Principal Research Results

Development of Multifunctional Ultrasonic Inspection System and Numerical Modeling of Wave Propagation for Detection and Sizing of Flaws in Field Pipes with High Accuracy and Efficiency

Background

It is reported that type IV cracks resulting from creep damage happened in weldment of thick-walled pipes in fossil fuel power plants. A technique for detection and sizing of the type IV cracks with high accuracy is proposed, where the TOFD and phase array techniques are applied simultaneously to distinguish flaws in heat affected zone (HAZ) from welding defects. On the other hand, in order to optimize testing conditions and increase the efficiency of probe design, it is necessary to precisely predict received signals. Therefore, a numerical model of wave propagation by the finite element method has been developed for traditional probes with only single PZT elements. However, this model is not applied to the prediction of received signals in the TOFD and phased array techniques.

Objectives

An ultrasonic inspection system is developed to detect thick-walled field pipes, and the accuracy of proposed technique for detection and sizing of flaws is also verified. Furthermore, the numerical analysis mentioned above is extended so that it can also be applicable to the prediction of received signals in the TOFD and phased array techniques.

Principal Results

1. Development of inspection system for field pipes

A multifunctional inspection has been developed as shown in Fig.1, which has a scanner comprised of a driving unit and probe holders. For the system, not only phased array but also various testing techniques can be applied to detection and sizing of flaws in circumferential welded pipes. The scanner is adjustable to outer diameters of 350 to 700mm. It takes data acquisition time one sixtieth that of conventional systems.

2. Verification of the proposed technique

By the proposed technique, simulated type IV cracks in HAZs have been distinguished from weld defects introduced artificially based on defect position (see Fig.2). As shown in Fig.3, the measured heights and lengths are sufficiently accurate. The RMS errors of height, length and position of simulated type IV cracks are less than 1.5mm, 5.4mm and 3.2mm, respectively. They are smaller than those values of ASME code requirements, which regulate the RMS errors of crack height and length, which are 3.2mm and 19mm, respectively.

3. Extension of numerical model

As shown in Fig.4, the effects of scattering at grain boundaries have been taken into account in the extended numerical model. Therefore, it becomes possible to predict UT signals much closer to the measured for various testing techniques including the TOFD and phased array techniques. By the numerical model, diffracted waves from crack tips are observed clearly as shown in Fig.5 and it is possible to predict UT signals quantitatively. Furthermore, it ends up being possible to optimize UT conditions and increase the efficiency of probe designing with the numerical model.

Future Developments

The developed ultrasonic inspection system will be applied to pipes in power plants. In the meantime, the numerical model developed will also be actively used to optimize UT conditions and probe designing.

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Reference

1. H. Fukutomi, et al., 2005, "Use of Ultrasonic Nondestructive Evaluation of Cracking in Thick-walled Pipes (Part 3)", Central Research Institute of Electric Power Industry Report Q04016 (in Japanese).
2. S. Lin, et al., 2005, "Development of Ultrasonic Testing Techniques for Welding Parts of Austenitic Stainless Steel (Part 2)", Central Research Institute of Electric Power Industry Report Q04015 (in Japanese).

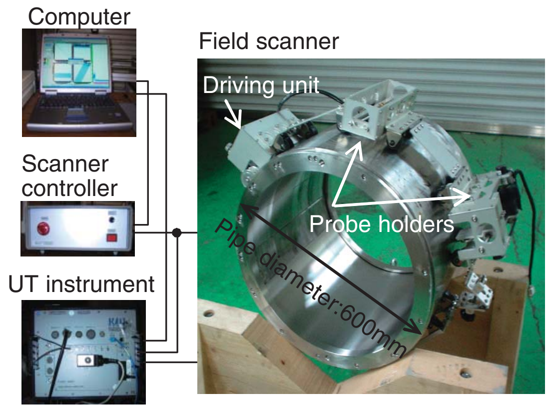

Fig.1 Configuration of ultrasonic inspection system

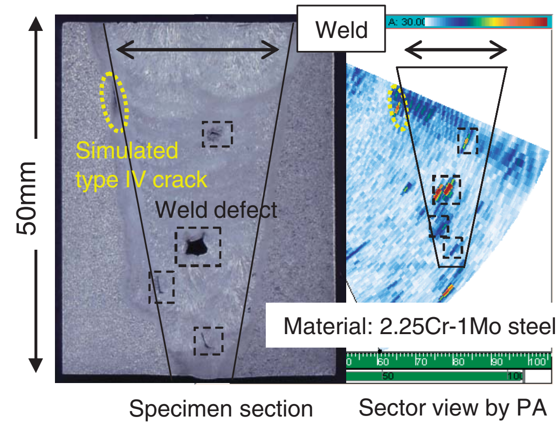

Fig.2 Simulated type IV crack and various weld defects

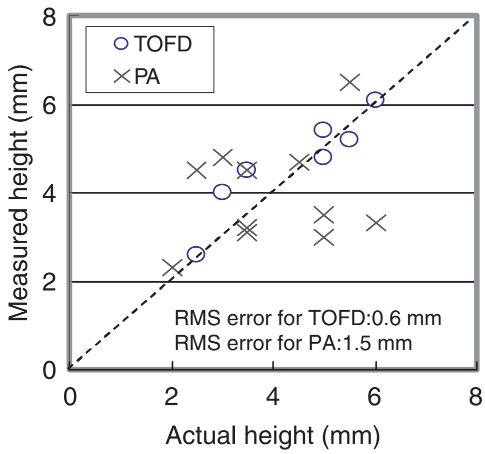

Fig.3 Measurement accuracy in defect height

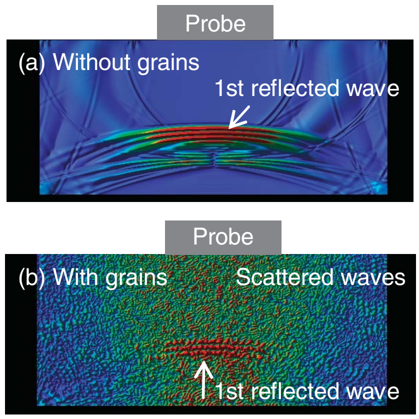

Fig.4 Wave propagation corresponding to various grain sizes

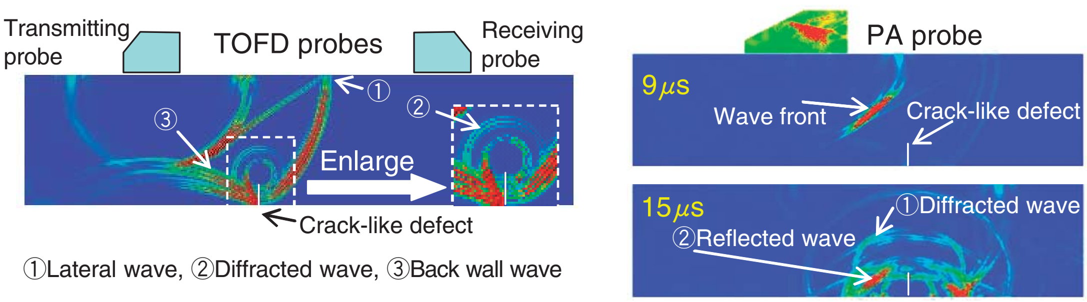

Fig.5 Wave propagation for TOFD and PA techniques