Priority Subjects — **Further Improvement of Facility Operations and Maintenance Technologies**

# Development of Nondestructive Inspection Technologies for Components and Piping in Nuclear Power Plants

## Background and Objective

For the sake of appropriate maintenance and securing the safety of electric power facilities including nuclear power facilities, the nondestructive inspection of defects in metals used in such facilities is important.
In this project, optimum NDE technologies are developed for important components related to the safety of light-water reactors to enhance their operational safety. Meanwhile, the standardization and implementation of a PD system*1 for these technologies are also taken into consideration.

## Main results

### 1 Development of depth sizing technique of cracks in dissimilar metal welds

Inspecting dissimilar metal welds (DMW: joint of low alloy and stainless steels with nickel based alloy weld), such as vessel nozzle to piping welds, is extremely difficult due to the difficulty in the detection of a crack tip echo of SCC (Stress Corrosion Cracking). A technique for determining a crack shape using the reflection of ultrasonic waves at the surface of the crack via phased array technology*2 has been developed (Fig. 1). By using the technique, the identification of the crack tip echo from material noise becomes much easier and the crack depth sizing becomes more accurate.

### 2 Prototype of a virtual testing system for ultrasonic examination engineers

The skill of examination personnel usually influences the reliability of inspection results, particularly in manual ultrasonic testing (UT). For PD examination and the training of examination personnel, numerous test specimens with various defects are necessary. To reduce cost and improve the effectiveness of the training and PD examination, a prototype of a virtual UT system simulating actual UT work of piping welds was developed (Fig. 2); performing ultrasonic testing virtually on specimens without defects is possible because the system makes use of ultrasonic signals acquired from actual test specimens. The system provides the potential for effective training and examination (Q14007).

### 3 Modeling for initiation behavior of stress corrosion cracking for sensitized stainless steel

To establish a modeling for initiation behavior of stress corrosion cracking for determining an appropriate inspection interval, a calculation technique, which could evaluate crack depth distributions, has been developed for the simulation model based on coalescence and growth of micro cracks*3. Since calculations that reproduce experimental crack depth distributions have not been reported, crack depth distributions were calculated using this technique. Crack depth distributions obtained from the calculation, assuming that cracks start growing with constant growth rate when stress intensity factors at crack tips exceed a threshold value, conformed to a normal probability distribution and well reproduced experimental results for sensitized stainless steel*4 (Fig. 3) (Q14013).

*1 Performance demonstration system for ultrasonic examination.
*2 Ultrasonic phased arrays use multiple ultrasonic elements and electronic time delays to control ultrasound propagation by interference.
*3 K. Tohgo, H. Suzuki, Y. Shimamura, G. Nakayama, and T. Hirano, Corrosion Science, 51, 2208-2217, 2009.
*4 M. Akashi and T. Kawamoto, Boshoku Gijutsu, 32, 9, 1983.

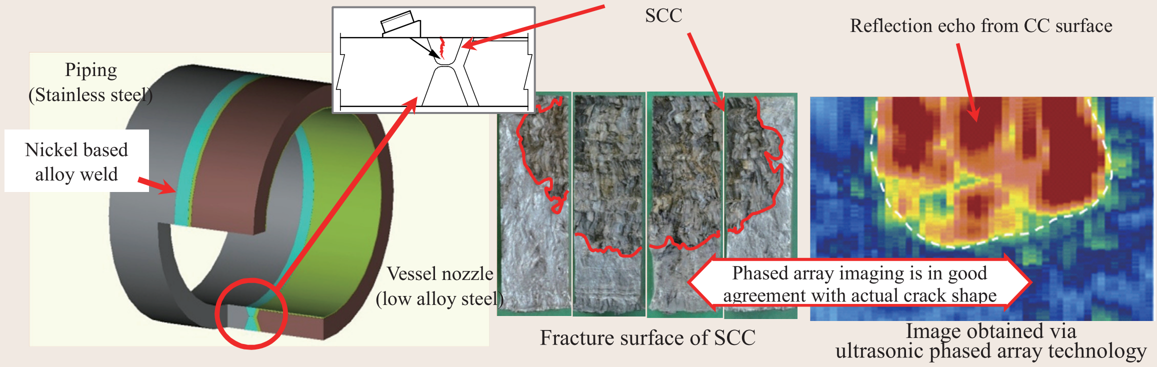
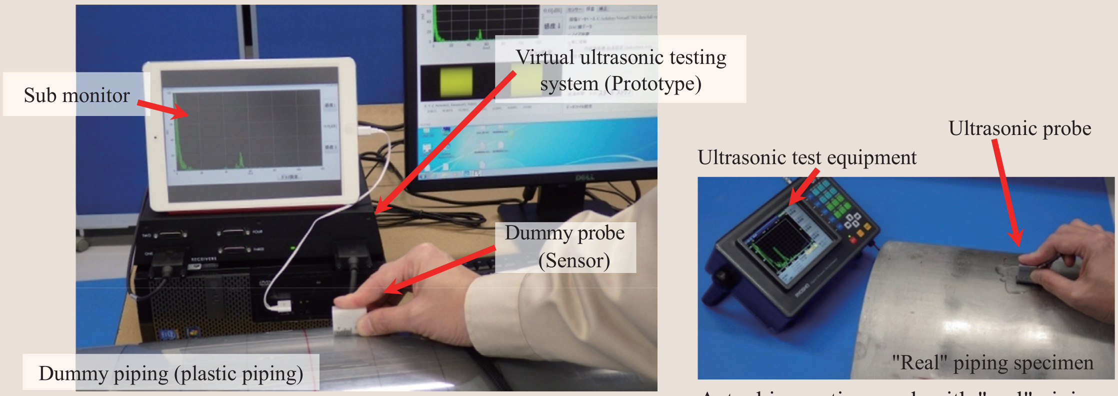



**Fig. 1: Comparison between actual shape of SCC and image obtained via ultrasonic test**

The identification of a crack tip echo from material noise becomes much easier by using the phased array crack shape imaging technique. This technique is helpful for improving the accuracy and the reliability of crack depth sizing of SCC in DMWs.

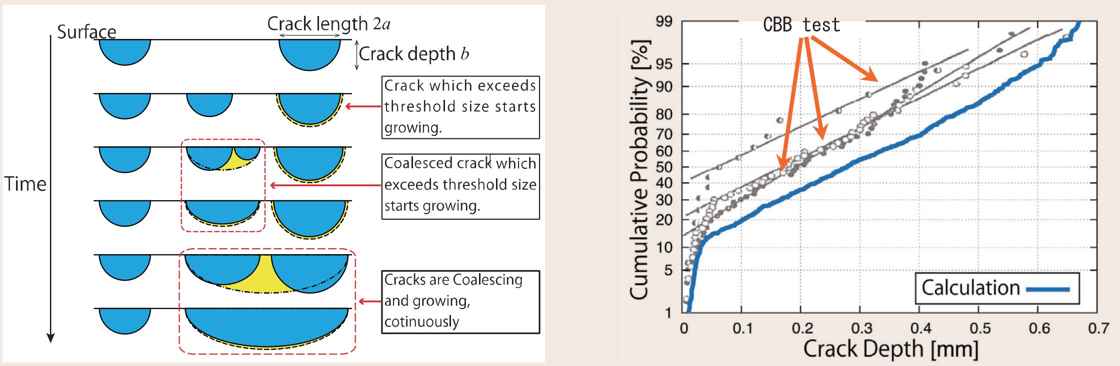



Overview of virtual ultrasonic testing system (Prototype)

Actual inspection work with "real" piping

**Fig. 2: Virtual ultrasonic testing system (Prototype)**

A prototype of a virtual ultrasonic testing system was developed which could display the ultrasonic waveform without time lag depending on the position of a dummy probe, skew angle and contact condition. This system provides the potential for effective training of examination personnel on a specimen without defects, which is similar to training performed on actual specimens. Further, the system can also simulate various cases by editing and modifying waveforms acquired from actual specimens.




A scheme of micro crack initiation, coalescence and growth process.

A normal probability plot of crack depth distributions at 100h.

**Fig. 3: Modeling for SCC with micro crack coalescence and growth**

The simulation adopted a model that randomly initiated micro cracks with constant aspect ratio b/a, which exceed a threshold size, and started growing at a constant growth rate. The calculated distribution well reproduced experimental distributions for sensitized stainless steel described by normal probability distributions with depths over 0.05 mm.