Project Research — **Further Improvement of Facility Operations and Maintenance Technologies**

Integrated Remaining Life Assessment Technology for Inspection, Prediction, and Monitoring

Background and Objective

Aged thermal power plants, which have achieved a cumulative operation time exceeding 100,000h, account for approximately 80% of the thermal power plants in Japan. The damage of equipment subjected to high temperatures in aged thermal power plants, which have achieved a cumulative operation time exceeding 200,000 h in particular, has become obvious and is a cause for concern. At ultra-supercritical pressure steam power plants with high thermal efficiency, various troubles caused by creep damage have occurred at the welded heat-affected zone (HAZ) of high chromium steel steam pipes, such as 9Cr steel pipes. Thus, highly reliable remaining life assessment technologies for facilities are becoming increasingly important to safely and rationally operate and manage these power plant facilities.

In this project, we aim to further advance two technologies: 1) an advanced nondestructive testing technology using ultrasonic waves, and 2) an analysis technology to predict the progress of damage with high precision, both of which have been developed by CRIEPI. We also aim to establish an integrated remaining life assessment technology for facilities based on the characteristics of these two technologies.

Main results

1 Development of Technology for Estimating the Shape of Weld Metal

Precise data on the shape of weld metal is necessary to appropriately evaluate creep damage, as the development of creep damage in the welded portion is affected by the shape of the grooves in the welded joints. We developed a method of nondestructively estimating the shape and width of weld metal, including re-welding, by measuring ultrasonic waves scattered at the welded portion (Fig. 1).

2 Estimation of Temperature History during Welding

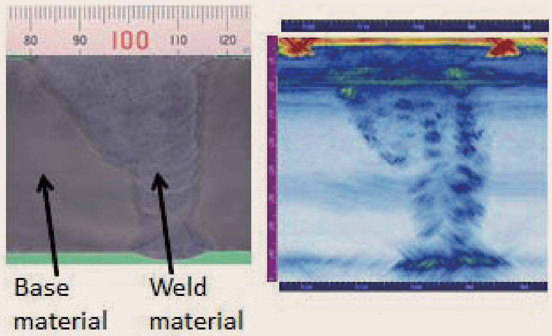
It is necessary to quantitatively predict the complicated temperature distribution and temperature history under the welding process to accurately evaluate the strength of a material subjected to multilayer welding. Therefore, we determined the shape of the molten portion by performing a welding simulation on the basis of temperatures measured during the welding of 9Cr steel (Fig. 2). The application of the shape data in the molten portion to the welding simulation enables us to estimate the widths of the HAZ and the temperature history of each measurement point in the welded joint of large-diameter 9Cr steel pipes.

3 Evaluation of the Creep Strength of Longitudinal Welded Pipes under Internal Pressure Conditions

Internal-pressure creep tests were carried out using many small-diameter longitudinal joint tubes (outer diameter: 60 mm) and a pipe specimen with the dimensions of actual equipment (outer diameter: 686 mm). The results indicate that the creep rupture life of the tubes under internal pressures tends to be equivalent to or shorter than that obtained by a uniaxial creep test (Figs. 3 and 4). Also, a large number of voids, a type of creep damage, were generated inside a thick pipe rather than on its outer surface. In addition, although the deformation of the pipe specimen with the dimensions of actual equipment was small before its rupture, the specimen rapidly broke with significant deformation along with the formation of a through crack at the HAZ of the longitudinal welded pipe (Fig. 5).

4 Proposal of a Method for Evaluating Creep Rupture Life

We proposed a method for evaluating the creep rupture life of high-chromium steel longitudinal welded pipes on the basis of the development of damage at the welded portion as revealed by the experiment and analytical investigation. This method can consider the effect of stress multiaxiality on the creep damage. The proposed evaluation method was applied to the results of creep tests on 9Cr and 12Cr steel tubes and pipe under the application of internal pressure. The creep rupture lives of the longitudinal welded specimens were estimated with high precision, demonstrating the validity of the proposed method (Fig. 6).



(a) Photograph of the cross section of the actual specimen

(b) Ultrasonic image of the cross section

Fig. 1: Estimation of the shape of weld metal

It is possible to estimate the shape and width of weld metal within an error of 2 mm by measuring the ultrasonic waves scattered at the welded portion (material, 9Cr steel).

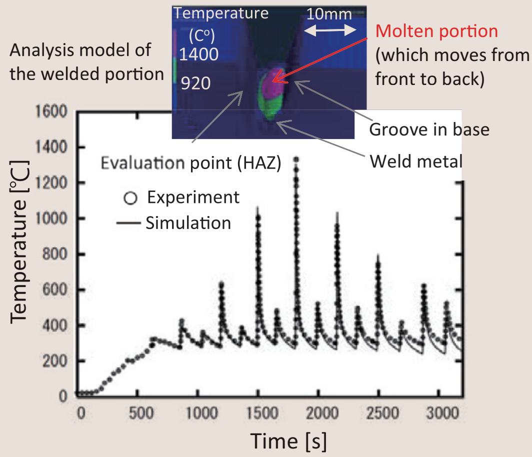


Fig. 2: Welding simulation of 9Cr steel

The complicated temperature history and the temperature distribution as a result of multiple passes of shielded metal arc welding are quantitatively reproduced.

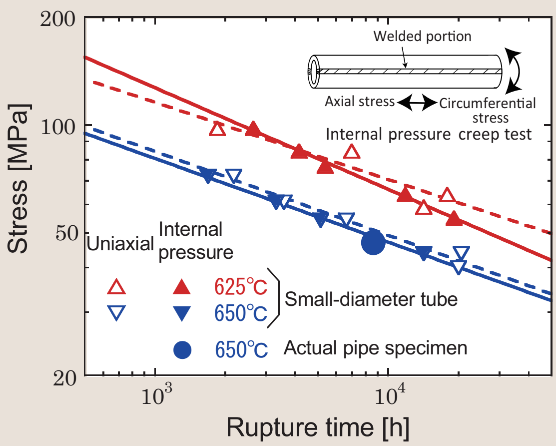


Fig. 3: Results of creep test of 9Cr steel welded joints

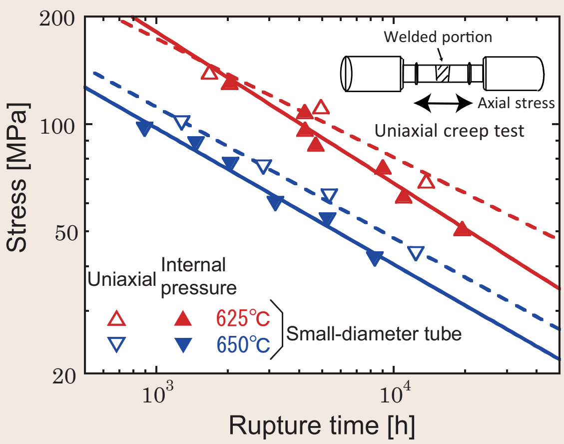


Fig. 4: Results of creep test of 12Cr steel welded joints

Fig. 5: Photograph of a ruptured 9Cr steel pipe with the dimensions of the actual equipment

(Temperature, 650℃; rupture time, approximately 8,600 h)

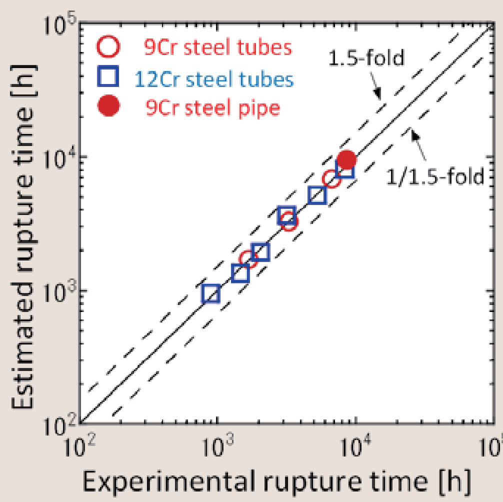


Fig. 6: Results of applying the proposed method to evaluate creep rupture life