Corrosion Characteristics of Inconel-600 at the NP(Cu)-HYBRID Decontamination Demonstration Test with HANARO FTL Specimen

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1. Introduction

Radioactive isotopes are observed in the corrosion oxide layer of the primary coolant system of a nuclear reactor during operation at high pressure and temperature and water chemistry. For the decontamination of these components, it is necessary to remove the oxide layer, especially the inner oxide layer in which Cr^{3+} is mainly deposited. Thus far, an alkaline permanganate (AP) or nitric permanganate (NP) oxidative phase has been generally used to dissolve the chromium-rich oxide [1, 2]. AP is advantageous for the corrosion resistance, but increases the volume of secondary waste during the decontamination procedure. On the other hand, NP has a high corrosion rate but reduces secondary waste. For the safe use of an oxidative phase in the primary coolant system, an oxidative decontamination solution with high corrosive resistance and less amount of secondary waste are required.

In this study, we modified NP oxidative decontamination solution by adding Cu^{2+} to reduce the corrosion rate. To evaluate the general corrosion characteristics, we measured the weight losses of selected specimens in an NP(Cu) and other solutions. The localized corrosion was observed using an optical microscope (OM). To compare the decontamination performance, we measured the contact dose rate of specimens treated in NP-HYBRID and NP(Cu)-HYBRID systems.

2. Experimental Methods

Inconel-600 and SS-304 specimens are used for the corrosion test. Test coupons are prepared with 20mm x 20mm x 2mm dimensions. For the general corrosion characteristics, we measured the weight loss of coupons and OM is used to compare the localized corrosions of each coupon. In the corrosion tests, we used three different types of oxidative solutions: NP, NP(Cu), and AP with pH 2.16.

To demonstrate the decontamination of the proposed oxidative solution, NP(Cu), we compared the contact dose rate of specimens obtained from HANARO FTL, which is a type 304 stainless steel (SS-304) in two different decontamination system: NP-HYBRID and NP(Cu)-HYBIRD. HYBRID developed by KAERI is a reductive decontamination solution by adding hydrazine based reductive ions. The HANARO FTL specimen was cut with a 3cm inside diameter and 4cm outside diameter and has about a 2cm length. The overall decontamination process is composed of two cycles pared with oxidation and reduction processes for each cycle. Each cycle was operated with 10 hour oxidation and 10 hour reduction at 93°C. The compositions of both decontamination systems are described in Table 1.

Table 1. Composition of decontamination solution

	NP-HYBRID	NP(Cu)-HYBRID
Oxidative decontamination solution	[NP] 0.61g/L $KMnO_4$ + 457$\mu\ell$/L HNO_3	[NP(Cu)] 0.61g/L $KMnO_4$ + 457$\mu\ell$/L HNO_3 + 0.5mM Cu^{2+}
Reductive decontamination solution	[HYBRID] 0.07M N_2H_4 + 4.8ml/L HNO_3 + 0.0362g $Cu(NO_3)_2$	[HYBRID] 0.07M N_2H_4 + 4.8ml/L HNO_3 + 0.0362g $Cu(NO_3)_2$

3. Results

Fig. 1 shows a comparison of the weight losses of Inconel-600 and 304-SS specimens by corrosion in NP and NP(Cu) as well as AP solutions. For all solutions, a greater weight loss was observed from Inconel-600. The weight loss of Inconel-600 in an NP is quantitatively 8-fold that in the AP. Both specimens in the NP(Cu) solution show a higher corrosion resistance than specimens in the NP solution by about 4 times. In all solutions, the corrosion of 304-SS was insignificantly small.

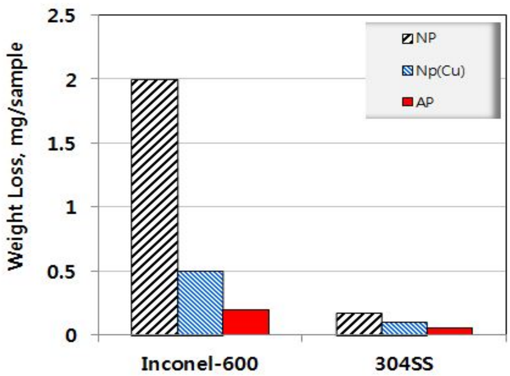

Fig. 1. General corrosion weight loss of Inconel-600 and 304 stainless steel in NP, NP(Cu) and AP solution.

The qualitative results of localized corrosion of specimens in NP and NP(Cu) solutions are shown in Fig. 2. The images were obtained using an optical microscope. In this figure, 304-SS in both NP and NP(Cu) has no corrosion, while Inconel-600 in NP has localized corrosion with pitting and an intergranular attack (IGA) on the surface. However, there was no observed corrosion such as pitting or IGA on the surface of the Inconel-600 specimen in NP(Cu).

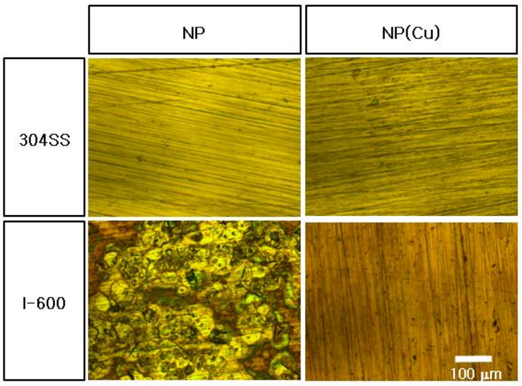

Fig. 2. Surface appearance of Inconel-600 and 304 stainless steel in NP and NP(Cu), showing localized corrosion on Inconel-600 surface corroded in NP solution(pH=2.16).

The demonstrative results of decontamination on the HANARO FTL specimen are shown in Fig. 3. The contact dose rates for both NP-HYBRID and NP(Cu)-HYBRID decontamination systems were compared. The contact dose rate in NP(Cu)-HYBRID decreases about 90% after a first cycle like NP-HYBRID. This result verifies that the NP(Cu)-HYBRID system has a high decontamination performance equivalent to the NP-HYBRID system.

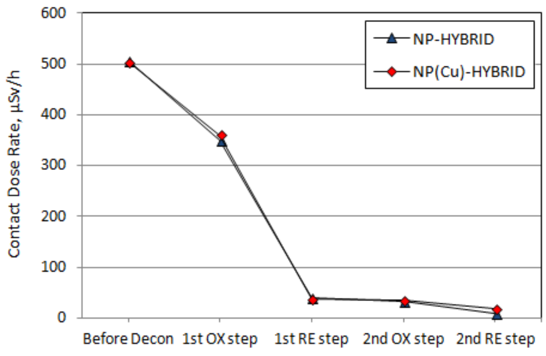

Fig. 3. Contact Dose Rate for FTL specimen in the NP-HYBRID and NP(Cu)-HYBRID.

4. Conclusion

The reduced corrosion characteristics of the Inconel-600 specimen in a NP(cu) oxidative solution was observed in terms of generalized corrosion as well as localized corrosion. Less corrosion characteristics do not affect the performance of the overall decontamination compared to the NP-HYBRID process. Therefore, our results support that the NP(Cu)-HYBRID decontamination process is appropriate for the decontamination of the primary coolant system in a nuclear reactor.

REFERENCES

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