Effect of Hydrogen on Creep of SUS304

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Introduction. The objective of this study is to clarify the effect of high-temperature hydrogen on the creep properties for advanced hydrogen energy technologies such as SOFC, SOEC, RFC and a hydrogen gas turbine.

Experimental procedure. We first developed a new testing machine that enables material testing in high-temperature hydrogen as shown in Fig. 1. The SSRT (Slow Strain Rate Testing) and creep test were then conducted in Ar and H₂ under a gas pressure of 0.12 MPa absolute pressure in accordance with ASTM G129 and JIS Z2271, respectively. The shape of the specimen is shown in Fig. 2. The test material was JIS SUS304 austenitic stainless steel. The strain rate for the SSRT was 10⁻⁵ 1/s. The creep test was carried out at 600 °C in Ar and H₂.

Results. Figure 3 shows the results of the SSRT. A significant ductility loss due to the hydrogen occurred at 25 °C. On the other hand, no ductility loss occurred at 100 °C and higher temperatures. The possible reasons are an interaction between the hydrogen and deformation and microstructure changes. Dislocations, which act as hydrogen trapping sites at room temperature, do not work as hydrogen trapping sites at high temperature⁽¹⁾. In addition, strain-induced martensite transformation, which enhances the effect of hydrogen at room temperature, is suppressed at high temperature⁽²⁾. As an important result obtained from this experiment, the work hardening rate in H₂ at 600 °C decreased compared for that in Ar at 600 °C. Considering no interaction between the dislocations and hydrogen, different mechanisms that affect the deformation in hydrogen are expected.

Fig. 1 Testing machine for SSRT and creep in Ar and H₂ at 600 °C

Fig. 2 SSRT and creep specimen

Figure 4 shows the creep rupture time curves in Ar and H₂. The creep life was significantly reduced in hydrogen. Yokogawa reported that hydrogen reduced the creep life⁽³⁾. This study reproduced the trend of their experiment. The morphology of the fracture surface is also shown in Fig. 4. In Ar, dimple and intergranular fracture surfaces were observed at $\sigma = 310$ MPa. Most of the fracture surface was covered by intergranular cracking when $\sigma = 270$ MPa. In H₂, the major fracture surface was dimple at $\sigma = 310$ MPa, and dimple and intergranular fracture surfaces at $\sigma = 270$ MPa. The change in the fracture surface and the change in the slope of the creep curve suggested multiple reasons for hydrogen affecting the creep life.

References.

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Fig. 3 Effect of temperature on SSRT of SUS304 in H₂

Fig. 4 Reduction of creep life of SUS304 by H₂