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A Study on Relationship between SCC and local micro-strain of Ni Alloy

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1. Introduction

Ni-based alloys are widely used as structural materials in nuclear power plants due to high resistance to general corrosion. However, there have been many localized corrosion failures in operating nuclear reactors, especially, intergranular stress corrosion cracking (IGSCC) in primary and secondary side of PWRs. Those failures are unacceptable because radiation may be spread into the atmosphere along the through-wall cracks. So it is important to understand the main factors influencing IGSCC resistance of Ni-based alloys.

Many studies have currently focused on investigation of IGSCC mechanism of Ni-based alloys, particularly effects of grain boundary character and local strain distribution when they are strained. Recent studies on crack initiation use novel microstructural analysis methods such as scanning electron microscopy (SEM), electron backscatter diffraction (EBSD), transmission electron microscopy (TEM), and nano-beam diffraction (NBD) as ex-situ techniques for crystal orientation, local strain, and chemical analysis of the alloys tested in the corrosive environments. Those techniques, however, can provide only information on the final state of the materials after the corrosion test. To investigate the SCC initiation at transient state during the corrosion test, it is necessary for an in-situ analysis technique.

Present work was undertaken to establish an in-situ technique for analyses of IGSCC initiation mechanism of the Ni-based alloys.

2. Experimental procedures

2.1 Materials and test specimen

Alloy 600 (heat no. 770177) steam generator tubing was used in this study and its chemical compositions are shown in Table 1. Fig. 1 shows the schematic drawing of the unstressed (as-received) c-ring having an outside diameter (OD) of 19.05 mm [1]. All the c-rings were thermally sensitized at 600 ℃ for 20 hours.

The EBSD specimens were ground to one of the flat sides of the c-ring using abrasive papers up to 2000 grit, then polished by diamond paste up to 0.25 ㎛, and finally followed by 0.02 ㎛ colloidal silica for 40 min in order to achieve relatively flat surface free from damage. [2]. The EBSD analysis was performed on apex of flat side of the as-received (unstressed) and stressed specimens with a step size of 0.5 ㎛ and 1.3 ㎛ at magnification 300 x.

Table 1: chemical compositions of Alloy 600 (wt%)

C	Si	Mn	S	Cr	Ni	Fe	Cu
0.020	0.41	0.19	0.0005	16.29	73.0	9.45	0.010

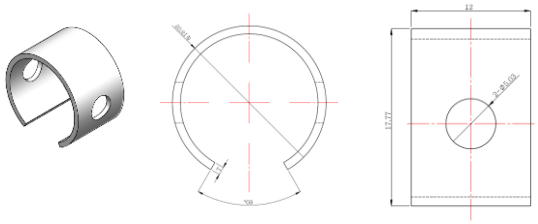


Fig.1. Schematic drawings of C-ring used in this work.

2.2 Test conditions and procedure

SCC tests of stressed c-rings were carried out in 0.1M sodium tetrathionate ($Na_2S_4O_6$) solution at room temperature [3], the well-known corrosive environment leading to IGSCC of the sensitized Ni-based alloy [3-4]. Crack initiation and propagation on the stressed c-rings in $Na_2S_4O_6$ solution were recorded for 24 hours with a video microscope; VOMS-100i lens x 10,850 magnification, the video resolution was 1920 x 1080, and the frame rate was 29/sec.

3. Results and discussion

Fig.2, Fig.3 and Fig.4 were taken when the OD is located at the bottom portion. Fig. 2 shows a kernel average misorientaion (KAM) maps of unstressed and stressed C-ring specimen to OD of 17 mm. The EBSD pattern was analyzed using CHANNEL 5 software. The KAM is determined as the numerical average mis-orientation of a given point (or pixel) with all of its neighbors in a grain. The KAM is commonly known to be closely related with degree of plastic or residual strain; this can be used as an appropriate parameter to evaluate the local strain distribution [4].

It was found that the KAM value of the stress specimen was higher than that of the unstressed specimen [6]. From this, it can be predicted that the crack initiated at the misorientation is high region.

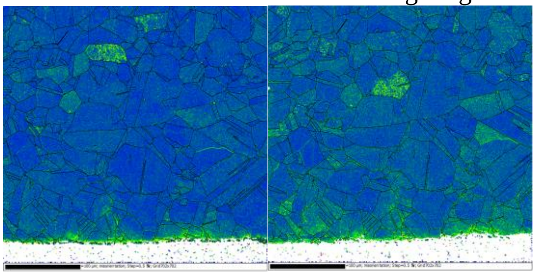
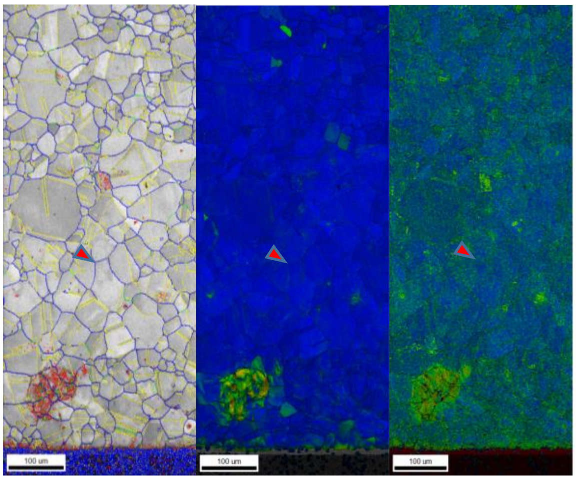

(a) (b)

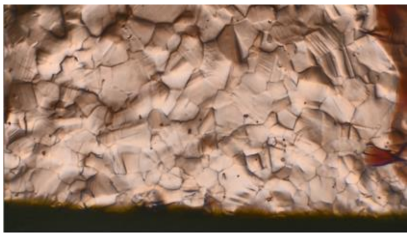
Fig. 2. EBSD results of the C-ring (a) unstressed (b) stressed C-ring specimen to OD of 17 mm



(a) (b) (c)

Fig. 3. EBSD results of the stressed C-ring specimen to OD of 17.5 mm (a) IQ map, (b) GROD map and (c) KAM map

Types of boundaries, Grain reference orientation deviation (GROD) and KAM map obtained by EBSD measurement in the other stressed C-ring specimen to an OD of 17.5 mm at the apex of flat sides are shown in Fig. 3. The EBSD pattern was analyzed using OIM-software. Fig. 4 gives optical stereo-micrographs of cracking stages on the specimens immersed in sodium tetrathionate solution. The red triangles in Fig.3 and Fig.4 represent the same grain and crack initiation from that point. When compared with the KAM map, the cracks initiated at randomly highly residual strained area and grew along random high-angle grain boundaries [5-6].


(a)

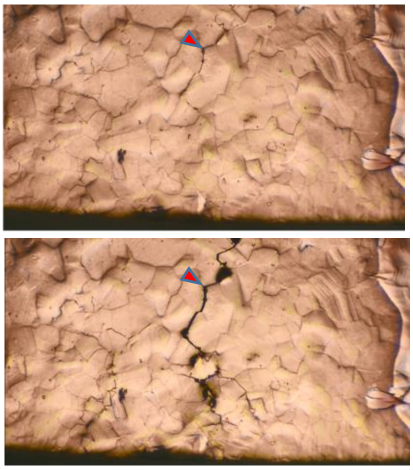

(b)
(c)

Fig. 4. Stereo-micrograph of crack progress (a) initial, (b) initiation and (c) propagation

4. Conclusion

This work aimed to invesitage IGSCC initiation of Ni-based Alloy and its relationship with local strain and GB character using in-situ technique with the aid of EBSD. It was found that crack first initiated at highly strained surface and grew along random high-angle grain boundaries.

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