

Propagation Behavior of SH Guided Waves in a Tapered Plate

テーパ部を有する板中の SH ガイド波の伝ば挙動

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1. Introduction

The behavior of shear horizontal (SH) guided wave has been an interesting subject for decades since its aspects are intriguing and potential to be applied for nondestructive evaluation (NDE). Despite the popularity, most reported work on SH guided wave behavior is based on simulation such as scattering behavior around defects [1-2], while experimental investigation is rarely reported mainly due to difficulty in SH wave generation by conventional piezoelectric transducer [3].

Smooth dents and defects are often found in pipeline failure. Our research group reported the application of SH guided wave for pipeline inspection [4]. Except for the fundamental mode, group velocity of SH guided waves is significantly affected by the thickness of waveguide and it will reach zero at a critical thickness, which we call the cut-off thickness. The conversion to lower mode is expected in that situation. Thus, we have proposed a new method of ultrasonic NDE method based on the group velocity change of SH guided waves. Here, we study the influence of the defect-edge smoothness on behavior of SH wave propagation. The fundamental (SH_0) and first asymmetric (SH_1) modes are chosen. The experimental works are verified by numerical simulation.

2. Experimental Setup

A periodic-permanent-magnet electromagnetic acoustic transducer (PPM-EMAT) was used to generate SH wave [3]. The specimens were three defective aluminum plates having dimension of

$1000 \times 200 \times 3 \text{ mm}^3$ (length \times width \times thickness). The dimension of defect was $100 \times 100 \times 1.7 \text{ mm}^3$ for all specimens, and the edge of defect was smoothly tapered by 0° (step edge), 30° , or 5° , assigned as specimens 1, 2 and 3, respectively. SH_0 and SH_1 modes were generated and propagated in each specimen. **Figure 1** shows the measurement setup. The high-power rf bursts were applied to the generator EMAT. Depending on the driving frequency and the magnet periodicity, a particular mode can be generated. The propagating waves are detected by a needle-type piezoelectric sensor (pinducer), which was manually moved point-wise along the measuring line. The received signal was sent back to the superheterodyne spectrometer (RAM system) to be further processed.

3. Results and Discussion

Figure 2 shows the typical wave forms detected by the pinducer for each mode. Intended signals are the first arriving ones, denoted by mark ovals. **Figure 3** shows a 2D representation of SH_0 and SH_1 modes propagating in specimen 3, with color indicating the amplitude. These figures are derived from typical signals shown in Fig. 2 and display propagation distance versus time. The slope corresponds to the group velocity and dashed lines indicate edges of defect. In all figures, the intended waves are the first signals. In addition to the intended wave, there exist some other waves following it. They show the same slopes with those of the first direct waves, indicating that they are also the SH mode.

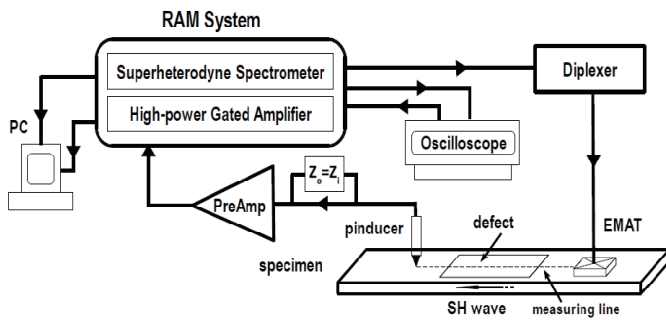


Figure 1 Measurement setup

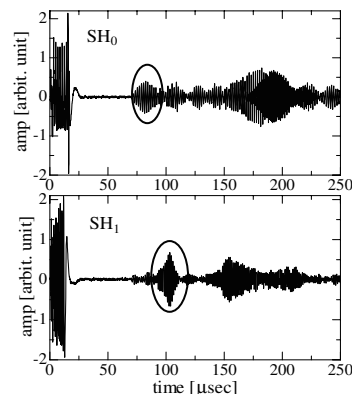


Figure 2 Typical signals for SH_0 and SH_1 modes

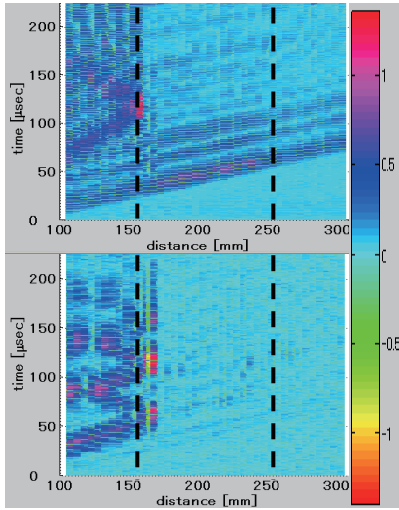


Figure 3 SH₀ (up) and SH₁ (bottom) modes propagate in specimen 3, represented in 2D. Dashed lines indicated the edges of defect

The physical form of pinducer is a cylindrical rod with piezoelectric transducer located in the bottom face. A conically-shaped needle provides contact between pinducer and the specimen. Those later signals experience a longer distance being compared to the first direct one since they also propagate back and forth inside the pinducer.

When the SH₀ mode is generated, other modes having smaller group velocity are also generated, which are most probably Lamb waves. When SH₁ mode is generated, SH₀ mode is also generated with much smaller amplitude, as indistinctly seen. This is due to imperfectness of the magnet periodicity in the EMAT since it is a hand-made.

The SH₀ mode is less reflected in the near edge as the edge is smoother. In specimen 1 with the step edge, the SH₀ mode converts to SH₁ mode after the edge, indicated by larger slope. This mode conversion is related with displacement redistribution, as depicted in **Fig. 4**. This behavior is not observed in specimen 3. In this specimen, the SH₀ mode propagates through the defect smoothly with measured group velocity of 3.1 mm/μsec.

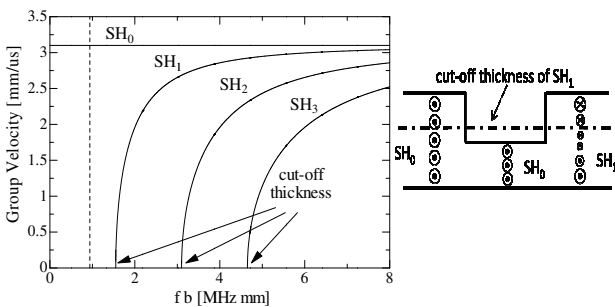


Figure 4 Dispersion curve of SH guided modes in aluminum plate of 3 mm thick with dashed line indicating the operating line of the present experiments.

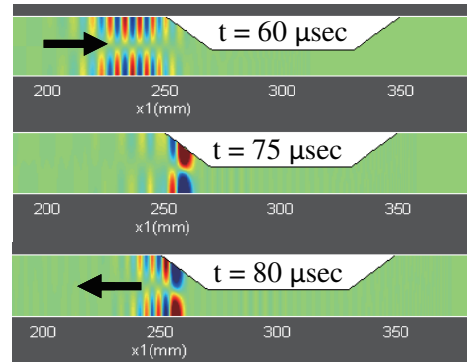


Figure 5 Snapshots of SH₁ mode propagation

The SH₁ mode shows the different behavior. The smoother the edge, the more it is reflected back. In the defective region of specimen 1, the SH₁ mode converts to SH₀ mode since the remaining thickness of the defected region is smaller than the cut-off thickness of SH₁. Figure 4 shows the group velocity dispersion curve of SH guided wave; the dashed line denotes the operating line in the defective region. It is clear that in this region, only SH₀ mode exists so that SH₁ mode should convert to SH₀ mode. It then converts back to SH₁ mode after the defect. These mode conversions are indicated by the slope changes in each region which corresponds to group velocity of 1.82 mm/μsec, 2.79 mm/μsec, and 1.71 mm/μsec, respectively. In specimen 3, all part of SH₁ mode is reflected back, leaving no propagating wave into the defected region as can be seen in Fig. 3.

Figure 5 shows cross-sectional view snapshots of SH₁ mode propagation obtained from FEM simulation. Arrows denote the propagation direction. Similar to specimen 3, the edges of defect are inclined by 5°. The thickness is enlarged for easier observation. The results of both experiment and simulation agree with each other. Simulation result reveals that the wavenumber of SH₁ mode is modified along the slope and it reaches zero when the thickness equals the cut-off thickness. At this point, the SH₁ mode has zero group velocity and reflection to the opposite direction occurs to satisfy conservation of momentum. In addition, high energy accumulation is observed there.

References

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