1P2-14

Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 63-64
20-22 November, 2013

Inspection of Thick Structure using Beam Steering Phased Array for Complex Surface
複雑形状に対応したビーム制御方式フェーズドアレイ UT による厚板構造材探傷

Setsu Yamamoto[‡], Jun Semboshi, Takahiro Miura, Makoto Ochiai,
Tadahiro Mitsuhashi, Hiroyuki Adachi and Satoshi Yamamoto (Toshiba Corporation)
山本摂[‡]，千星淳，三浦崇広，落合誠，三橋忠浩，安達弘幸，山本智 (株式会社　東芝)

1. Introduction

Phased array ultrasonic testing (PAUT), which can vary its refraction angles and focal points by pulsing multiple elements of a probe separately, has been applied to many targets as a superior alternative technique for conventional single element probe testing[1]. However, it was known that applying PAUT to components with complex surface geometry was difficult because setting of the probe on the surface or the control of emitting angle was complicated. To solve this problem, several PAUT technologies have been developed. Major countermeasures are probe shape deformation using a flexible probe[2] and ultrasonic beam control[3]. Toshiba has developed a ultrasonic beam control PAUT technology combined with easily formable gel (soft shoe) as propagation medium[4]. This has an advantage of exploiting exisiting and proven array probes.

In this paper, the authers confirmed the detectability of this technique using a thick walled specimen with a structure simulating a part of boiling-water reactor (BWR) atomic power plants.

2. Principles

In the inspection of our system, two steps are needed before inspection: surface profile measurement and calculation of delay time depending on the surface profile. In the surface profile measurement, ultrasonic wave is transmitted sequentially by each element that composes an array probe. Reflected ultrasonic wave on the measurement surface is received by all elements (from “element 1” through “element n”). Then, a set of n×n signals will be acquired. Intensity of reflecting waves from material surface is visualized by the synthesis aperture focusing technique using these wave signals. This method provides surface profile measurement with higher precision.

A schematic diagram of controlling ultrasonic beam to inspect partly dented surface is shown in **Fig.1**. In this figure, solid lines show trajectories of successfully emitted ultrasonic beam. Dashed lines represent trajectories of ultrasonic beam emission due to the existence of curved surface .In the case of conventional PAUT, the delay time is controlled under an assumption that the surface is flat. Therefore the refraction angle deviates from the right direction shown as the dashed line in Fig. 1 (a) because the ultrasonic beam is emitted with the same control of delay time as that for a flat surface. In this case, inspection refracting angles should be changed in accordance with the surface profile shown in Fig.1 (a). The authors have succeeded in transmitting the ultrasonic beam into the material in the right direction by properly controlling the delay time corresponding to the surface profile. In this technology, firstly the focal point and inspection refracting angle are determined, then the incident point and optimum incident angle are uniquely determined. Lastly the ultrasonic beam driving elements are selected so that the driving elements are located on the line that is calculated backward from the focal point in light of the surface profile. This method makes it possible that ultrasonic beams in the material are parallel to each other as shown in Fig.1 (b).

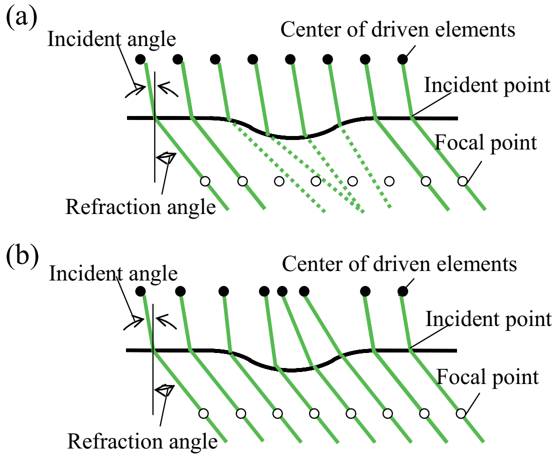

Fig. 1 Concepts of beam steering: (a) beam forming of conventional PAUT, (b) beam forming of this system.

e-mail address: setsu.yamamoto@toshiba.co.jp

3. Experiment

3-1. Experimental Setup

Figure 2 shows a schematic diagram of a PAUT system and a thick walled specimen. A detector, an array probe and a control PC are depicted. The detector (T-PA256(3D) manufactured by Toshiba) has 256ch pulse generators and receivers. A 2-MHz, 128-elements, 1.5-mm pitch and R 500 mm focus shaped array probe was adopted. All signal processing and evaluations were conducted by the control PC. The specimen simulated a bottom part of the reactor pressure vessel (RPV) of BWR plants. The maximum thickness was 170 mm and the bottom was cladded 8 mm thick by welding. The curvature radius of the surface of the specimen was R2522 mm. A leg piece was jointed by welding at the center of the specimen bottom. The material of RPV part and leg was carbon steel and cladding and welding were with Ni based alloy. A stress corrosion cracking (SCC) with 20 mm depth was artificially fabricated in the corner of the welded area. The array probe was located the opposite side of cladding and SCC.

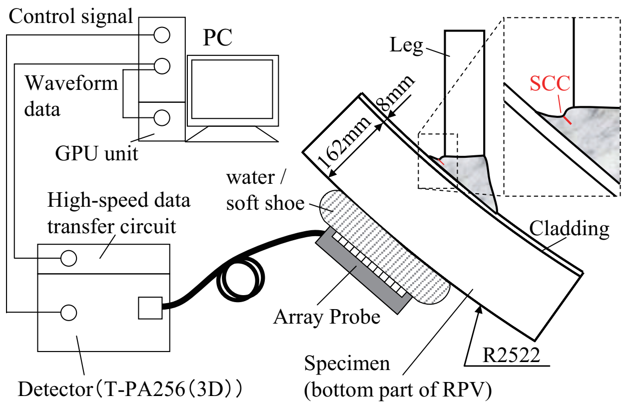

Fig. 2 Experimental setup of the system.

3-2. Experimental Result

Measurement results of the SCC were shown in **Fig. 3**(a) and (b). Testing condition was as follows; the number of driving elements was 32, refraction angle was 15 degrees and focal depth was 180 mm. Probe was placed with 80 mm water gap. Fig. 3(a) shows the B-Scope image using conventional PAUT and Fig. 3(b) shows the B-Scope image using this system. Circled areas of each image show echo from the SCC. In Fig. 3(a) SCC echo was observed at one point. This result shows conventional PAUT is capable of SCC detection but the SCC size measurement is difficult. On the other hand, in Fig. 3(b), echoes from SCC were observed at two points. The left echo showed the opening corner of the SCC and right echo meant the tip of the SCC. Measuring the distance of each echo, the depth of SCC was estimated to be 16 mm. Comparing the result with the nominal depth of the artificial SCC (20 mm), obtained measurement error was 4 mm. This value is highly accurate for the case of thick target and the SCC which is located in Ni based alloy. It would appear that the ultrasonic beam of conventional PAUT was distorted by curved surface while angle fixed ultrasonic beams with shape adaption were uniformly propagated through the testing area. Therefore bottom echo shape of Fig. 3(b) retrieved the bottom surface better compared with Fig. 3(a).

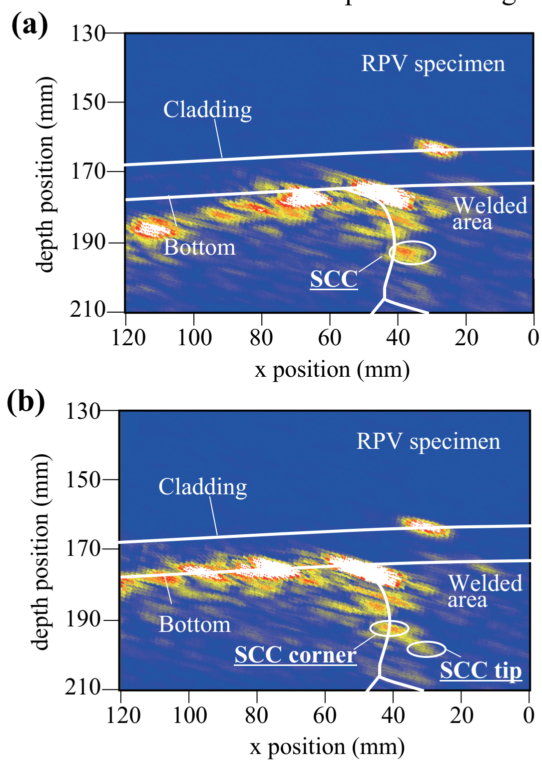

Fig. 3 Measurement result of the SCC: (a) B-Scope image of conventional PAUT, (b) B-Scope Image of this system.

4. Conclusions

The Authors have developed a shape adaptive ultrasonic beam control PAUT system and easily formable soft shoe. Using the system, SCC fabricated in a welded area of thick walled spherical specimen was measured. Separated crack corner and tip echoes were clearly observed. This system showed the capability of more precise crack evaluation.

References

1. I. Komura, S. Nagai, H. Kashiwaya, T. Mori and M. Arii: Nuclear Engineering and Design **87** (1985) 185.
2. S. Mahaut, O. Roy, C. Beroni and B. Rotter: Ultrasonics **40** (2002) 165.
3. R. Long and P. Cawley: AIP Conference Proceedings **894** (2007) 814.
4. S. Yamamoto, J. Semboshi, M. Ochiai, T. Mitsuhashi and S. Yamamoto: Proceedings of JSNDI Spring Conference (2012) 19.