A New Test Method to Determine the Initiation Time of Stress Corrosion Cracking

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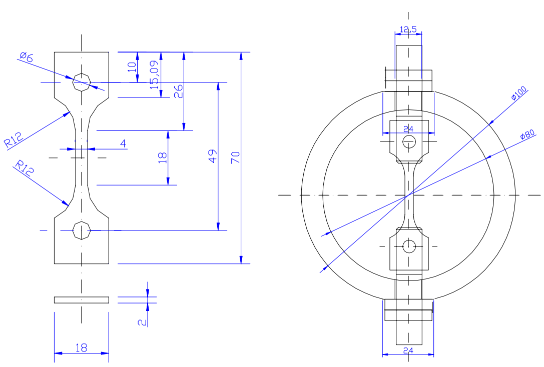
1. Introduction

Stress corrosion cracking (SCC) has been observed in nuclear power systems, which is one of primary degradation modes occurred in Ni-base alloy tubing and penetration nozzles of pressurized water reactors (PWR's) [1]. Cracks caused by SCC have a long initiation time, which is dependent on microstructure, stress condition, and environmental factors. An empirical equation to predict the crack initiation time was developed [2] but such an empirical equation has uncertainty for a material parameter and activation energy. To obtain the crack initiation time experimentally, a reverse U-bend (RUB) test has been widely used, which is a modified test from a usual U-bend test [3] to simulate the primary side SCC in PWR's. To determine the initiation time of SCC more precisely, a new test method using a proving ring and maintaining a constant load condition has been developed.

2. Experimental

2.1 Design of Proving Ring Test Specimen

Fig. 1 shows the drawings for a test specimen and a proving ring with a test specimen. The test specimen design was based on a general tensile test specimen's design. A proving ring was made of alloy 718, precipitation hardened nickel-base alloy, which is much harder than the test specimens. The proving ring makes the test specimen under the constant load condition at least until crack penetration is not much deep. Before straining the specimen, the electrolytic Ni plating was applied on the surface except a small area for the crack



(a) (b)

Figure 1. Drawings for (a) a test specimen and (b) a proving ring with a test specimen.

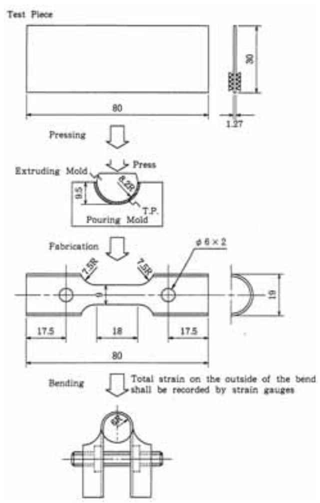


Figure 2. Preparation procedures and drawings for a reverse U-bend specimen.

initiation site. To detect the SCC crack initiation, a direct current potential drop (DCPD) method was adopted.

Fig. 2 shows the preparation procedures and drawings for a RUB specimen. RUB specimens are under a constant strain condition so that the stress is relieved after crack formation. RUB specimens were compared with proving ring specimens. RUB specimens also were equipped with the DCPD method.

2.2 Experimental Conditions

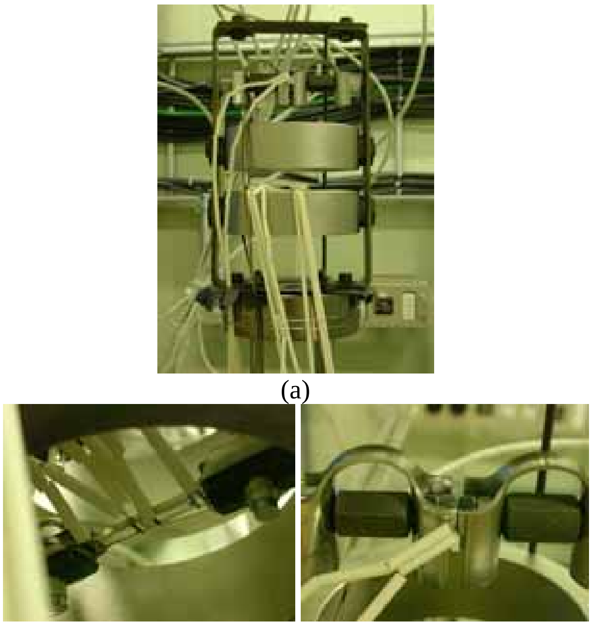
The test materials were alloy 600, of which the chemical composition is shown in Table 1. The materials were annealed at 1050 ^{o}C during 2 hours and then water quenched.

Two proving ring specimens and two RUB specimens

Table 1. Chemical compositions of test specimens (wt.%) [4].

C	Si	Mn	P	S	Ni	Cr	Mo
0.055	0.31	0.25	0.008	<0.001	75.45	15.24	0.11
Al	Nb	B	Fe	Ti	Cu	N	O
0.17	0.014	0.0019	7.81	0.36	0.10	0.0077	0.001

were installed in a 2 gallon autoclave made of 316 SS, as shown in Fig. 3. In Fig. 3, the near views for the proving ring specimen and RUB specimens show the configuration for DCPD probes. The proving ring specimens were strained up to 6.1 % and the applied stress was 280 MPa. The yield strength of the test materials was 188 MPa. The specimens were exposed to the simulating primary water chemistry conditions, which are composed of 1200 ppm boron, 2 ppm lithium, and 30 cc/kg dissolved hydrogen. The test temperature and pressure were 360 ^{o}C and 195 atm, respectively. At outlet line, pH, conductivity, dissolved hydrogen, and dissolved oxygen concentration were continuously monitored. The dissolved oxygen concentration was maintained less than 5 ppb through the test period.



(b) (c)

Figure 3. Photographs showing (a) the autoclave internal structures installed with test specimens and the near views for (b) Proving Ring specimen and (c) RUB specimens with DCPD probes.

3. Results & Discussion

3.1 Application to PWSCC Initiation

With the proving ring test specimen equipped with DCPD probes, it was tried to detect the primary water SCC (PWSCC) initiation time. Fig. 4 shows the DCPD results for the proving ring and RUB specimens, which are part data of whole test data during one month. As shown in Fig. 4, the DCPD signals are very clear. Constant signals mean that any detectable crack was not initiated on the specimens' surface. Even after one month test, the DCPD signals were maintained constant. The crack initiation time predicted by the empirical equation was more than one year under the test conditions. The test method needs to be improved.

3.2 Further Improvement

To increase the stress condition, Ni plating will be conducted after the straining the specimens.

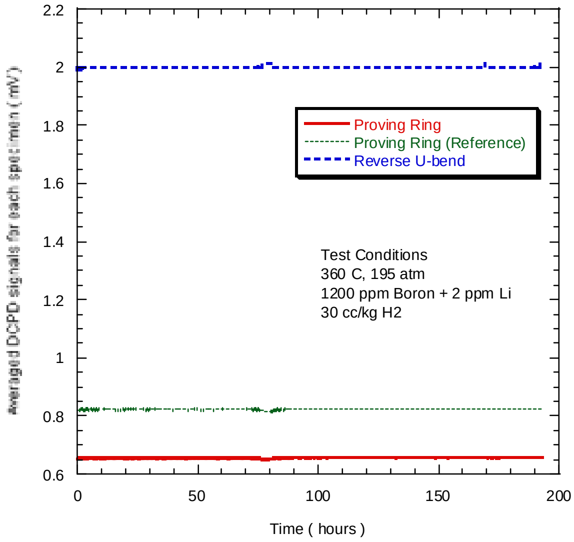


Figure 4. Averaged DCPD signals for the proving ring and RUB specimens, which are part data of whole test data during one month.

4. Summary

A proving ring test method equipped with DCPD was developed and applied to detect the crack initiation time in PWR primary water conditions. The specimens were exposed to the PWR primary water environment during one month. The DCPD signals were very clear but the crack initiation was not detected manly because of the low stress condition. To increase the stress condition, Ni plating will be conducted after the straining the specimens.

ACKNOWLEDGEMENT

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