Nondestructive Evaluation of Wedge-Shaped Surface Defects by Photoacoustic Microscopy

Haruo Endoh, Naoki Ohtaki†, Yoichiro Hiwatashi and Tsutomu Hoshimiya (Tohoku Gakuin Univ.)

1. Introduction

Since the photoacoustic microscopy (PAM) has been revealed effective for the detection of the surface, internal and through defects, in which the detection is difficult in the conventional inspection method, the nondestructive detection with it has been expected to play a key role to evaluate the size, the shape and the position of the defect and the crack, and to evaluate the direction of the crack extension. The wedge-shaped defect in which the depth changed with the surface length of the defect is a suitable simulated defect for evaluation. In this paper, three kinds of the defect were used as specimens, and the configuration of the wedge-shaped surface defect was detected, and the gradient of the wedge was quantitatively evaluated by the phase information obtained with PAM.

2. Experimental Apparatus and Specimen

The basic arrangement of the PAM system constructed for this experiment is the same as that described in a previous publication. The specimens used in the experiments were pure aluminum plates with the dimension of $40 \times 40 \times 10$ mm and set in the photoacoustic (PA) cell. The surface defect considered was a slit-type simulated defect with a wedge shape, whose maximum depth was fixed to be approximately 0.3 mm. The surface defect with a width of 0.3 mm was introduced into the specimen by mechanical processing (inclined end-mill cutting). The length ($l$) of the surface defect was 1.0, 1.5 and 3.0 mm, respectively. The defect shape is shown in Fig. 1. The dimensions in the figure are all nominal values.

A scanning laser microscope (SLM) was used to measure the defect shape and gradient ($\tan \theta$) of the surface defect bottom. The measurement of defect depth, length and gradient coincided with the nominal value approximately.

3. Experimental Results and Discussions

The experiments were carried out at different modulation frequencies, and the data at 54Hz only were shown here for comparison.

Fig. 2 shows the phase image obtained at the modulation frequency of 54 Hz for the specimen for the wedge-shaped surface defect with a length of 1.0 mm and the measured area was 1.5 mm× 1.5 mm. Bright and dark areas correspond to phase advance and delay regions, respectively. Since amplitude and phase signals are coupled in a complex variable in PAM measurement, those areas correspond to PA amplitude strong and weak regions in ref. 2, respectively. A bright areas aligned at the center of the phase image were observed in
Fig. 2(a), which corresponds to the surface defect with wedge shape. In this image, the deepest position of the surface defect with wedge shape was placed to locate at the lower part of the figure. Fig. 2(b-1) shows the phase signal distribution on the A-A’ line of the phase image in Fig. 2(a). In this figure, it is found that the difference of the defect depth is clearly shown in the phase signal distribution. The phase delay is large at the position of maximum depth. As the wedge-shaped defect is shown by the signal distribution, the estimation of the surface defect shape is possible. Fig. 2(b-2) shows the phase signal distribution on the B-B’ line of the phase image in Fig. 2(a). In this figure, it is found that the difference at the gradient of those signal distributions exists. In order to evaluate phase variation with position, the phase changes per unit length for the three specimens were calculated from Fig. 2(b-1), Fig. 3(b), and the result were 1.9, 4.7 and 5.4 (degree/mm), respectively. As the result, it was shown that the linearity between the gradient obtained from the PA signal distribution and gradient of the nominal value.

**4. Conclusion**

In this study, PA signals were processed to measure the inclination of wedge-shaped surface defects. It was possible to estimate surface defects with a complicated shape and to find the difference between the gradient of wedge-shaped surface defect. As the result, the gradient of the wedge-shaped defect calculated from PA signal distribution showed good linearity with respect to gradient of the nominal value for the fabricated surface defect.

**References**