILITY OF DIFFERENT WAVE DESCRIPTION MODELS FOR ULTRASONIC CHARACTERISATION OF AN AUSTENITIC STAINLESS STEEL WELD

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ABSTRACT

Owing to a complex solidification process, the microstructure of austenitic stainless steel welds consists of long columnar grains with varying preferential orientation. Ultrasonic inspection of such welds has always been a challenge with grain scattering and beam deviation originating from the preferential alignment as the main obstacles. Whilst the former may be to some extent circumvented by reducing the frequency of inspection, the latter requires some a priori information on the structure of the grains (essentially, the orientation of the stiffness tensor) within the weld. Grain stiffness map may be obtained from either a forward weld formation model, or measurements. The most accurate direct method - electron backscatter diffraction (EBSD) measurement - is a lengthy and costly process. At the same time, the level of detail available from an EBSD map is unnecessarily high from the viewpoint of ultrasound propagation. The time of flight of the wave, which is the most common feature of interest, e.g. in imaging, is affected by local variations of crystal orientation only in an average sense. Therefore, sufficient information on the distribution of the orientation sensor should be available from ultrasound measurement. Previous work confirms that such an inversion, based on ultrasonic measurements is possible [1]. It is favourable to use a simple weld formation model, such as MINA [2] or a geometrical description, to reduce the number of parameters to be identified during the inversion. In this contribution, we investigate how well a typical weld can be described by small-parameter models and the effect of the choice of the model on the inversion process.

FIGURE 1: Experimental setup for ultrasonic weld characterisation.

A mock-up austenitic stainless steel V-weld, with a documented manufacturing procedure and metallographic examinations, is considered (Figure 1). We compare ultrasonic shear wave array measurements with predictions coming from both ray tracing and finite element models. The measurements are taken using a pair of array transducers with the transmitting one mounted on a rexolite wedge to predominantly excite shear waves in the sample (see Figure 1). The receiving transducer records rays after the reflection from the backwall, which may happen before or after the wave travels through the weld.

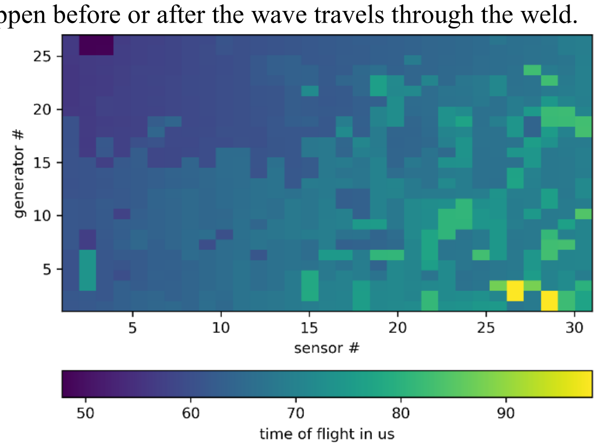

FIGURE 2: Illustrative time-of-flight map recorded in a preliminary experiment.

An illustrative time-of-flight map is shown in Figure 2. The values were extracted from recorded time histories using a CLEAN-type algorithm [1]. The changes in the times in Figure 2 are quite abrupt, which is partly related to a high level of structural noise. Additional measurements are currently underway to enhance the data gather during the first measurement.

Ultrasound simulations are based on weld maps coming both from the MINA model, the Ogilvy map (see [1] for references) and processed metallographic images (see Figure 3). We first extracted the average grain orientation over a regular 1 mm grid, analogous to that typically used in MINA (Figure 3). Then, based solely on local orientations, we optimised both MINA and Ogilvy parameters to match the data extracted from the metallographic image. As shown in Figure 3, there are quite significant localised differences.

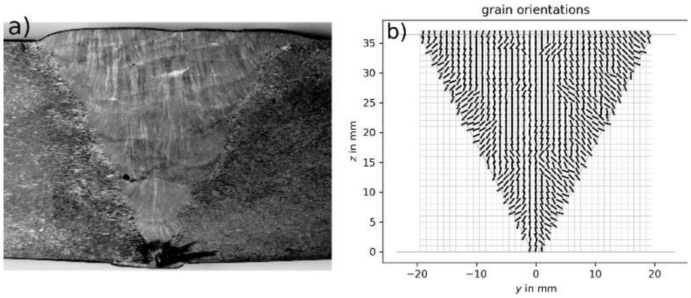

FIGURE 3: Grain orientations in the weld under consideration: a) metallographic image; b) extracted orientations over a regular 1 mm grid.

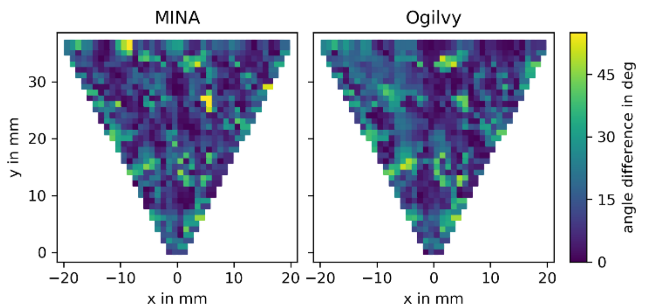

FIGURE 4: The difference in local orientations between the data extracted from the metallographic image and: a) an optimised MINA model; b) an optimised Ogilvy map.

In this paper, we will show how these differences affect ultrasound propagation using simulation and verification against array measurements. The comparison allows for assessing how well the formation models represent the weld under consideration, and identifying the level of complexity that is sufficient to obtain suitable weld stiffness maps. Further, we conduct a sensitivity analysis revealing the effect of the adopted weld description on the times of flight and their potential impact on the inversion process.

Keywords: austenitic weld characterisation, MINA, wave propagation, inversion

ACKNOWLEDGEMENTS

This research is conducted within the ADVISE project, funded by the EURATOM Research and Training Programme 2014-2018 under Grant Agreement No 755500.

We acknowledge the contribution of Fabian Schreyer and Martin Werz at MPA (University of Stuttgart, Germany), whose team manufactured the weld and gathered metallographic images. We also thank Antoine Ferre at EDF, France for providing pixel orientation data using their proprietary *c_image_orientation* tool.

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