Detection of flaws on metal surfaces using tone burst laser ultrasound

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1. Introduction

Metal surface flaws can be detected using the frequency transmission characteristics of surface acoustic waves (SAW). In addition, noncontact, remote detection can be made possible by using laser ultrasound. So far, broadband SAW generated by a single generation laser has been used for surface flaw detection[1]. Results have shown that the SAW transmitted across a slit of depth 0.5 mm showed a large decrease in frequency components over 1 MHz. Higher frequencies are needed to detect shallower slits, but the frequency spectrum of SAW generated by a single generation laser cannot be controlled. As a consequence, SAW of higher frequencies could not be selectively generated, and detection of shallower slits has not been difficult.

The frequency of SAW can be controlled by using tone burst SAW, which can be generated using multiple generation lasers[2]. In this research, tone burst SAW generated using 8 lasers is used for detection of artificial slits on metal specimens.

2. Experimental Apparatus

A schematic diagram of the laser ultrasonic system for generation of tone burst SAW is shown in Fig. 1. The system consists of 8 generation lasers (wavelength 532 nm, maximum pulse energy 120 mJ, repetition rate 20 Hz), a photorefractive interferometer (wavelength 1064 nm, peak output 500 W, repetition rate 20 Hz), and optics for focusing the laser beams on the specimen surface. The frequency of tone burst SAW can be controlled by adjusting the timing of firing of the generation lasers. The tone burst SAW is detected at a point 50 mm away from the nearest generation laser beam by the interferometer.

An example of the tone burst SAW waveform is shown in Fig. 2(a). Here the peaks corresponding to SAW generated by adjacent generation lasers was set to $T=400$ ns. The frequency spectrum of the waveform, obtained by FFT, is shown in Fig. 2(b). The maximum peak appears at the fundamental frequency $f_0=1/T=2.5$ MHz and local maxima appear at the harmonics $2f_0$ and $3f_0$.

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3. Surface slit detection

The detection ability of tone burst SAW was evaluated using specimens with artificial slits. The specimen material was SUS316, and the size is shown in Fig. 3. Three specimens with slit depths \( d = 0.2, 0.4, 0.6 \) mm, and one specimen with no slit were fabricated. The generation lasers and detection laser were spaced 50 mm apart, and the slit was placed near the midpoint.

![Fig. 3. Specimen and configuration used in the surface slit detection experiments.](image)

Tone burst SAW waveforms obtained using each specimen, for fundamental frequencies \( f_0 = 1, 2, 4 \) MHz are shown in Fig. 4. Each of the waveforms represent an average over 100 laser shots, and have been filtered using a frequency filter centered at \( f_0 \) in order to eliminate noise. The time \( t=0 \) corresponds to the firing of the first generation laser. In Fig. 4(a), no change in the amplitude with respect to slit depth can be observed, which shows that \( f_0 = 1 \) MHz is too low to detect slits of depth \( d \leq 0.6 \) mm. In Fig. 4(b) the amplitude has decreased dramatically for \( d \geq 0.4 \) mm, and in Fig. 4(c) the amplitude has decreased dramatically for \( d \geq 0.2 \) mm. These results show that the slit depth \( d \) can be inferred directly from the change in the amplitude of the tone burst SAW. In contrast, when using broadband SAW, FFT is necessary.

4. Conclusion

Tone burst SAW was generated using 8 lasers. The fundamental frequency of tone burst SAW could be controlled in the range 1-4 MHz. Tone burst SAW was applied to detection of surface slits on metal surfaces, which showed that a slit of depth 0.2 mm could be detected using tone burst SAW of fundamental frequency 4 MHz. The slit depth could be inferred directly from the change in the amplitude, without frequency spectrum calculation.

![Fig. 4. Waveforms of tone burst SAW for specimen with no slit, and for specimens with slit depth 0.2, 0.4, and 0.6 mm. The fundamental frequency is (a) \( f_0 = 1 \) MHz, (b) \( f_0 = 2 \) MHz, (c) \( f_0 = 4 \) MHz.](image)

References