# Development of New Accurate Flaw Depth Sizing in Ultrasonic Nondestructive Inspection

## Background

Ultrasonic nondestructive inspection has been conducted for inner diameter flaws of piping in thermal and nuclear power stations. In recent years, not only flaw detection but also flaw depth sizing is required in primary loop recirculation systems in boiled water reactor-type nuclear power stations. The crack tip diffraction (CTD) technique and TOFD technique are well-known as accurate flaw depth sizing techniques. The CTD technique needs onerous tasks because beam path length of tip echo and corner echo has to be read, by moving a transducer. On the other hand, TOFD is straightforward for measuring the flaw depth, while TOFD is hardly applied to thick-wall, welded austenitic stainless steel whose thickness is over 30 mm. Detailed understanding of wave propagation behavior around a flaw provides an idea of a new accurate technique to resolve the issues noted above.

## Objectives

To understand wave propagation behavior around a crack precisely and develop a new accurate flaw depth sizing technique.

## Principal Results

### 1. Understanding of wave propagation behavior

(1) By scanning a 0-degree transducer for reception on a surface orthogonal to a surface where a transducer for transmission is positioned, wave fronts of shear and longitudinal wave were visualized experimentally. As shown in Fig.1, since wave propagation behaviors visualized by a computer simulation program, which was developed by CRIEPI [*1], were in excellent agreement with the relative experimental measurements, the efficacy of the program was firmly established.

(2) After incident wave from an angle beam transducer impinged a flaw tip, two wave fronts $L_1$ and $L_2$ traveling directly above the flaw with a time difference were observed in Fig.2. $L_1$ is the longitudinal wave diffracted at the flaw tip, and $L_2$ is the longitudinal wave reflected at the back wall.

### 2.Development of new depth sizing technique

(1) Echoes due to $L_1$ and $L_2$ were detected by a 0-degree transducer positioned directly above the flaw. A half of difference of beam path length between an $L_1$ echo and an $L_2$ echo corresponds to the flaw depth. By using this phenomenon, CRIEPI newly proposed an efficient flaw depth sizing technique named the “short path of diffraction (SPOD)” technique [*2]. (See Fig.3.) It is expected that SPOD has an advantage over CTD and TOFD, in that attenuations due to scattering or grain boundaries do not critically have an influence on the echo.

(2) SPOD was applied to depth sizing of fatigue cracks and stress corrosion cracks in austenitic stainless steel test blocks to which it is difficult to apply TOFD. The results revealed that accuracy of depth sizing by SPOD was equal to or more than CTD as shown in Fig.4 and listed in Table 1. Moreover, the time for measuring the depth by SPOD based on manual scans was reduced by a factor of five, in comparison to that by CTD.

## Future Developments

Optimal essential parameters in SPOD will be investigated.

***Main Researcher:*** Hiroyuki Fukutomi, Ph. D.,
Research Scientist, Structural Materials Characterization Sector, Materials Science Research Laboratory

***Reference***

H. Fukutomi, et al., 2006, “New Ultrasonic Examination Technique for Accurate Flaw Depth Sizing”, CRIEPI Report Q05003 (in Japanese)

＊1：CRIEPI Report, T03074 (2004)
＊2：Application for patent (July 6, 2005)

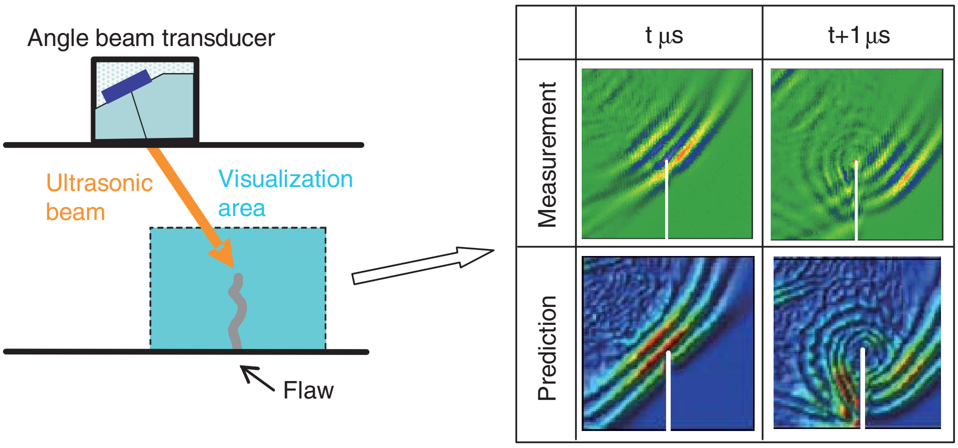


**Fig.1** Measured and predicted wave propagation behaviors around a slit

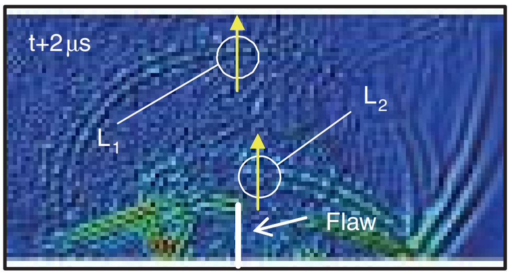


**Fig.2** Predicted wave propagation behavior

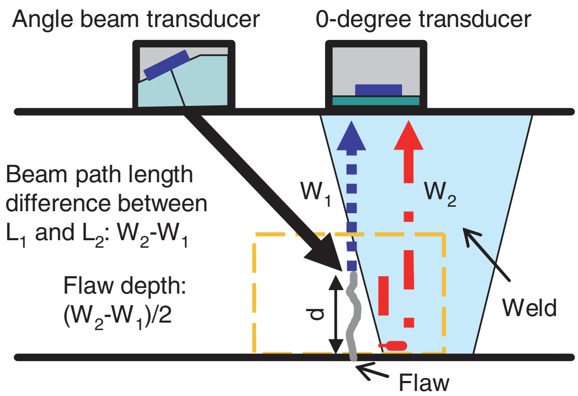


**Fig.3** Principle of SPOD

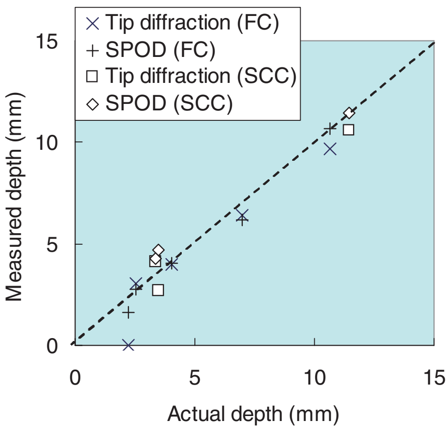


**Fig.4** Comparison between actual and UT measured depths

**Table 1** Root mean square errors of fatigue crack and stress corrosion crack

| | RMS error (mm) | |
|---|---|---|
| | Fatigue crack | Stress corrosion crack |
| CTD | 1.14 | 0.81 |
| SPOD | 0.46 | 0.86 |