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Discrimination of a crack in the Ultrasonic Spectrum signal of multi laser beams

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1. Introduction

A laser ultrasonic inspection system is a non-contact inspection device which generates and measures ultrasounds by using a laser beam. A laser ultrasonic inspection system provides a high measurement resolution because the ultrasonic signal generated by a pulse laser beam has a wide-band spectrum and the ultrasonic signal is measured from a focused small spot of a measuring laser beam. In this paper, we have studied a discrimination technique for a crack by a spectrum analysis of multi laser ultrasonic signals. We experimentally confirmed that the defect information can be extracted through observing the frequency of the attenuation variation of coefficients.

2. Configuration of the system

Fig. 1 is a schematic diagram of the configured laser ultrasonic inspection system. A pulse laser beam is divided into two directions by a beam-splitter. A beam in one direction is segmented to four parts by a grating. When the segmented beams are lighted to the object, then an ultrasonic signal is generated by a momentary heating-energy inflow. Generated surface wave propagates on the surface of the measurement object. Another direction beam is transmitted to computer through a trigger. CFPI (Confocal Fabry-Perot Interferometry) used to acquire an ultrasonic signal by using a frequency stabilized CW laser beam. The ultrasonic signal will be detected after the laser beam is demodulated by the CFPI. The computer converts the analog signals to digital signals by using a high-speed A/D converter.

3. Methods and Results

We used a pulse laser (Quanted-Brilliant) to generate ultrasonic. The energy of the pulse laser beam is about 10 to 100mJ. A CW laser beam is used to measure the laser ultrasonic signal. The energy of the CW laser beam is about 400 mW and the wave length is 532 nm. The coherence length is equal to or greater than 1000 m. An Al-6061 specimen is prepared for an experiment. The length of specimen is 150 mm, and width is 150 mm, and thickness is 10 mm. The surface of specimen is polished to reflect well the laser beam. Also, we artificially designed a crack on surface of specimen for the experiments. The width of crack is 100 ㎛, and depth is 100 ㎛. A pulse laser beams segmented by a grating are focused on the surface of an object. The experimental procedure to detect a surface-breaking crack is shown in Fig.2. The ultrasonic signal generated by a pulse laser beam propagates along the surface. Ultrasonic signal is received by the CFPI that uses a CW laser. As shown in Fig.2, that is no crack in Test 1, but there is a surface-breaking crack in front of the pulse laser beams, in Test 2. In the case of Test 3, the crack exists in the middle of pulse laser beams. The number of the four segmented laser beams is assigned from the front.

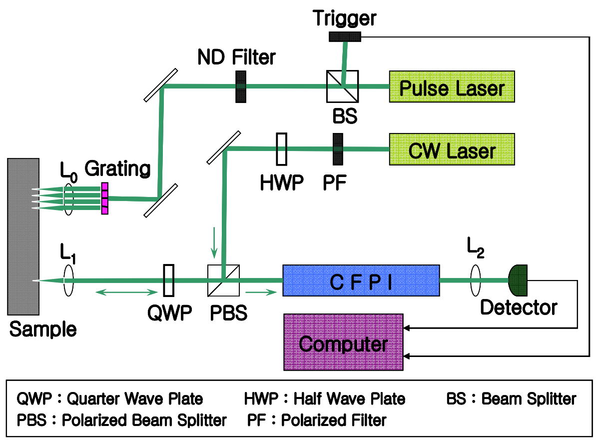

Fig.1. Configuration of the laser ultrasonic inspection system

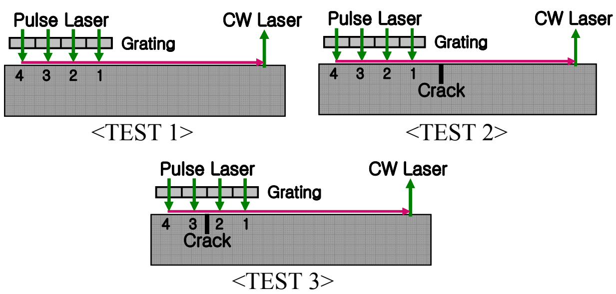

Fig.2. Experimental method

The measured surface waves of the laser ultrasound in the time domain are shown in Fig. 3. We can see the amplitude decrease in the ultrasonic signal which passes a surface-break crack. In the case of Test 1 that is no defect, the amplitude in four signals is greater than other cases. In the case of Test 2 that all multi-beams pass the crack, the amplitude of four signals is smaller than Test 1. In the case of Test 3 where the two beams of number 3 and number 4 pass the crack, the amplitude of the ultrasonic signal of number 3 and number 4 is decreased more than the value of number 1 and number 2.

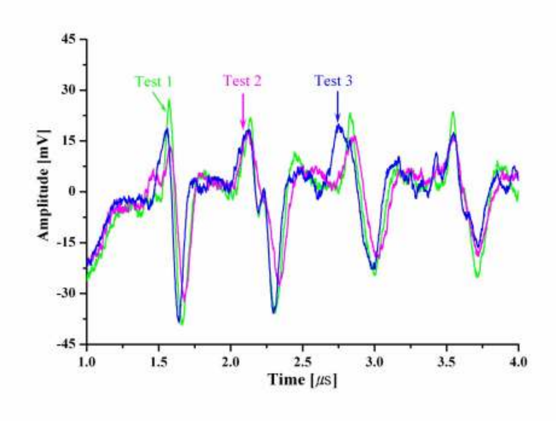

Fig.3. Comparison of received laser ultrasonic signals

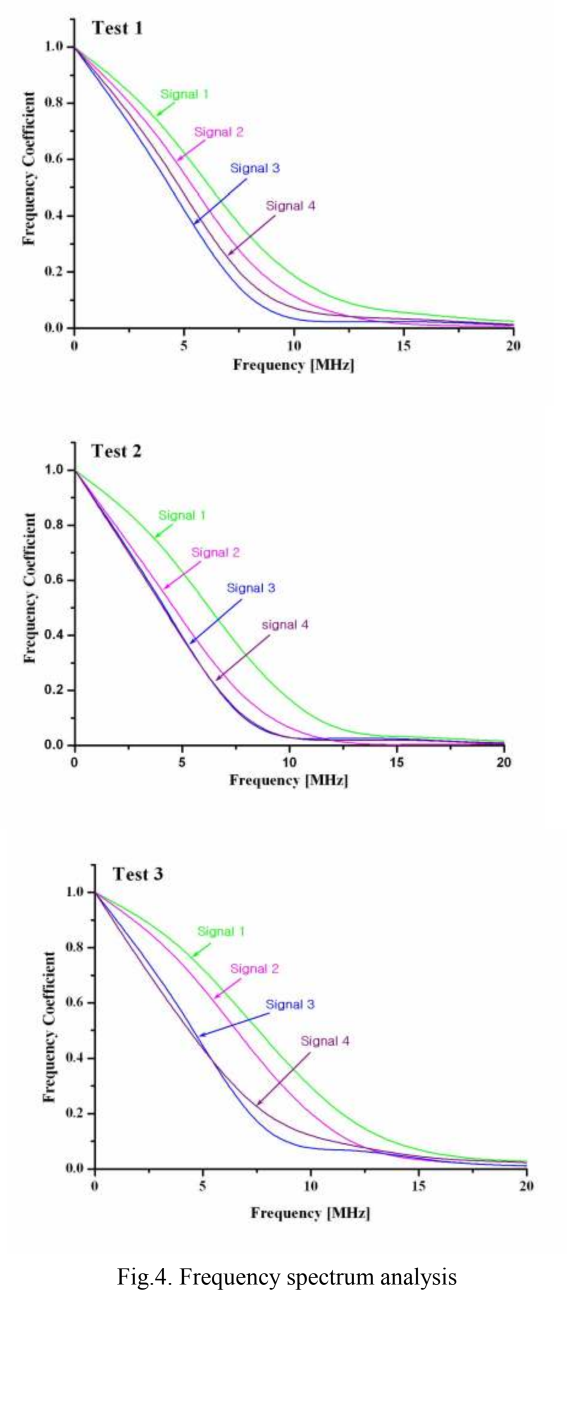

Fig.4. Frequency spectrum analysis

The surface wave spectrum of the laser ultrasound in the frequency domain is shown in Fig.4. We compared signal 2 with signal 3 because both signals affected by the crack. Test 1 show that both signals have a similar frequency band because these two signals did not pass the crack. Also, in Test 2, two signals show a similar frequency band because the two signals passed the crack. In the case of the Test 3 spectrum, when we compare both the signal 2 and signal 3 the frequency band is different because one signal passed the crack and the other signal did not passed the crack

4. Conclusions

This paper studied a crack detection method by using multi laser surface waves. The laser surface waves are generated by using multiple pulse laser beams, and those signals are measured by using a laser interferometer with a continuous wave (CW) laser beam.

From the experimental results, we could confirm that the discrimination of a crack is possible by observing the variation of the frequency coefficients. The amplitude and high frequency components in the frequency spectrum of the laser surface waves are decreased by the crack.

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