EXPERIMENTAL EVALUATION OF ULTRASONIC SIMULATION TECHNIQUES IN ANISOTROPIC MATERIAL

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INTRODUCTION

The high performance of the available computer technology provides the possibility to simulate the real life for ultrasonic inspections in terms of primary ultrasonic data like rf-time signals. For isotropic material codes like Generalized Point Source Synthesis (GPSS) or Elastodynamic Finite Integration Technique (EFIT) and the theoretical predictions correlate well with experimental results. Recently, the codes mentioned above have been extended to operate also in anisotropic material. In a first step the codes GPSS and EFIT have been expanded to work in materials of parallel oriented columnar grain structure with transversely isotropic symmetry. In order to verify these codes a set of experiments was carried out on weld metal pads and on welds of defined grain structure. Radiation, propagation, reflection on boundaries and interaction of the sound field with defects for the modes "through transmission" and "pulse echo" were simulated and compared with the experiments.

The purpose of this work is to present and discuss the results of code verification.

CODES

Elastodynamic Finite Integration Technique (EFIT)

EFIT is a full numerical code and works like a finite element code [1]. The code calculates the particle displacement on a 2D or 3D lattice by solving the elastic wave equation on all lattice nodes. EFIT is able to compute the ultrasonic wave field including the interaction of the wave field with defects like cracks with arbitrary shape. The primary results are so called snap shots which are particle displacement fields for discrete time points. Using this information it is possible to calculate A-scans for a fixed probe position.
**Generalized Point Source Synthesis (GPSS)**

GPSS is a semi-numerical, semi-analytical code to calculate the sound field distribution of ultrasonic transducers [2]. Based on Huygen's principle and starting with point sources covering the transducer aperture on the surface of the component under testing the sound field at the observation point is calculated by summation of all wave contributions coming from the transducer aperture using a Green's function as propagation operator. The primary results are particle displacement fields for discrete time points and A-scans for through transmission experiments without defects in the material.

**SPECIMENS**

In order to verify the codes a set of specimens was built up. Figure 1 shows three specimens built up from simple weld metal parts with transversely isotropic structure to simulate welds with columnar grains perpendicular and parallel to the specimens’ surface embedded in austenitic base material. The specimens were built up using a multibead welding pad with transversely isotropic structure which is embedded in an austenitic base material block by a diffusion welding process. For the base and weld material Austenit 308 had been chosen. In order to simulate defects the specimens contain notches within or near the weld flanks.

**MEASUREMENT TECHNIQUE**

Four kinds of measurement were carried out (Figure 2 and 3):

1. Single through transmission with normal incidence

![Figure 1. Austenitic specimens.](image)
Figure 2. Measurement technique for through transmission experiments.
Figure 3. Measurement technique for V-through transmission and pulse echo experiments.

Figure 4. Result of a calibration measurement.
(2) single through transmission with angle of incidence (45°)
(3) v-through transmission with angle of incidence (45°)
(4) pulse echo with angle of incidence (45°)

For (1) and (2) the normal and tangential particle displacement was measured on the far surface using small piezoelectric and electromagnetic probes.
For (3) and (4) A-scans were measured while the probes were moving on a line on the specimens' surface.
All measurements were carried out with an ISSEL-manipulator and a Scan-Master equipment.

CALIBRATION

In order to compare the experiment and simulations the following calibration procedure was applied:
(1) for all through transmission experiments the maximum measured and the maximum simulated amplitudes in the base material are set on the same level.
(2) for all pulse echo experiments the maximum measured flaw signal amplitude and the maximum simulated flaw signal were set on the same level.
Figure 4 shows an example for the calibration of a single transmission experiment where both amplitudes are set on the same level with a maximum value of 1.0.

COMPARISON: EXPERIMENT - GPSS-SIMULATION

Figure 5 shows the result of a single through transmission experiment carried out in a weld metal pad containing columnar grains with an inclination of 7.5°. The particle displacement on the upper surface on two scan lines are compared with the GPSS prediction. In comparison with Figure 4 the skewing effect (skewing angle = 18°) and the beam spreading can be observed clearly (half the value width 36° for isotropic and 53° for transversely isotropic material).

Figure 5. Comparison of GPSS-Simulation with experiment.
The through transmission of an austenitic weld containing perpendicular weld flanks and parallel columnar grains is shown in Figure 6. The measured particle displacement and the one predicted are compared by EFIT. The strong skewing angle of about 45° can clearly be observed.

Figure 7 shows the v-through transmission carried out on an austenitic weld containing columnar grains perpendicular to the specimens' surface. The deviation between simulation and measurement in the amplitude dynamic curve is due to the fact that the EFIT code does not contain the material attenuation.

In the last example the EFIT simulation of the pulse echo experiment is compared with the measurement. Figure 8a shows the inspection situation with the simulated and measured A-scan for an austenitic weld containing perpendicular columnar grains and a notch with a depth half of the wall thickness. All significant pulses measured are also visible in the EFIT simulation.

By simulation and measurement of 264 single A-scans the amplitude dynamic curves for the notch tip and the angle mirror echo could be estimated as shown in Figure 8b.
Figure 8. a) Comparison of EFIT-simulated and measured A-Scan.
b) Comparison of EFIT-simulated and measured amplitude dynamic curve.
CONCLUSION

The demonstrated examples show that - except missing attenuation in the EFIT and GPSS code - the simulations correspond well to the experimental results. Both codes represent a good basis for further expansion of simulations on real austenitic welds containing curved columnar grains.

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