Corrosion Compatibility Studies on Inconel-600 in NP Decontamination Solution

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1. Introduction

About 75% of primary side surface of PWR is composed of Inconel-600 or similar Ni-base alloys whose oxide properties have a critical influence on decontamination performance [1]. The surface in the cooling circuits is contaminated with radioactive isotopes during the normal operation. It is well known that corrosion and contamination process in the primary cooling circuit of nuclear reactors are essentially interrelated: the contaminant isotopes are mostly corrosion products activated in the reactor core, and the contamination takes place on the out-core of Inconel-600 surface. This radionuclide uptake takes place up to the inner oxide layer and oxide/metal interface. So, it is necessary to remove inner oxide layer as well as outer oxide layer for excellent decontamination effects. The outer oxide layers are composed of Fe_3O_4 and $NiFe_2O_4$. On the other hand, the inner oxide layers are composed of Cr_2O_3, $(Ni_{1-x}Ni_x)(Cr_{1-y}Fe_y)_2O_4$, and $FeCr_2O_4$ [2]. Because of chromium in the trivalent oxidation state which is difficult to dissolve, the oxide layer has an excellent protectiveness and become hard to be decontaminated. Alkaline permanganate (AP) or nitric permanganate (NP) oxidative phase has been used to dissolve the chromium-rich oxide [3, 4]. A disadvantage of AP process is the generation of a large volume of secondary waste. On the other hand, that of NP process is the high corrosion rate for Ni-base alloys. Therefore, for the safe use of oxidative phase in PWR system decontamination, it is necessary to reformulate the NP chemicals for decrease of corrosion rate.

This study describes the corrosion compatibility on Inconel-600 and type 304 stainless steel in NP decontamination solution for PWR applications. To evaluate the general corrosion properties, weight change of NP treated specimens was measured. NP treated specimen surface was observed using optical microscope (OM) and scanning electron microscopy (SEM) for the evaluation of the localized corrosion. The effect of additives on the corrosion of the specimens was also evaluated.

2. Experimental Methods

Inconel-600 specimens were in the form of coupons 20 mm by 20 mm by 2mm. The specimens were polished using 600-grit emery paper, degreased with acetone and ethanol, rinsed with deionized water before NP treatment.

Test solution was 0.3 ~ 2.0 g/L of potassium permanganate + 0 ~ 0.3 g/L of nitric acid at 93°C. Weight loss during NP treatment was measured and the surface morphology of the specimens after NP treatment was examined by OM and SEM.

3. Results

3.1 General Corrosion

Fig.1 shows the comparison of the weight loss for Inconel-600 and type 304SS in the nitric permanganate step and HYBRID step. HYBRID means the reductive decontamination method developed by KAERI. The general corrosion rate in HYBRID decontamination solution is negligible for Inconel-600 and 304 SS. The general corrosion in NP step for Inconel-600, however, was very high. Fig. 2 shows the effect of pH on the general corrosion for Inconel-600 and 304SS. The general corrosion of type 304 stainless steel in NP solution was very low and does not affected by solution pH in the range of 2.0 ~ 6.5. The solution pH, however, plays an important role on the general corrosion of Inconel-600. The general corrosion rate of Inconel-600 was exponentially decreased with pH as follows;

$$WL = 15.05 \exp(-0.756pH)$$

So, it is necessary to optimize the NP solution for the decrease of the general corrosion rate of Inconel-600.

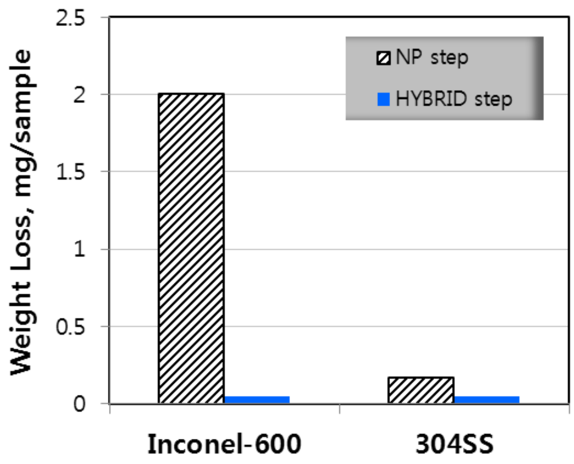

Fig. 1. Weight loss for Inconel-600 and 304SS in the typical NP step and HYBRID step.

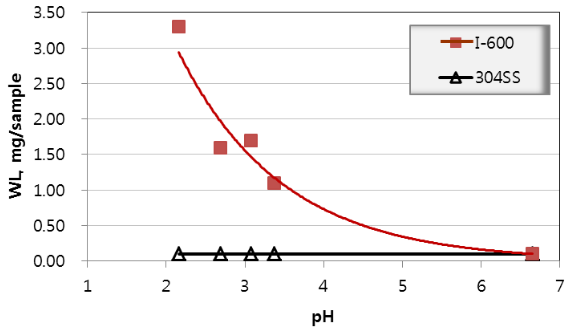

Fig. 2. The effect of pH on the corrosion of Inconel-600 and type 304SS.

3.2 Localized Corrosion

Fig. 3 is the surface morphologies of Inconel-600 and type 304SS after NP decontamination for 4h at 93°C. The figures show the localized corrosion such as pitting and intergranular attack (IGA) on the Inconel-600 surface. There are no appearances of localized corrosion on the 304SS surface; however, there are small and large pits as well as many initiations of intergranular attack on the Inconel-600 surface in spite of no stressed specimen. There are many stressed position of PWR steam generator U-tubes that have the possibility of stress corrosion cracking (SCC) during NP decontamination process. So, it is also necessary to optimize for NP solution water chemistry in order to protect localized corrosion of Inconel-600.

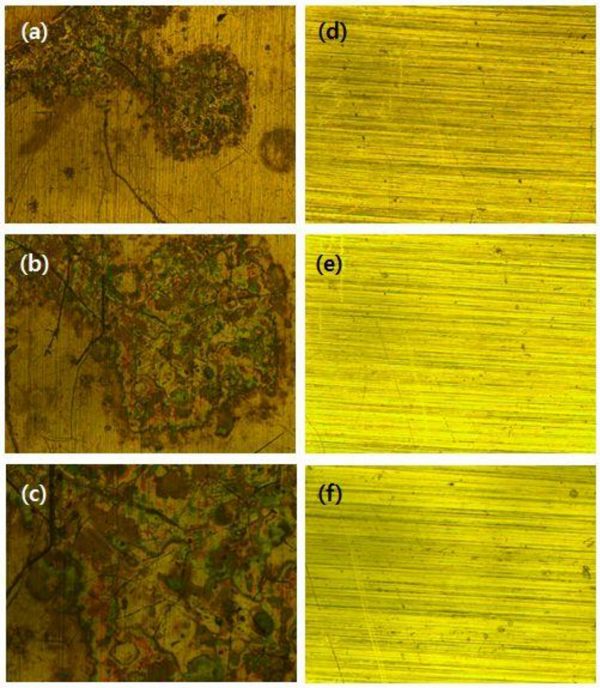

Fig. 3. Surface morphologies of Inconel-600 and type 304SS after NP decontamination treatment, showing localized corrosion on the Inconel-600 surface; (a) 50X, (b) 100X, (c) 200X for Inconel-600 and (d) 50X, (e) 100X, (f) 200X for 304SS.

The effect of corrosion inhibitor on IGA of Inconel-600 surface will be studied in the future.

4. Conclusions

This study describes the corrosion compatibility on Inconel-600 and type 304 stainless steel in NP decontamination solution for PWR applications. It is revealed that Inconel-600 specimen is more vulnerable to general corrosion as well as localized corrosion than 304 SS. The solution pH plays an important role on the general corrosion of Inconel-600. It is necessary to optimize for NP solution water chemistry in order to protect general and localized corrosion of Inconel-600.

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