

Electrochemical study on the PbSCC of SG tube material at a high temperature

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1. Introduction

In the development of steam generator tube materials, Alloy 600 is expected to endure the high temperature corrosive environment of nuclear power plants. However, the occurrence of a stress corrosion cracking (SCC) of steam generator tubes is not unusual as nuclear power plants have been operated for a long time. Since Copson and Dean reported that the SCC susceptibility of steam generator tubes could be affected by lead [1], many other researchers have investigated a SCC of steam generator tube materials in a lead-containing test solution, and they have revealed that lead is one of the detrimental contaminants for the damage of tube materials [2-6]. Some of the plants in the world have reported that the steam generator was contaminated by lead with a high concentration [7].

This study was performed to observe a lead induced SCC (PbSCC) in relation to the electrochemical property on the surface of an Alloy 600 MA tubing material. The Steam generator tube materials which were used in nuclear power plants were named (heat-treatment) Alloy 600 MA (meal annealed), 600 TT (thermally treated), 600 HTMA (high temperature meal annealed), Alloy 800 and Alloy 690 TT (thermally treated)

2. Methods and Results

The PbSCC behavior of Alloy 600 was investigated by a constant extension rate tester (CERT) at the different electrochemical potential levels in a caustic solution of pH_{25°C} 7 and pH_{25°C} 10 at 300°C. The initial pH of the solution was adjusted by a NaOH compound in distilled

water at room temperature. The strain rate was 2×10^{-7} /sec during this test. Table 1 shows the chemical composition and mechanical properties of the Alloy 600MA used in the CERT tests. Alloy 600 MA was meal annealed at 960°C for 10 minutes. The lead concentration was maintained at 1,000 ppm by the addition of PbO powder. The test solution was deaerated by using a high purity nitrogen gas purging before tests. The potentials loaded on to a specimen were applied by a PAR 273 potentiostat by using an Ag/AgCl external reference electrode. The reference electrode was filled with a 0.01M KCl solution as an electrolyte and it was designed as a pressure balanced type to maintain the same pressure as the high temperature vessel. Platinum wire was used for a counter electrode in this electrochemical system. An anodic polarization curve was obtained as shown in fig. 1 by the EG&G 273 potentiostat with a potential scanning rate of 1mV/sec in the same conditions as the CERT tests. After the specimen was fractured, the SCC ratio (% , SCC area/total fractured surface area) was evaluated by the SEM photographic analysis technique.

The CERT test was performed with an applied potential in the range of 40 mV to -1260 mV vs. an Ag/AgCl external reference electrode with 0.01M KCl electrolyte. The strain-stress curves of the Alloy 600 MA were obtained under the various applied potentials. After a specimen was fractured, the SCC area ratio (%) was evaluated from the SEM photograph of the fractured surface. In the case of pH_{25°C} 10, a PbSCC of the Alloy 600MA specimen was not observed at the potential range above -560 mV, but a PbSCC occurred at less than the potential value of -580 mV. It is comparable to the anodic polarization curve of the Alloy 600 MA as shown in Fig. 2. In the potential range of

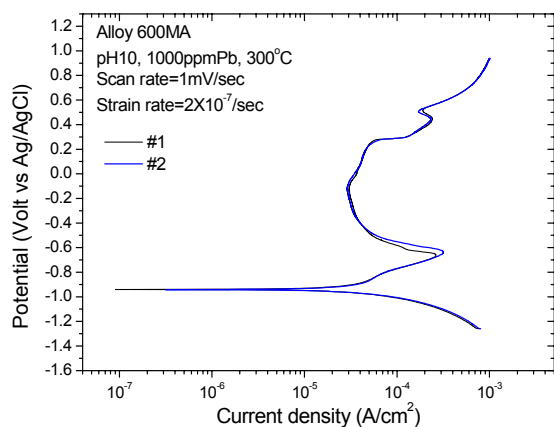


Fig.1 Polarization curves of Alloy 600

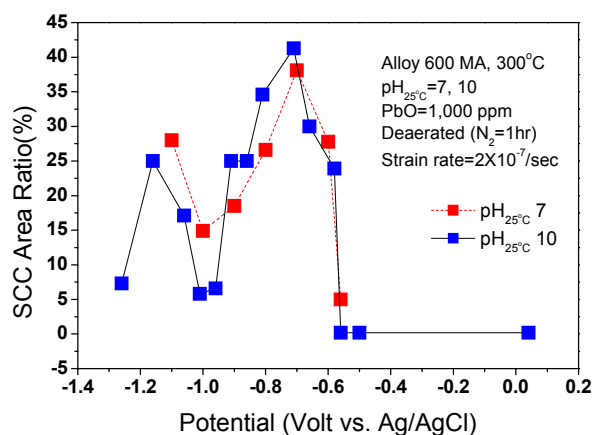


Fig. 2 Applied potential effects on SCC Area ratio in Pb containing environments.

above about -550 mV, it shows a passive state until the potential value of about 300 mV. In this range, the surface of the Alloy 600 MA specimen is considered to form a passive oxide layer. As shown in Fig. 2, a PbSCC was initiated below the potential value of an active to passive transition, about -580 mV. The most severe PbSCC occurred in the vicinity of a potential value of -710 mV, in which the critical current density was revealed, and the maximum PbSCC ratio was 42% at that potential. However, the SCC ratio was decreased at the range of -950 ~ -1,000 mV, and this potential range is near to the corrosion potential value, about -930 mV. Another PbSCC peak was observed at below that of the potentials, which was maybe due to a hydrogen evolution, and then it was diminished as the potential stat goes to cathodic direction. In the tests of pH25°C 7, the effect of an applied potential on Alloy 600 MA showed a similar occurrence of a PbSCC of the pH25°C 10 tests. The PbSCC was initiated from the potential value of -560 mV at pH25°C 7 with the SCC ratio value of 5%, whereas in the case of pH25°C 10, a SCC did not occur at this potential. The SCC area ratio calculated from the tests of pH25°C 7 were a little bit smaller than that of pH25°C 10. In spite of the fact that the tests have not been completed as yet at pH25°C 7, these results indicated that the PbSCC susceptibility of the SG tubing material was affected by the electrochemical potential of the corrosive environment.

3. Conclusions

The PbSCC of Alloy 600 MA was affected by the applied potential level. In the potential range of a passive film formation, a PbSCC was not observed. PbSCC began to occur at the active to passive film transition potential and it occurred most severely near the active current peak potential. The difference of the pH showed a similar trend for a SCC occurrence with the potential, but the cracking area was smaller when the pH of the water moved to a neutral condition.

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