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

Research of Advanced Nondestructive Evaluation

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 the operation safety of light-water reactors. Meanwhile, standardization and implementation of a PD system*1 for these technologies are also taken into consideration.

Main results

1 NDE method development for fatigue cracks in embedded foundation bolts

Wave propagation in bolts was simulated to develop an ultrasonic phased array technology*2 for inspection and sizing of fatigue cracks in the embedded foundation bolts of nuclear power plants. Numerical results show that two peaks can be observed in the curve of echo intensity versus refraction angle. One of the peaks corresponds to the vicinity of crack tip and strongly depends on crack depth. This phenomenon is also verified by experiments. A conservative method for depth sizing of fatigue cracks is proposed by making use of this peak. The deviation between actual depth and determined value is smaller than 2 mm.

2 Elucidating initiation and growth behavior of stress corrosion cracking for low carbon stainless steels

A series of creviced bent beam tests for low carbon stainless steel was conducted to clarify the initiation behavior of SCC on PLR piping. The tests revealed that distribution of crack depth initiated on the CBB*3 specimen does not depend on a strained surface condition. In addition, the number of cracks greater than 20 μm depth (correspond to average depth of single grain) gradually increase with testing time in the early stage, then increase rapidly, as shown in Figure 2. The results indicate the possibility that crack depths greater than 20 μm is caused by coalescence of small cracks. Therefore, further investigation on the coalescence process is needed. (Q13008)

3 Effectiveness of the PD qualification system

PD Center has conducted PD examination of SCC depth sizing for nuclear power plant piping based on PD qualification code NDIS0603 of JSNDI*4. The result (44 out of 89 persons passed from March 2006 to January 2013) indicates that the passed candidates can size SCC depth with high accuracy (Fig. 3)[1]. This means the PD qualification system improved the reliability of crack depth sizing and contributed to the management and maintenance of nuclear power plants.

[1] H. Shohji et al., E-Journal of Advanced Maintenance Vol.4 (2013) 125-132

*1 Qualification and certification of personnel for performance demonstration of ultrasonic testing systems
*2 A technology possibly fires ultrasonic waves with different directions and focus positions by controlling transmission and reception timing of each individual elements in a phased array transducer.
*3 Environmental acceleration testing method by introduce crevice to the bended specimen.
*4 The Japanese Society for Non-destructive Inspection

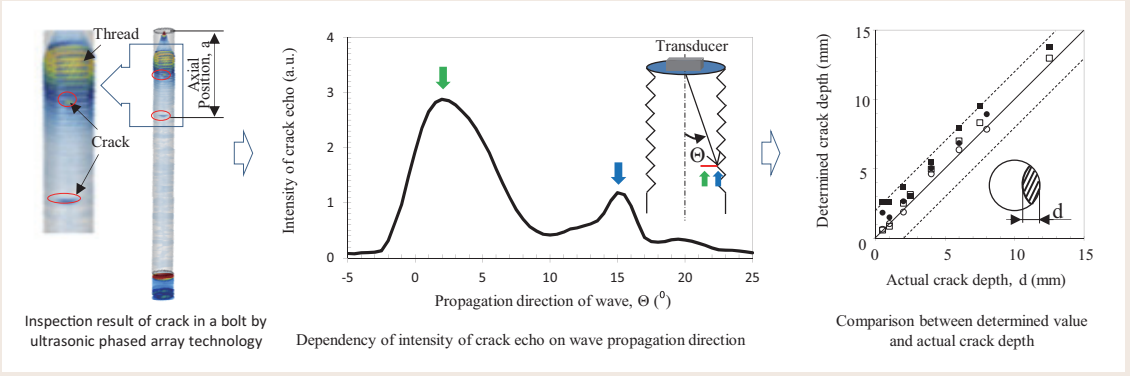

Fig. 1: Inspection and sizing method of cracks for embedded foundation bolts

It is possible to observe two peaks corresponding to the corner and the vicinity of a crack in a bolt when it is inspected by ultrasonic phased array technology (These two peaks overlap for a shallow crack). The peak resulted from the vicinity strongly depends on crack depth, therefore, the position of this peak can be used to determine crack depth.

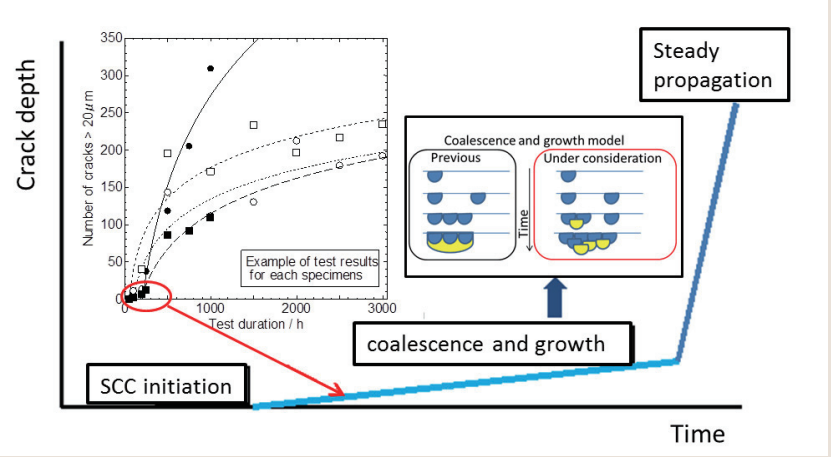

Fig. 2: Time dependence of crack depth (greater than 20 micrometers) for low-carbon stainless steel

Number of cracks greater than 20 mm in depth obtained by CBB tests for low-carbon stainless steel gradually increase at first, then increase rapidly. Previous model based on the coalescence process then growth is not able to explain the behavior of early stage. The results indicate the step by step coalescence and growth in early stage. Detailed investigation on coalescence and growth process is needed to clarify the SCC initiation and propagation behavior.

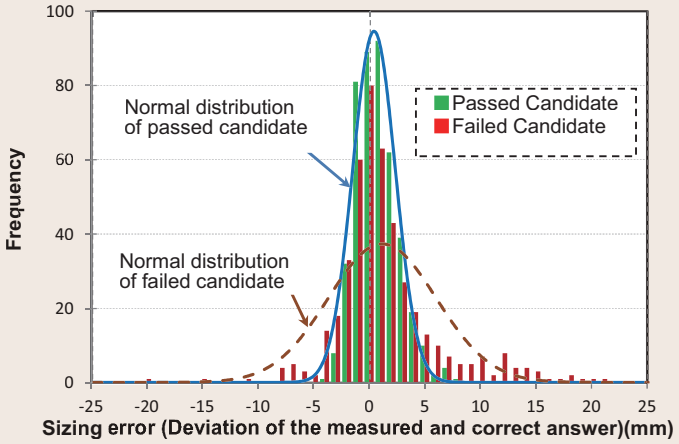

Fig. 3: Analysis of the PD examination results

The passed candidate can measure SCC depth in high accuracy (Average error: 0.33 mm, standard deviation: 1.92 mm). For a failed candidate, the average error is 1.05 mm and standard deviation is 4.87 mm.