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

Development of Life Assessment Technology for High Temperature Structural Components of High Chromium Steels

Background and Objective

Ultra-supercritical (USC) pressure thermal power plants supply power with high efficiency and large capacity. However, trouble caused by creep*1 damage has occurred in various types of welded joints in the large-diameter high chromium steel (9Cr and 12Cr steel) pipes of such plants. Such trouble adversely affects the stable operation of USC thermal power plants. The establishment of highly reliable diagnostic technologies for high-temperature equipment made of high-Cr steel is required as a preventive measure. In this project, we aim to develop diagnostic techniques for assessing creep damage in girth welds and nozzle stub welds of the high-Cr steel pipes, which are both welds vulnerable to creep damage, and to apply the technologies to the on-site maintenance and operation of facilities.

Main results

1 Development of a method for estimating creep life of 9Cr steel welded joints considering welding conditions

A creep test was carried out at 650°C using 9Cr steel welded joint specimens with different properties, such as the angle of weld groove*2 and rewelding position, to estimate their creep rupture life under given stress conditions. The results indicate that a portion of 9Cr steel welded joints had a creep rupture life up to approximately 1/5 of that of standard joints. A method for estimating the creep rupture life using the angle of weld groove and rewelding position as parameters was also developed and applied to the estimation under the conditions adopted in the above creep test. It was confirmed that the developed method can be used to estimate the creep rupture life of 9Cr steel welded joints, which depends on the welding conditions, with a certain level of accuracy (Fig. 1).

2 Application of a nondestructive inspection technique for 9Cr steel girth welded joints

A bending-internal pressure creep test was carried out up to approximately 6500 hours using a 9Cr steel hot reheat pipe with a girth joint as a specimen. As test conditions, the temperature was 650°C and the ratio of circumferential stress to axial stress was 1:1. When approximately half the test duration (3500 h) passed, the test was ceased to inspect the specimen using phased array ultrasonic testing. As a result, faults considered to be creep damage were detected inside the specimen in the thickness direction (Fig. 2). It was suggested that nondestructive ultrasonic testing is effective for detecting faults inside 9Cr steel pipes with a girth joint in the thickness direction.

3 Proposal for a new index for creep damage, void cluster

The void number density is a typical conventional index for creep damage. However, its values measured in the latter half of the life of specimens were found to vary among individuals who measured the index. It was clarified that this variation was caused by unclear criteria for judging voids at the coalescence and integration stages (Fig. 3) (R14009). To solve this problem, we regarded a bunch of voids adjacent to each other at the crystal grain level as a void cluster and proposed it as a new index for creep damage. When creep damage on a 9Cr steel welded joint was evaluated using the void cluster, there was less variation in the evaluation results in the latter half of the life of the joint among individuals who measured the index (Fig. 4). In addition, a measurement technique based on image processing that adopted the void cluster as a criterion for identifying voids was developed. By applying the technique to the evaluation of creep damage on the 9Cr steel welded joint, a high repeatability of the measurement results was obtained and the measurement processing speed was improved.

*1 A phenomenon in which a material deforms over time when a certain stress is continuously applied to the material.
*2 A groove made on the mother material to be welded.

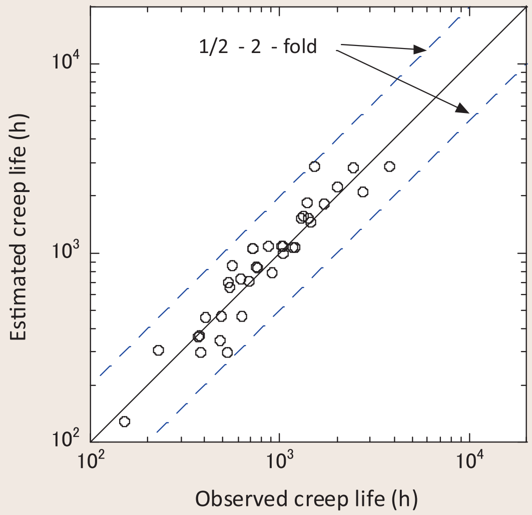

Fig. 1: Estimated results for creep life of 9Cr steel welded joint

The creep rupture life of the 9Cr steel welded joint, which depended on welding conditions, was estimated with a certain level of accuracy by considering the angle of weld groove and rewelding position.

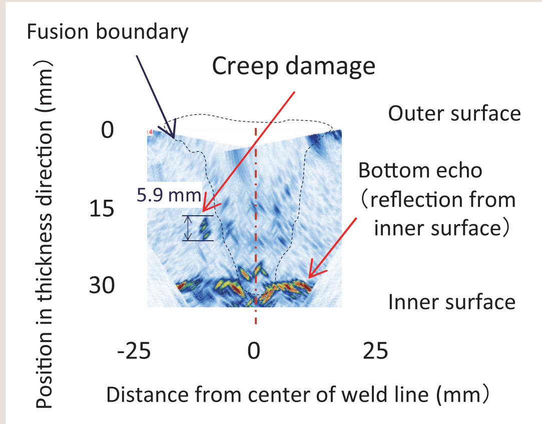

Fig. 2: Results of ultrasonic testing for 9Cr steel girth welded joint

Creep damage inside the joint in the thickness direction was successfully detected.

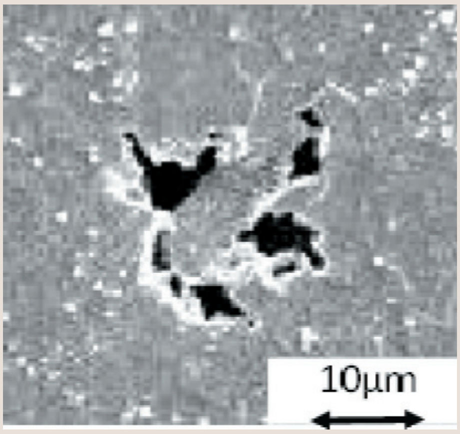

Fig. 3: Voids at coalescence and integration stage (9Cr steel)

Several coalesced and integrated voids are observed in the specimens in the latter half of their life. In the case of the above image, the number of detected voids was varied in the range of 1-8 among individuals who measured the index. Thus, the void number density depended on the individual involved.

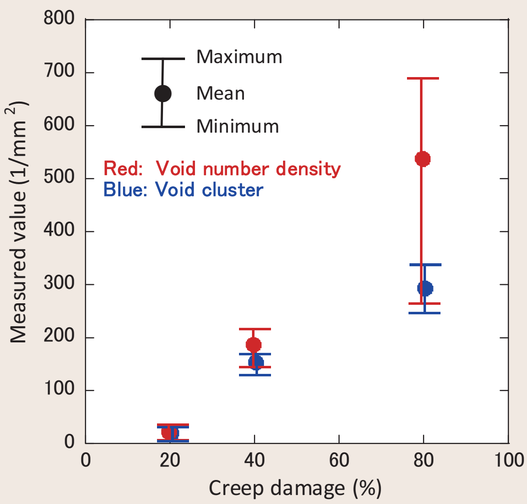

Fig. 4: Proposal of a new index for creep damage

The void cluster was proposed as a new index for creep damage that leads to less variation in measurements than the void number density. The maximum, mean, and minimum in the graph are the values obtained from the results of nine individuals who measured the index.