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Nondestructive Evaluation of Weld Defect by Photoacoustic Microscopy and its Destructive Inspection using Replica

光音響顕微鏡による溶接欠陥の非破壊評価およびレプリカを用いた破壊検査

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1. Introduction

In many structural components, such as aircraft, automobile and electronic product, the welding technology is used widely with various welding techniques. In a welding junction, deformation and various weld defects tend to occur by careless weld. Due to the necessity to inspect the existence and to estimate the shape of the defect to ensure the safety of the structure, the nondestructive inspection technique of the weld has become more and more important. The photoacoustic microscope (PAM)[1-3] has been revealed effective tool for the nondestructive detection of the surface, internal and through defects, in which the detection is difficult with the conventional inspection method.

In this study, the welded specimen was fractured by forced bending in order to measure the size and shape of the defect in the weld directly. To gather the information on the internal defect, the measurement of size of the weld defect and shape was carried out using the replica technique. The analytical result of the replica specimen obtained by the destructive inspection was compared with the obtained photoacoustic (PA) amplitude image.

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.[3] The specimens used in the experiments were aluminum plates. The aluminum specimen sampled from welded plates was chosen to include the weld defect. Two 45 degree-cut aluminum plates with the dimension of 25 mm×40 mm and a thickness of 4 mm were welded along y-direction as shown in **Fig. 1(a).** Fig. 1 (b) shows conceptual view of internal weld defect and measurement direction by PAM. For the measurement of the internal defect shape, silicone rubber was poured into the specimen to contact the fracture surface, which was formed by compulsory destruction, and the replica specimen of the internal defect was manufactured. **Fig. 2** shows the photograph for the specimen surface of the

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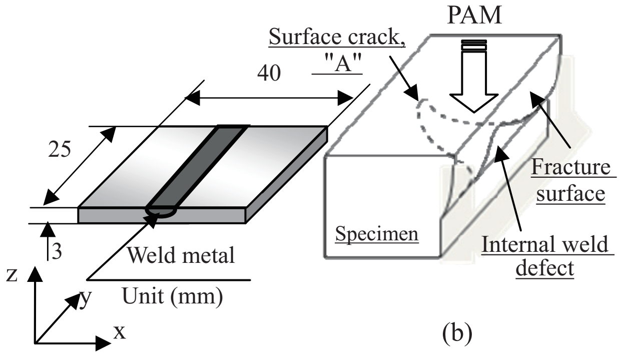


Fig. 1 (a) Schematic drawing showing specimen preparation and (b) Conceptual view of internal weld defect and measurement direction by PAM.

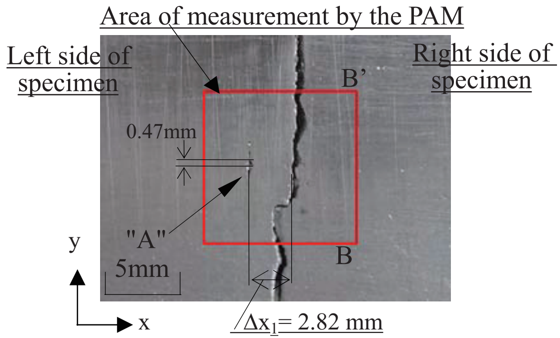


Fig. 2 Photograph of the specimen surface.

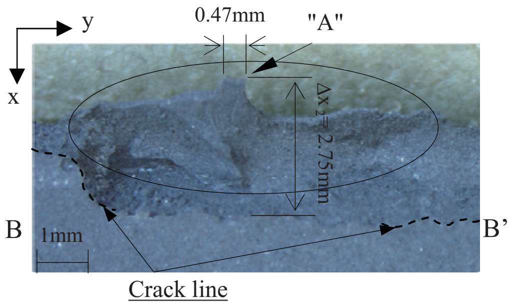


Fig. 3 Photograph of the replica specimen including the internal defect in the fracture surface of left side specimen.

condition where the fractured specimen was butted. The region surrounded in the square was measured by the PAM. Weld internal defect exists for the specimen of left side. The arrow "A" in Fig. 2 is a surface crack. Symbol B and B' in Fig. 2 and Fig. 3 is being written in order to help the direction of the figure. A laser displacement measuring instrument was used for the measurement of the internal defect shape of the replica.

3. Experimental Result and Discussions

Fig. 3 shows the photograph of the replica specimen including the internal defect in the fracture surface of left side specimen. The elliptically surrounded region is the internal defect of the replica. The arrow "A" in Fig. 3 is the positions which internal defect reaches to the specimen surface. The distance from the position where fracture surfaces were butted to the arrow "A" was about Δx_1=2.82 and Δx_2=2.75mm in Fig. 2 and 3, respectively. Therefore, it is found that "A" shows the same position and its length is about 0.47mm.

A bird's-eye view of the internal defect in the replica specimen obtained by the laser displacement measurement is shown in **Fig. 4**. The arrow "A" in Fig. 4 shows a position same as it in Fig. 2 and 3. From Fig. 4, it can be discerned that the internal defect shape is complicated.

The experiments by the PAM were carried out at different modulation frequencies to obtain the depth profiling by changing the thermal diffusion length. **Fig. 5(a)** shows the PA amplitude image obtained at the modulation frequency f of 12 Hz for the specimen for the weld defect and the measured area was 10.0 mm× 10.0 mm. The thermal diffusion length at a modulation frequency of 12 Hz is about 1550 μm. A bright area at the center of the PA amplitude image in Fig. 5(a) shows the weld defect and its shape. Then, it is proven that the defect shape estimated from the PA image shows the almost same shape for the result obtained from Fig. 3 and 4 in the replica specimen. In addition, from PA signal distribution in Fig. 5(b), the distance from the position which butted fracture surface to the arrow "A" is approximately 2.84mm. From this fact, it is found that the defect shape obtained from the PAM image and the defect shape obtained from the replica specimen are almost with the same dimensions.

Fig. 6(a) shows the PA amplitude image obtained at the modulation frequency of 90 Hz for the same specimen with the internal weld defect. Fig. 6(b) shows the signal intensity distribution on line C-C' of the PA amplitude image in Fig. 6(a). The thermal diffusion length is approximately 566 μm. From both figures, most of the internal defects were not detected and it is found that only defect formed by butting the fracture surface and surface defect ("A") was detected.

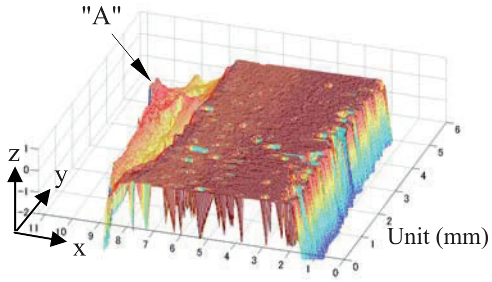
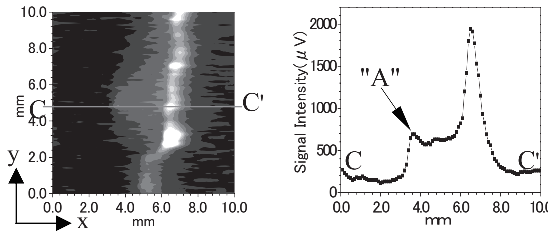
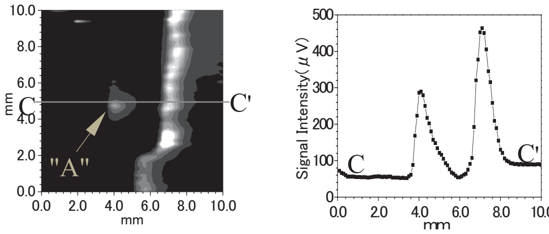


Fig. 4 Bird's-eye view of the internal defect in the replica specimen.



(a) Amplitude image (b) Signal distribution line C-C'

Fig. 5 PA amplitude image and signal distribution for the specimen with internal weld defect (f= 12Hz)



(a) Amplitude image (b) Signal distribution line C-C'

Fig. 6 PA amplitude image and signal distribution for the specimen with internal weld defect (f= 90Hz)

4. Conclusion

In this study, replica technique was carried out for the measurement of the internal weld defect of the welded specimen. Both the shape measurement of the obtained replicated weld defects and nondestructive measurement by PAM were performed. As a result, the size of the weld defect obtained by both methods almost agreed in dimension.

References

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