Causes of PWSCC in a Alloy 600 Nozzle of a PWR

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1. Introduction

Primary water stress corrosion (PWSCC) of alloy 600 in a PWR has been an important concern. This PWSCC has been reported in the control rod drive mechanism (CRDM), the pressurizer instrumentation nozzle, and the pressurizer heater sleeve [1]. Since the first report of a PWSCC in a steam generator (SG) drain nozzle at the Shearon Harris plant in 1988, more cases have been reported around the world. Recently, two cases of a boric acid precipitation were reported on the bottom head surface of a SG in Korea. Cracking was only found in the cold leg drain nozzles made of alloy 600 in two units. The hot leg side nozzles are corrosion resistant alloy 690.

The objective of the present work is to evaluate the crack morphology of a degraded nozzle, and to seek the causes of the cracking.**).**

2. Experimental Procedures

The drain nozzle, which was contaminated with radioactive materials was transferred to a hot laboratory at the Korea Atomic Energy Research Institute (KAERI).. The location of the cracked area was marked on the nozzle before the destructive examination. Fig. 1 shows the alloy 600 nozzle sample in this work.

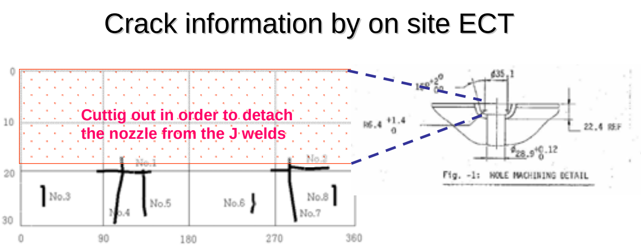

Fig. 1 Location of the cracks determined by destructive examination

The specimens for the microstructural analysis were prepared by general metallography procedures like a cutting, mounting, grinding and a polishing. To observe the carbide distribution, the specimens were etched in a bromine solution and a two-step etching solution [orthophosphoric acid, and then nital]. The bromine solution enables the carbide morphology to be observed clearly by a scanning electron microscopy (SEM), the etching in the orthophosphoric acid reveals the grain boundaries carbide, and the Nital etchant clearly reveals the grain boundaries of the alloy 600 specimens. All the samples were examined with SEM or an optical microscopy. A transmission electron microscope (TEM-JEOL 2000FX-II) equipped with Oxford Link EDX (Model ISIS-5947) was utilized for the analysis of the carbide structure and the chemical composition.

Dye penetrant test was performed to confirm the location of the cracks. After marking a reference position for the radial and the longitudinal directions, the nozzle was cut longitudinally and circumferentially in order to observe a fracture surface and as many cracks as possible as shown in Fig. 2.

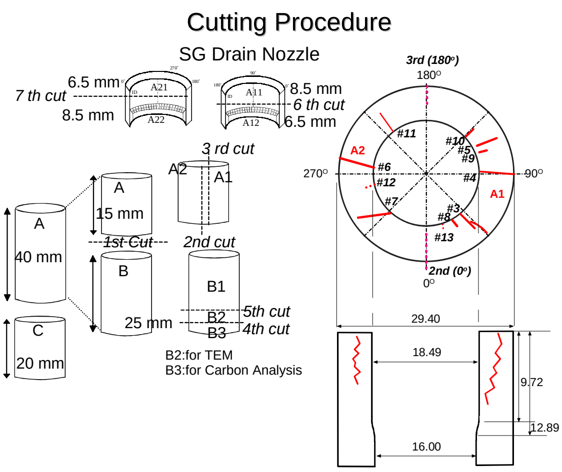

Fig. 2 Cutting procedure of the cracked nozzle.

3. Results and discussion

3.1 Carbide morphology

Solution treatment temperature of 980 oC is considered to be a little too low to dissolve all the carbides in the nozzle material with 0.04% carbon. Grain boundary carbides were relatively well developed in the material as shown in Fig. 3. A Cr-depletion was not observed near the grain boundaries. From the

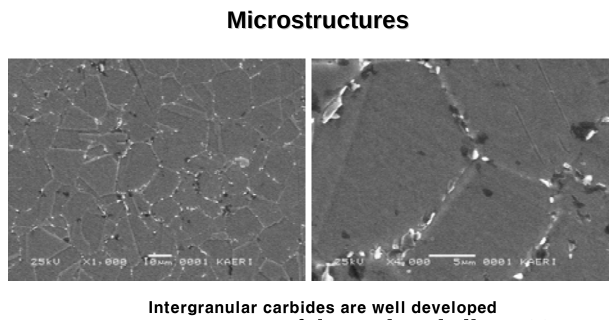

Fig. 3 Microstructure of the analyzed alloy 600 nozzle

observed SCC resistant microstructure [1,2], it was considered that the material itself was not the cause of the cracking. Rather, the weld residual stress could be the main cause of the PWSCC of the alloy 600 nozzle.

3.2 Fracture surface analysis

A typical morphology of the cracks is shown in Fig. 4. The cracks were developed from the inside of the pipe wall and propagated outward. Intergranular nature of the cracks suggests that the nozzle was attacked by a PWSCC.

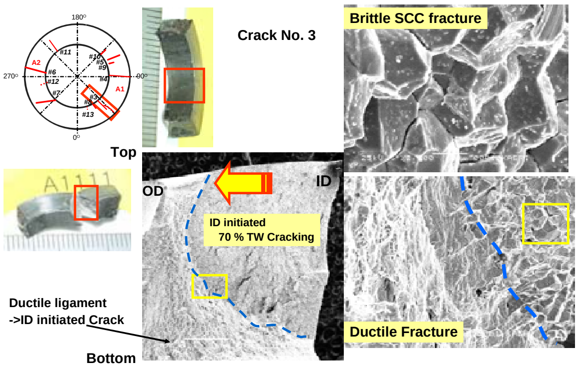

Fig. 4 Feature of cracks developed on the nozzle

It was found that two cracks out of twelve had fully penetrated the pipe wall, and the maximum length was 7.2 mm. Because the upper part of the nozzle was ground out during the pulling process, the longest crack length could be longer than the measured value by the destructive examination.

Fig. 5 represents a schematic of the crack locations. The cracks were observed in the alloy 600 base material, not on the weld metals, and distributed near the bottom of the J weld. This suggests that a high tensile stress in the region caused the PWSCC of the nozzle.

There was no indication of a crack initiated at the OD (outer diameter).

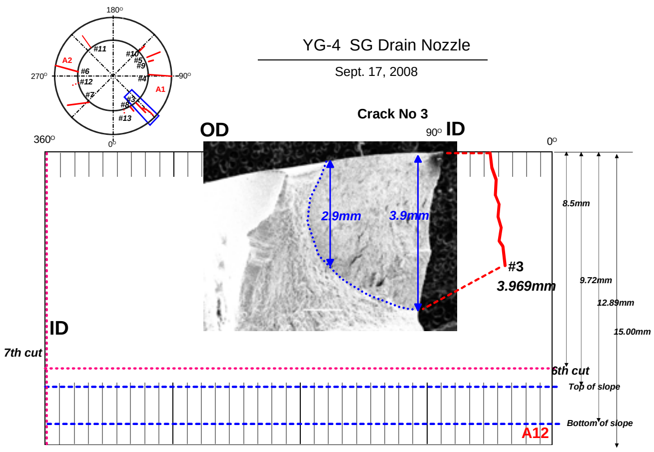

Fig. 5 Location and depth of the no. 3 crack

4. Conclusions

(1) Grain boundary carbides were well developed in the material, therefore, the material itself was not the cause of the cracking.

(2) Residual stress due to the welding process could be a main cause of the PWSCC of the alloy 600 nozzle.

(3) The defects were typically primary water stress corrosion cracks in terms of their intergranular morphology and their initiation site.

(4) Two cracks out of twelve had penetrated 100 % of the wall thickness, and the maximum length was 7.2 mm.

(5) It was found that the twelve cracks were distributed near bottom of the J weld region, which was considered to be the high tensile stress area.

REFERENCES

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