Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Detection of a Surface-Breaking Crack by Using the Surface Wave of a Laser Ultrasound

Seung-Kyu Park[a], Sung-Hoon Baik[a], Hyun-Kyu Jung[a], Young-Sang Joo[a], Hyung-Ki Cha[a] and Young-June Kang[b]
[a] *Korea Atomic Energy Research Institute, Dukjin-Dong 150, Yusong, Daejon 305-353, Rep. of Korea*
[b] *School of Mechanical Engineering, Chonbuk National University, Duckjin-dong 1ga, Duckjin-gu, Chonju, Chonbuk, 561-576, Rep. of Korea*
skpark4@kaeri.re.kr

1. Introduction

A laser ultrasonic system is a non-contact inspection device with a high spatial resolution and a wide-band spectrum. Also it provides absolute measurements of the moving distance and can be applied to the hard-to-access locations with curved or rough surfaces like a nuclear power plant[1]. Several laser ultrasonic techniques are applied for the detection of micro cracks in a nuclear power plant[2,3]. Also, laser ultrasonic techniques are used to measure the grain size of materials and to detect cracks in railroads and aircrafts[4,5].

Though the laser ultrasonic inspection system is widely applicable, it is comparatively expensive and it provides a low signal-to-noise ratio when compared to the conventional piezoelectric transducers. Many studies have been carried out to improve the system performance. One of the widely used measurement devices of a ultrasound is the Confocal Fabry-Perot Interferometer(CFPI) with a dynamic stabilizer. The dynamic stabilizer improves the stability of the CFPI by adaptively maintaining the optimum working status at the measuring time of the CFPI[6].

In this paper, we have investigated the detection methods of the depth of a surface-breaking crack by using the surface wave of a laser ultrasound. We have fabricated a laser ultrasonic inspection system on an optical table by using a pulse laser, a CFPI with a dynamic stabilizer and a computer. The computer acquires the laser ultrasound by using a high speed A/D converter with a sampling rate of 1000 MHz. The dynamic stabilizer stabilizes the CFPI by adaptively maintaining it at an optimum status when the laser ultrasound is generated. The computer processes the ultrasonic signal in real time to extract the depth information of a surface-breaking crack. We extracted the depth information from the peak-to-valley values in the time domain and also from the center frequencies of the spectrum in the frequency domain.

2. The laser ultrasonic inspection system

The hardware configuration of a configured laser ultrasonic inspection system on an optical table is shown in Fig. 1. We configured a laser-based ultrasonic inspection system by using a personal computer with a high-speed data acquisition board(AL81G, ALI) whose sampling rate is 1000 MHz and a multifunction board (PCI9112, ADLink), a pulse laser (Quantel-Brilliant), a stabilized CW green laser and a CFPI(CFT-500, Buleigh, FSR 150MHz). The computer controls a 2-D translator(ATS212-M, Aerotech Inc) through the Ethernet communications by using a LAN port. We configured a high-speed and high-gain APD sensor(C3090E, PerkingElmer) to acquire the transmitted ultrasonic signal of the CFPI. The optimum period of the pulse laser is 10 Hz and the FWHM of a pulse laser beam is about 10 ns.

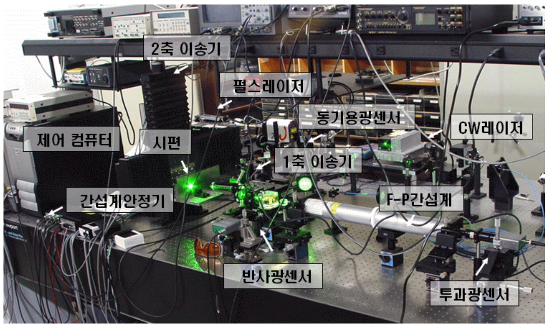

Fig. 1 Photograph of a configured laser ultrasonic inspection system

The ultrasound is generated when a pulse laser beam is targeted on to the surface of an object. Then, the CFPI measures the surface displacement caused by the ultrasound at the target position of a CW laser beam.

3. Experiments for the detection of a surface-breaking crack by using the surface wave of a laser ultrasound

We artificially designed crack samples on stainless steel 316 for experiments. The crack depths are 100 um to 500 um with the same width of 300 um. The experimental set-up to detect a surface-breaking crack is shown in Fig. 2. A line-shaped pulse laser with the length of 7 mm is used to generate ultrasound with a strong directivity. The CFPI measures the ultrasound passing a surface-breaking crack. The measured ultrasound is the differential value of the surface movement where the measuring laser beam is pointed. The distance between the pulse laser beam and the measuring laser beam is about 40 mm. There is a surface-breaking crack in the middle of the two laser beams as shown in Fig. 2.

The amplitude and the high frequency component of the measured ultrasound are decreased in proportion to the depth of a surface-breaking crack.

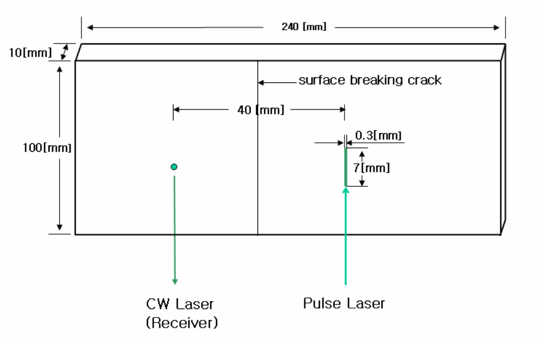

Fig. 2 Experimental configuration for the detection of a surface-breaking crack.

The peak-to-valley values in the time domain according to the depth of 0.0 mm, 0.1 mm, 0.2 mm, 0.3 mm, 0.4 mm, 0.5 mm are shown in Fig. 3. The peak-to-valley value is an averaged value from 40 ultrasound signals. As we can see in Fig. 3, the amplitude of the laser ultrasound is proportionally decreased according to the depth of a crack. But the decreasing rate is not linear like that of the piezoelectric transducer.

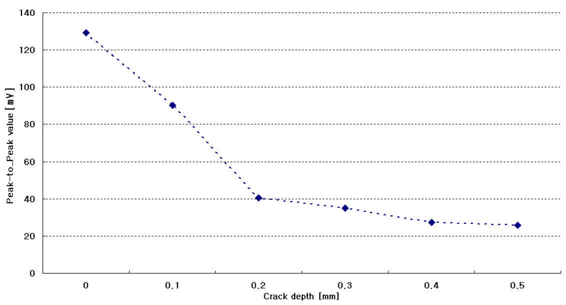

Fig. 3 Measured peak-to-valley values according to the depths of surface-breaking cracks.

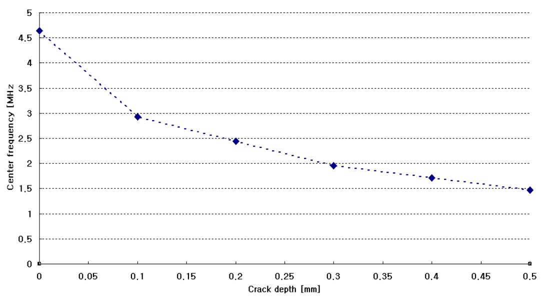

Fig. 4 Measured center frequencies of the spectrums according to the depths of surface-breaking cracks.

In this paper, we also extracted the centroid of the ultrasound spectrum in the frequency domain to get the depth information of a crack. The higher frequency components are more highly decreased in proportion to the deeper crack depth. Also, the center frequency value of each ultrasound spectrum is decreased in proportion the crack depth.

The extracted center frequency from each ultrasound spectrum according to the depth of a surface-breaking crack is shown in Fig. 4. The center frequency is also an averaged value from 40 ultrasound spectrums. We can clearly see that the value of the center frequency is proportionally decreased according to the crack depth. When we compared the experimental results between Fig. 3 and Fig. 4, the observation method of the center frequency in the frequency domain is more efficient than the peak-to-valley value in the time domain to measure the depth information of a surface-breaking crack.

4. Conclusion

We have investigated the measuring methods of the depth information for a surface-breaking crack by using the surface wave of laser ultrasound. As for the experimental results, the value of the center frequency in the ultrasonic spectrum provided more precise depth information than the peak-to-valley value in the time domain

REFERENCES

[1] C. B. Scruby and L. E. Drain, “Laser Ultrasonics : Techniques and Applications,” Adam-Hilger, New York, (1990)

[2] M. Ochiai, N. Mukai, Y. Sano and H. Nakano, Compact and robust inspection system for micro cracking detection using laser-induced surface waves, 10th International Symposium on Nondestructive Characterization of Materials, Karuizawa, Japan, June 2000

[3] T. Miura, M. Ochiai, H. Kuroda, S. Soramoto and S. Kanemoto, Laser-induced surface wave testing: a new method for measuring the depth of cracks, ICONE-9, Paper No. 312, April, 2001

[4] S. Kenderian, B. B. Djordjecvic and R. E. Green, "Point and line source laser generation of ultrasound for inspection of internal and surface flaws in rail and structural materials," Res Nondestr Eval, Vol. 13, pp. 189-200, (2001)

[5]M. Z. Silva, R. Gouyon and F. Lepoutre, "Hidden corrosion detection in aircraft aluminum structures using laser ultrasonics and wavelet transform signal analysis," Ultrasonics, Vol. 41, pp. 301-305, (2003)

[6] R. J. Dewhurst and Q. Shan, Modelling of confocal Fabry-Perot interferometers for the measurement of ultrasound, Meas. Sci. Technol., Vol. 5, pp. 655-662, (1994)