Development of Flaw Evaluation Method for Class 2 and 3 Light Water Reactor Piping

Background

The development of "flaw evaluation method" to determine whether detected flaws are acceptable for continued service has been addressed worldwide. In Japan, rules on fitness-for-service for nuclear power plants were revised and established for Class 1 piping [*1] by the Japan Society of Mechanical Engineers in 2002. The flowchart for the flaw evaluation method in the rules is shown in Fig. 1. It consists of two step evaluations; the first-step evaluation to compare characterized flaws by nondestructive examinations with the allowable flaw sizes, and the second step evaluation to compare propagated flaws with critical flaw sizes. On the other hand, Class 2, 3 piping [*1] are not normalized as flaw evaluation code in spite of their massive use in nuclear power plants. Consequently, the need for such criteria for Class 2, 3 piping is becoming more pressing. CRIEPI and Hitachi have promoted the cooperative study to develop flaw evaluation method for Class 2, 3 piping since 2000, and have put together technical basis to prepare rules on fitness-for-service.

Objectives

This study intends to develop the evaluation methods both for allowable flaw sizes and critical flaw sizes that form the basis of flaw evaluation method. Two types of moderate-toughness carbon steels typical of Class 2, 3 piping are used in the study.

Principal Results

1. Study on allowable flaw sizes

Using the failure assessment curve by which ductile crack initiation/propagation could be assessed, an approach to identify the allowable flaw sizes for acceptance standards was newly proposed. The approach provided comparable allowable flaw sizes with present standard for Class 1 piping. Allowable flaw sizes for Class 2, 3 piping were then derived based on the approach, which gave almost constant flaw depth for the pipe thickness larger than 10 mm (Fig. 2).

2. Study on unstable fracture evaluation

Cracked pipe fracture tests as well as finite element analysis and simplified fracture analysis by the reference stress method were conducted using moderate-toughness pipe materials typical of Class 2, 3 piping. The experimental and analytical results were reduced to the Z-factor [*2] (load correction factor) to predict fracture loads of cracked pipes. Fracture loads for Class 2, 3 piping were smaller than those for Class 1 piping, consequently Z-factors for Class 2, 3 piping were about 25% higher than those for Class 1 piping (Fig. 3).

Future Developments

The results obtained from the study are expected to be reflected on the rules on fitness-for-service for Class 2, 3 piping.

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Reference

Naoki Miura, et al., 2004, "APPROACH TO ESTABLISH FLAW EVALUATION METHOD FOR CLASS 2 AND 3 LIGHT WATER REACTOR PIPES," Proceedings of The ASME Pressure Vessel and Piping Conference, Volume 471, pp. 71-78.

＊1：Class 1 piping is the piping constitutes pressure boundaries; Class 2 piping is the piping related to safety equipments, and Class 3 piping is other piping. Class 1 piping usually shows relatively higher toughness, while Class 2, 3 piping fabricated from ferritic pipes has so-called "moderate-toughness."

＊2：Z-factor is the multiplier to the applied stress to determine a critical flaw depth for a given flaw length, and is defined as the Net-Section collapse load normalized by the fracture load. Once we formulate Z-factor as a function of pipe geometries, critical flaw sizes can be easily calculated.

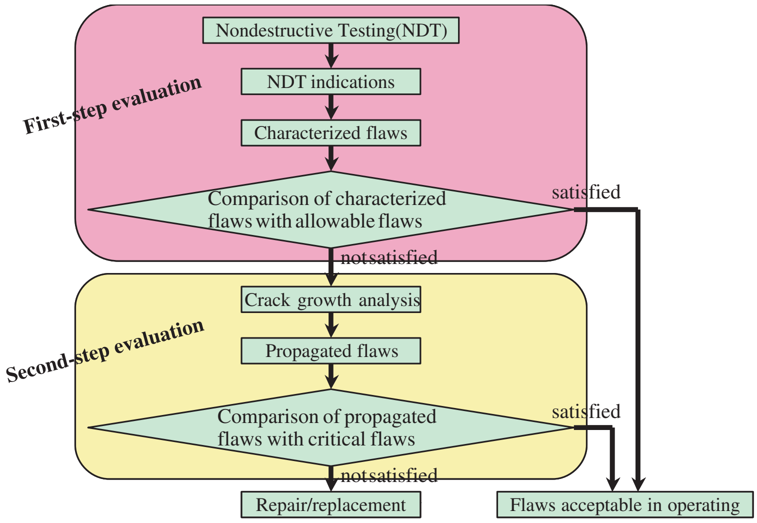

Fig.1 Flaw evaluation flowchart for Class 1 piping in current code

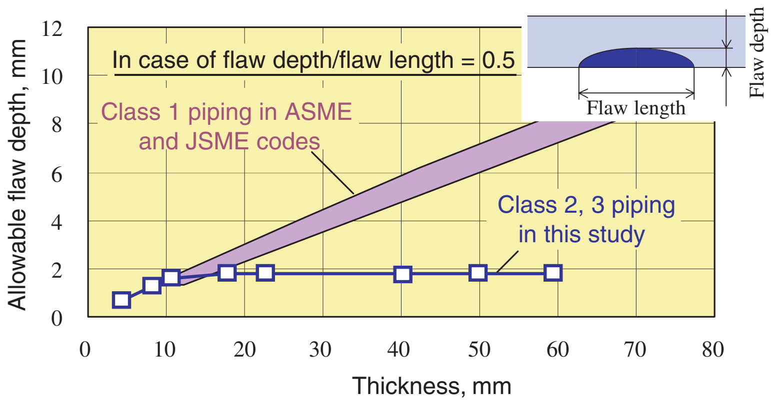

Fig.2 Comparison of allowable flaw depths for Class 1 and Class 2, 3 piping

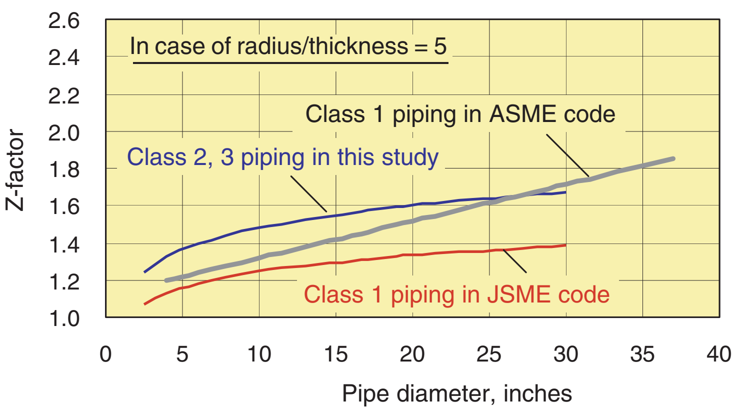

Fig.3 Comparison of Z-factors for Class 1 and Class 2, 3 piping