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Detection of micro-defects by acoustic waves propagating in topographic waveguide

トポグラフィック導波路を伝搬する超音波による微小欠陥の検出

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1. Introduction

Bearing rollers, which are indispensable to automobiles and robots, have become smaller in diameter over time. However, the conventional brazing method for depositing a sintered cemented carbide to a jig surface whose width is several millimeters to prevent abrasion has a high failure rate. Therefore, we are developing a new jig which was deposited cemented carbide directly on a jig substrate by using direct energy deposition (DED) which is one of three-dimensional (3D) printing methods (additive manufacturing, AM). On the other hand, non-destructive inspection of the thin jig is required to confirm the reliability. We are also developing an inspection technique of the jig by laser ultrasonics (LU) and detected spontaneously occurring cracks under the surface of the deposited layers.[1] The surface to be inspected in the jig can be regarded as a convex waveguide and is called a topographic waveguide[2]. In this study, we used LU to analyze the acoustic field of the scattered waves of defects in the topographic waveguide.

2. Experimental Setup

Fig. 1a shows a schematic diagram of the specimen. Carbon steel (JIS: S50C) was processed into a shape of jig substrate. In the actual jig, the tungsten carbide is deposited on a 1.5 mm wide surface, but in this study, a specimen without the tungsten carbide was used. A hole of 0.3 mm in diameter with a 1 mm depth was made on a 1.5 mm wide surface to simulate defects. To generate an acoustic wave, a solid-state laser was used. The frequency of excitation was 4 kHz and the energy was 8 μJ. The laser beam focused on a spot diameter of approximately 0.1 mm. The scan area shown in Fig. 1b on the specimen was scanned point-by-point with the laser beam to generate acoustic waves. To detect acoustic waves, laser Doppler vibrometer (LDV) was used. The laser beam (probe) of LDV was fixed at one point for each defect, respectively. This LDV was designed to detect displacements on a flat surface, and the frequency range was from 50 kHz to 20 MHz. The output of the LDV was amplified with a 25 dB pre amp and a 22 dB power amp, and then averaged 65536 times with a digital oscilloscope before being imported into the PC.

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2. Experimental Results and Discussion

Based on our previous FEM calculations[3], a schematic drawing of acoustic waves propagating in the topographic waveguide is expected to look like Fig. 2. Acoustic waves generated by a point source spread out in a circle (Fig. 2a), and waves reflected by the walls also propagate in a longer direction (Fig. 2b) and eventually propagate as guided waves (Fig. 2c).

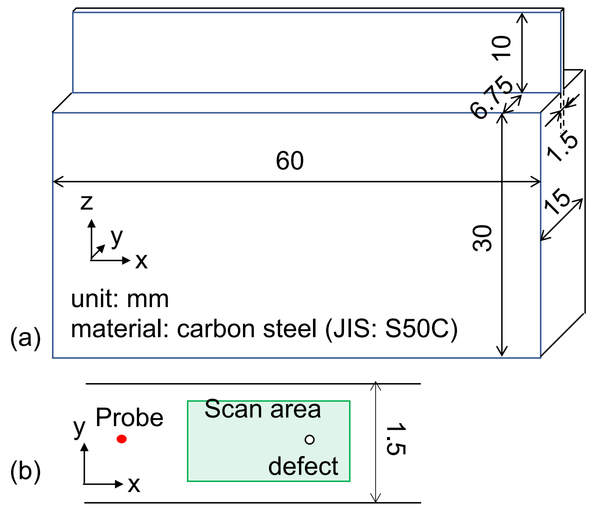

Fig. 1 Image of specimen and experimental setup

Fig. 3 shows the experimental results with a defect of $\phi 0.3$ mm, where the frequency range was 1.6 to 26, obtained by a complex discrete wavelet transform using an $m = 4, 3$ real-imaginary spline[4]. The x and y coordinate values indicate the irradiation position of the laser beam for generation. Generated wave propagating in the $+x$ direction, reflected waves following it, and scattered waves propagating in the $-x$ direction are observed. The defect is expected to exist around $x \cong 1.5$ mm from the position where the scattered wave was generated. It is also observed that the amplitude of the generated wave decreases beyond the defect. It can be seen that the reflected waves propagate faster than the generated wave and approach it. If we assume that the velocity of surface acoustic wave is about 3000 m/s, the wavelength is about 0.3 mm. Therefore, it is considered that a defect of about the wavelength was detected.

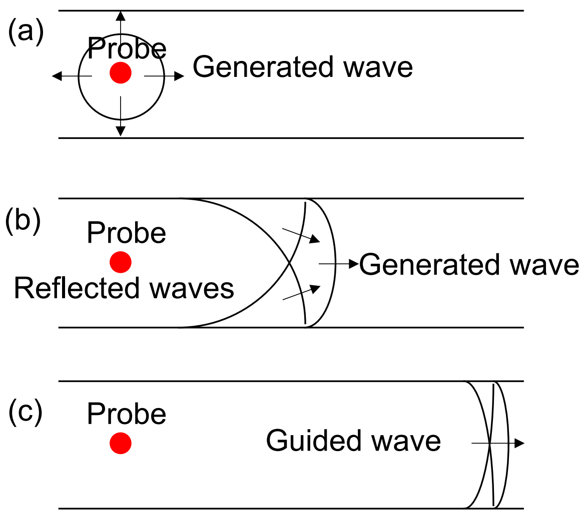

Fig. 2 Image of acoustic waves propagating in topo-graphic waveguide

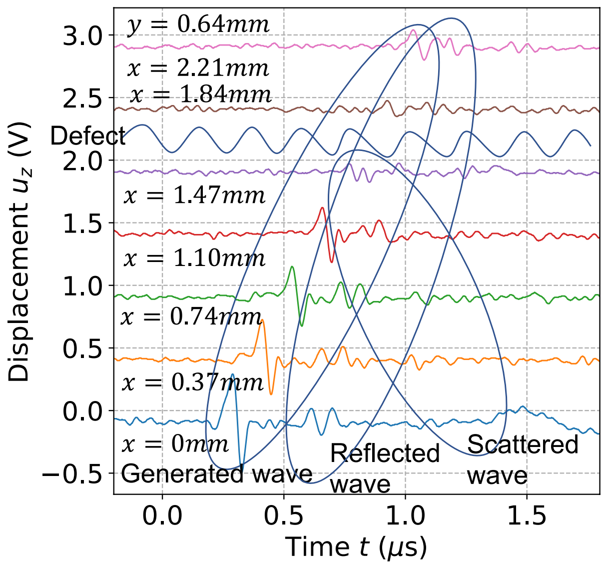

Fig. 3 Acoustic waves propagating in in topo-graphic waveguide

Fig. 4 shows the displacements at $t = 0.628$ μs (Fig.4a) and $t = 0.878$ μs (Fig.4b). Due to the reciprocity, the ultrasonic wave is generated at the irradiation position of the LDV probe and appears to propagate in the $+x$ direction.[5] Generated and reflected waves are observed in Fig. 4 a and b, and scattered waves from the defect are also observed in Fig. 4b. The separation of the generated and reflected waves confirms that this experiment was conducted to detect the defect in the region shown in Fig. 2b.

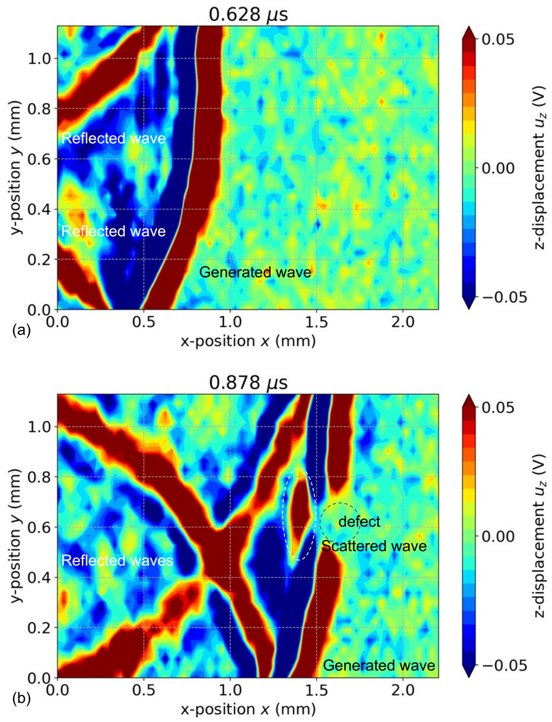

Fig. 4 Acoustic field around $\phi 0.3$ mm-defect

3. Conclusions

The authors have visualized the acoustic field in the near-field region of a topographic waveguide and successfully detected scattered waves from a $\phi 0.3$ mm defect.

Acknowledgment

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