# Stress Corrosion Crack Growth studies of Alloy 600 in Boride Containing Caustic Solutions

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## 1. Introduction

Alloy 600 used as a steam generator (S/G) tubing material are known to be susceptible to stress corrosion cracking (SCC) in both the primary and secondary conditions of S/Gs. Numerous studies have been performed to develop and qualify the corrosion inhibitors for the SCC. Borides are candidate inhibitors recently proposed by KAERI [1]. In this study, using tube compact tension samples, SCC growth rates of Alloy 600 in boride containing caustic solutions were measured to examine the effect of boron on the SCC growth rates of Alloy 600.

## 2. Experimental procedures

The materials used in the SCC tests are Alloy 600 HTMA (NX8524) steam generator tubing with an outer diameter of 19.05mm and a thickness of 1.09mm. A 10% NaOH solution was used as a reference solution and NiB and $CeB_6$ were added to the reference solution. The concentration of the borides added to the solution was 2g/l. Fig. 1 shows the shape and dimensions of tube CT samples used in the SCC tests. Samples were fatigue precracked in air at a frequency of 5Hz and a load ratio(R)=0.1. The stress intensity factor ($K_I$) for the tube specimen is expressed as a function of the load, P, and the crack length, a, [2];

$$K_I = 8.1121 \times P\sqrt{-1.122 \times 10^{-4} + 1.247 \times 10^{-2} a} \qquad (1)$$

where $K_I$ is in MPa√m, P in N, and a in m.

SCC growth rates were obtained using constant displacement tests. Constant displacement conditions were achieved by securing a wedge inside the notch of a sample (See Fig. 2). The amount of displacement was adjusted so that the maximum $K_I$ on the samples could range from 37 to 38 MPa√m. The tests were done in a 2ℓ volume static autoclave made of Ni. Before the tests, the solution was deaerated by a bubbling with pure nitrogen gas for 1hr and it was finally pressurized to 200psi with a cover gas of 5% $H_2$-95% $N_2$. To accelerate the SCC, using a potentiostat (EG & G Model 363), samples were polarized to 200 mV above the open circuit potential (OCP) during the tests. A nickel wire and an autoclave were used as the reference and counter electrodes, respectively. Test temperature was 315°C and the samples were exposed to each solution for 120 h. After the SCC tests, samples were broken by fatigue in air and the fracture surface was examined with SEM. From the SCC fracture surfaces, average crack growth rates (CGR) were determined by the following equation [3];

$$\text{Average Crack Growth Rate} = \frac{\text{IG Area}}{\text{Specimen Thickness} \times \text{Exposure Time}} \qquad (2)$$

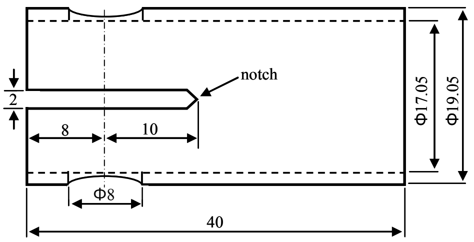


Figure 1. Shape and dimensions of the tube CT sample.

Figure 2. Photograph showing a sample and a wedge for loading.

## 3. Results

Fig. 3 shows an SEM micrograph of the fracture surfaces of the samples tested in the reference and boride containing solutions. In these figures, the boundaries between the fatigue precrack and the IGSCC and the fatigue postcrack are clearly revealed. An intergranular (IG) crack initiated and propagated largely in the reference solution while a small crack did so along the outer surface of the samples in the boride containing solutions. IG areas on the fracture surfaces were measured and the average CGRs were calculated using Eq. (2). The resulting average CGRs are summarized in Fig. 4. The CGR in the reference solution ranged between $2.3 \times 10^{-10}$ and $5.3 \times 10^{-10}$ m/s, which was 4 times higher than that of Alloy 600 in a primary water condition [4]. This figure shows that the CGRs in the boride containing solutions decreased to about one fourth of that in the reference solution.

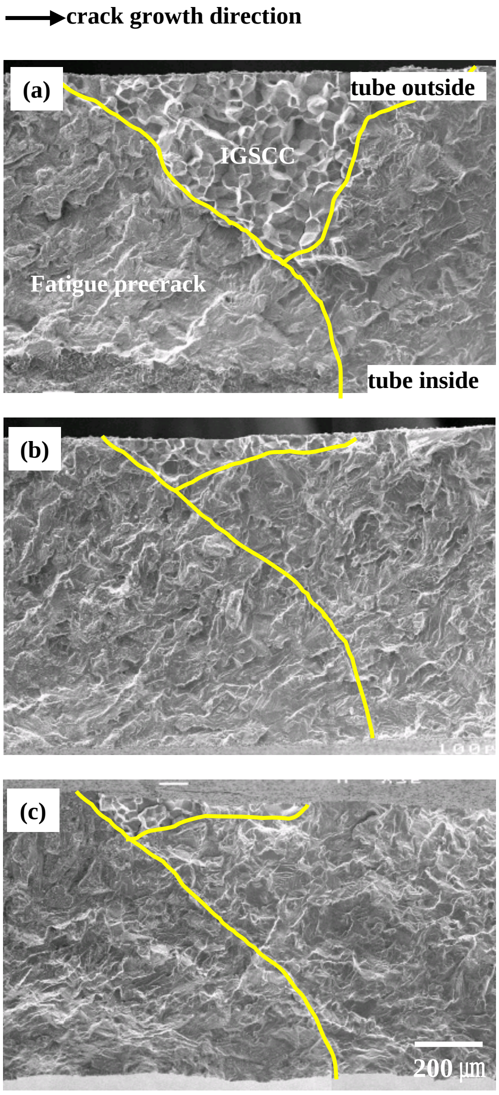


Figure 3. SEM micrograph of fracture surface of Alloy 600 tested in (a) 10% NaOH (reference solution), (b) 10% NaOH+NiB (c) 10% NaOH+CeB$_6$.

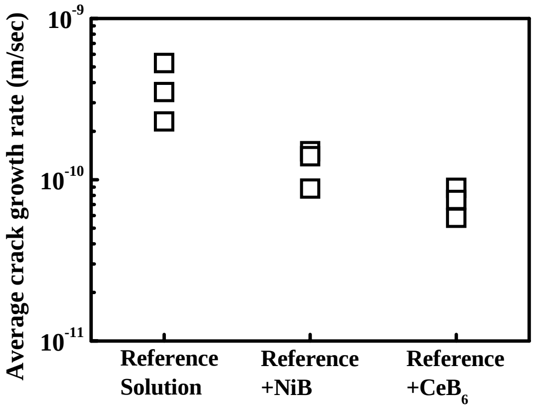
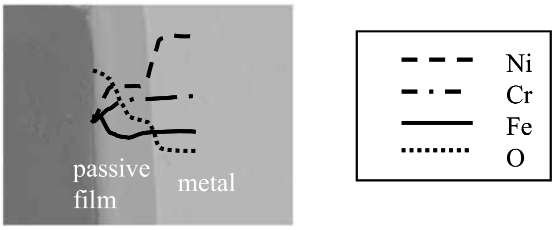
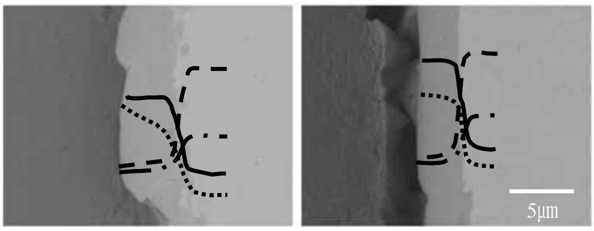


Figure 4. Average crack growth rates of Alloy 600 tested in 10% NaOH solution with and without borides for 120h.



(a) 10% NaOH (Ref.)



(b) Ref.+NiB (2g/l) (b) Ref.+CeB$_6$ (2g/l)

Figure 5. Chemical compositions of surface oxides of the samples exposed to the reference and boride containing solutions.

On small coupons taken from the SCC tested samples, the compositions of the surface oxides were analyzed using an SEM EDX (See Fig.5). About 5μ m thick oxides were observed in the reference and boride containing solutions. Fig. 5 shows that, in the oxides formed in the boride containing solutions, the concentrations of Cr and Ni decreased and the concentration of Fe increased. Although the analysis by the SEM EDX provides a rough estimation about the oxide compositions, these results seems to provide a clue about the role of boride on the oxide formation of Alloy 600. Further analysis is being performed and it will be possible to draw a conclusion after the analysis is completed.

## 4. Conclusion

The SCC growth rates of Alloy in 10% NaOH solutions with and without borides were quantitatively measured using tube compact tension samples. The CGR of Alloy 600 in a 10 % NaOH solution decreased significantly by the addition of borides.

## REFERENCES

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