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, troubles caused by creep damage have occurred in various types of welded joints in the large-diameter high chromium steel pipes of such plants. Such troubles adversely affect 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 Creep damage mechanism of 12Cr steel pipe girth welds

In order to clarify the creep damage mechanism of high-Cr steel girth weld, a creep test was performed under superimposed condition of an internal pressure and a bending load. The specimen was a large-diameter pipe with the dimensions of actual piping made of 12Cr steel with girth welds. The creep test was interrupted to inspect the specimen when its deformation rate increased rapidly. A surface crack was observed in the girth weld where axial tensile stress was applied due to the bending load (Fig. 1). Detailed observation of cross-sections of the girth weld in the specimen revealed that creep cracks initiated inside the wall thickness of the pipe and the cracks propagated along the fine-grained heat-affected zone (HAZ) of the base metal.

2 Nondestructive inspection and life assessment of girth welds in 12Cr steel pipe

To establish maintenance technology for high-Cr steel girth welds, ultrasonic nondestructive testing (UT) was carried out on the 12Cr steel pipe welds before the pipe was cut. Creep cracks were indicated over a wide area in the girth welds of the pipe wall thickness. This result was in good agreement with the observation of cross-sections of the girth welds, demonstrating the applicability of UT (Fig. 2). Using the analytical life estimation technology developed by CRIEPI, the creep life of the girth welds was successfully predicted with a high accuracy on the basis of the strain criterion.

3 Factors affecting creep life of 9Cr steel welds

To develop a highly reliable diagnostic technique for high-Cr steel welds, various factors affecting the creep life of 9Cr steel welds were experimentally investigated. It was found that the creep life becomes shorter as the angle between the fusion line and the stress direction, which is equal to 90 degrees minus the groove angle in welding joints, becomes smaller (Fig. 3). This suggests that the groove angle should be considered in the assessment of welds.

4 Assessment of remaining creep life of re-welded portions of 9Cr steel

A 9Cr steel weld subjected to creep damage was re-welded so that a groove edge in the re-welding was made in the initial weld metal. In a creep test performed after the re-welding, it was found that the remaining creep life was much shorter than that with no re-welding. In the creep test, a crack was generated from the HAZ, which was formed in the weld metal by the re-welding, whereas cracks are generated from the fine-grained HAZ in the base metal in the case of normal 9Cr steel welds. Finite element creep analysis was conducted by modelling each material property in the re-welded portion. As a result, strain concentration was found to occur in the HAZ of the weld metal (Fig. 4). This result suggests that numerical analysis can be an effective tool to assess the remaining creep life of re-welded portions which usually have a complex shape.

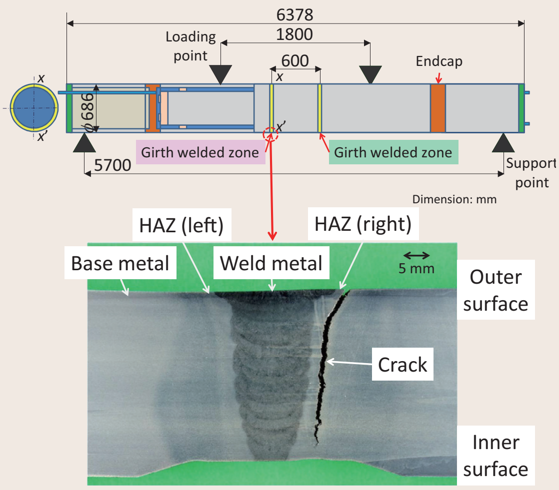

Fig. 1: Cross-section of a girth weld in 12Cr steel pipe after creep test

After a creep test at 650°C for approximately 8,000 h, propagation of a macroscopic crack was observed along the fine-grained HAZ of the girth weld where tensile stress due to bending was applied.

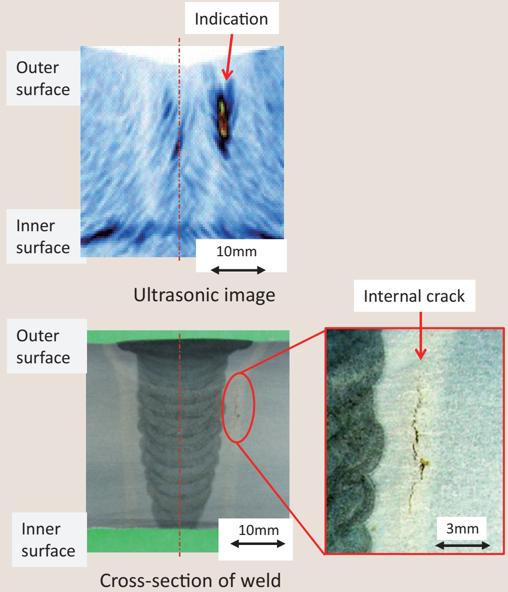

Fig. 2: Applicability of ultrasonic testing

Internal cracks in girth welds of 12Cr steel pipe were successfully detected by ultrasonic testing.

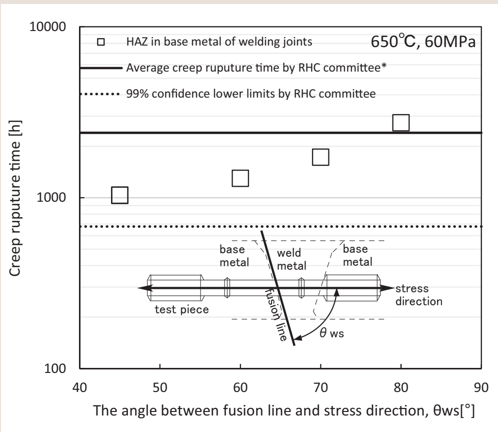

Fig. 3: Factors affecting creep life of 9Cr steel welds

The creep life decreases as the angle between the fusion line and the stress direction, which is equal to 90 degrees minus the groove angle, reduces.

*RHC committee: The Committee on Review on Reliability of High Temperature Strength Enhanced Ferritic Steels for Fitness-for-Service of Thermal Power Components

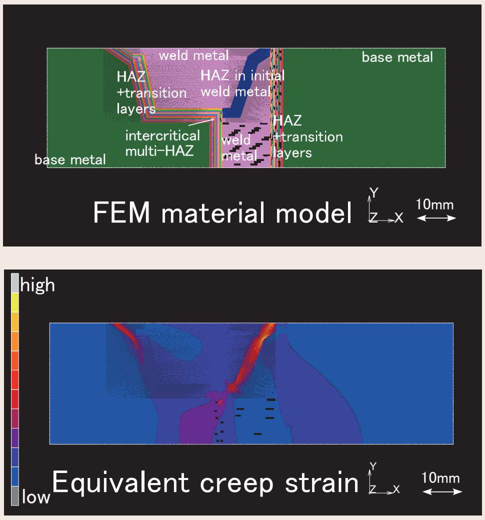

Fig. 4: Finite element creep analysis of a re-welded portion of 9Cr steel

Finite element analysis for a re-welded portion of 9Cr steel was conducted based on the modeling of each material property. Strain concentration was found to occur in the HAZ formed by the re-welding within the weld metal, where a creep crack was observed in an experiment.