Preliminary Evaluation of Film Products for In-Depth Compatibility and Feasibility Studies in NPP Secondary System

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1. Introduction

As of April 2023, ten domestic nuclear power plant units reached the end of their design life. Nuclear power plants reaching their design life undergo a safety re-evaluation and apply to the Nuclear Safety and Security Commission (NSSC) for continuous operation licensing review. Because this review process typically takes at least two yeasrs, plants generally maintain relative humidity at or below 40% during this period to minimize component material corrosion [1]. However, evaluating the aging degradation of key equipment structures is a crucial requirement thate must be assessed under the 40% relative humidity criterion. In practice, maintaining relative humidity below 40% during planned outages to minimize corrosion in secondary system materials presents prolonged period to reduce relative humidity below 40% adds further management challenges. To resolve these issues, this study aims to develop an application technology that minimizes corrosion by coating system surfaces with organic chemicals. As part of developing application of this coating technology, this study presents a preliminary experimental evaluation to assess the detailed feasibility of available organic chemicals and their compatibility with the secondary system.

2. Experimental Method

The organic chemical (due to commercial product names, they have been designated as **A** and **B**) used in the preliminary evaluation were **A** and **B**. The preliminary evaluation is an assessment of coating integrtiy based on organic chemical concentration. The specimens used in the preliminary experiment were fabricated from SA106 Gr.B, a material used for secondary system piping, to suit the experimental setup. To minimize measurement errors during evaluation, the fabrciated specimens were polished using #600 sandpaper. The evaluation was carried out by categorizing the specimen surfaces into untreated (hereafter referred to as bare metal) and oxidation-treated conditions (hereafter as oxidation).

2.1. Evaluation method of coating effectiveness

To evaluate the coating performance (before and after coating), contact angle measurements, surface morphology, and elemental composition analyses were utilized. In general, the effectiveness of a coating can be evaluated using the contact angle. That is, a surface contact angle below 90° indicateds hydrophilic characteristics, whereas an angle above 90° indicates hydrophobic characteristics [2]. The organic chemical to be applied is intended to minimize material corrosion during exposure to atmospheric conditions. Therefore, under normal operating conditions, it must be completely decomposed to minimize its on water chemistry and component materials. To achieve this minimal impact, the coating must be uniform and exert no adverse effect on corrosion products. To evaluate these factors, characterization and compositional analyses were performed.

2.2. Coating method depending on organic chemical

The coating of organic chemicals on the specimen surface was performed with reference to the method described in the EPRI (Electric Power Research Institute) report [2]. According to the EPRI report, in the case of **A**, a concentration of 25~30 g per 1 m^2 of surface area should be injected. On the other hand, the organic chemical **B** is specified to be injected at a dosage of 100 mg/kg in the secondary system water under AVT (All Volatitle Treatment) conditions. To evaluate surface coating, the secondary side normal operation conditions were simulated using an autoclave (batch type), and water chemistry conditions are presented in Table 1.

Table 1: Water Chemisty Condition for Surface Coating

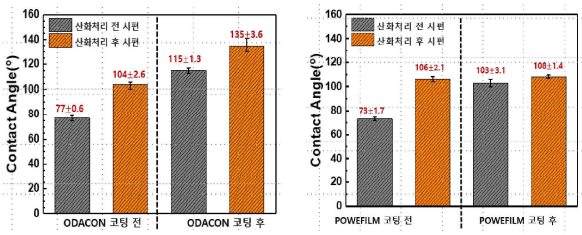
Parameters	pH (25℃)	DO (ppb)	Temp. (℃)	Immersion time (hr)
Condition	9.8 with ETA	< 0.5	230	24

3. Results & Disccusion

3.1. Measurement results of surface contact angles according to surface conditions and organic chemicals(Fig. 1)

The surface of the bare metal exhibited hydrophilic characteristics with an average contact angle of 73°~77°, whereas the oxidized surface showed hydrophobic characteristics with average angles of 104°~106°. Although oxidation caused the surface to exhibit hydrophobic characteristics, coating the surface with the **A** chemical was found to increase the contact angle, thereby enhancing its hydrophobicity. However, coating

the surface with **B** did not alter or enhance its hydrophobic characteristics. As shown in Figure 1(b), the transition from hydrophilicity to hydorophobicity upon applying **B** to the bare metal is attributed to surface oxidation during the coating process, rather than the coating itself.

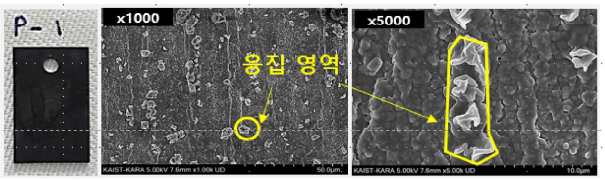


(a) **A** Chemical (b) **B** Chemical

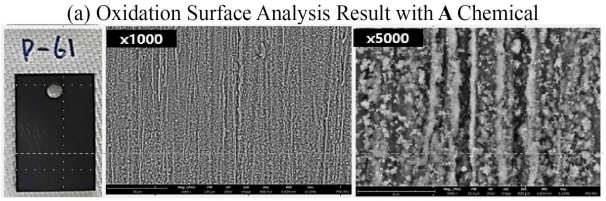
Fig. 1. Contact Angle Measurement Results about Surface Conditions and Organic Chemicals

3.2. Analysist results of surface with SEM(Fig. 2)

Figure 2 shows the state of the oxidized specimens after surface coating with **A** (a) and **B** (b), respectively. On the surface coated with **A**, the oxide particles appear blurrier, and some agglomeration of organic matter is observed. This is likely because **A** coated over the oxide particles, suggesting that **A** tends to agglomerate when the coating process is conducted under stagnant conditions. In contrast, the oxide particles remain clearly visible on the surface coated with **B**. These results indicate that **B** is ineffective at modifying the surfacc through surfacc coating. A similar trend was observed in the bare metal specimen and is therefore omitted.



(a) Oxidation Surface Analysis Result with **A** Chemical

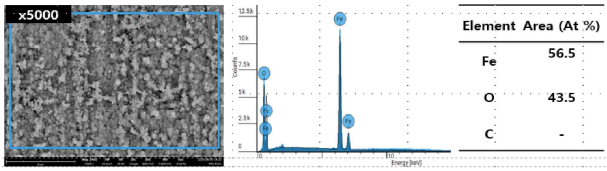


(b) Oxidation Surface Analysis Result with **B** Chemical

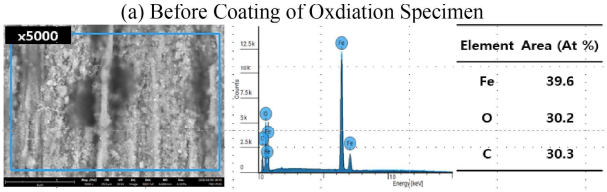
Fig. 2. Contact Angle Measurement Results about Surface Conditions and Organci Chemicals

3.3. Analysis results of surface with EDS(Fig. 3)

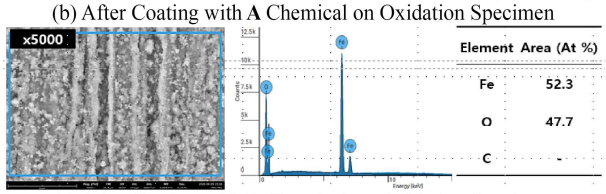
Figure 3 shows the elements before and after coating the oxidized specimens with **A** and **B**, respectively. When **A** was injected, carbon(C) was detected in the elemental analysis because organic matter was coated on the specimen surface. Conversely, despite the injection of **B**, carbon(C)-primary constituent of organic matter-was not detected on the surface. This finding aligns with the surface analysis results. In other words, while the organic components in **A** effectively serve as a surface coating, those in **B** appear to lack surface-coating functinalily.



(a) Before Coating of Oxdiation Specimen



(b) After Coating with **A** Chemical on Oxidation Specimen



(c) After Coating with **B** Chemical on Oxidation Specimen

Fig. 3. Area Element Analysis Results on the Surface of Oxidation Specimens

4. Conclusion & Future Work

Preliminary experiments were conducted to evaluate the feasibility and compatibility of the purchased film-coating chemicals in detail. The evaluation focused on whether the chemicals exhibited hydrophobic properties-the primary function of the coating-and whether they formed a uniform surface layer.

The results showed that **A** demonstrated or enhanced hydrophobic properties through coating, regardless of the surface condition (bare metal or oxidation). However, some chemical agglomeration on the surface was observed. Further experiments will be conducted to determine whether this stems from the coating process or intrinstic chemical properties. Conversely, **B** failed to form a film regardless of the surface condition. Rather than benefiting from a coating effect upon chemical injection, the hydrophobic properties were evaluated to be driven more by the oxides formed on the surface during the coating process.

REFERENCES

[1] Cycling, Startup, Shutdown and Layup Fossil Plant Cycle Chemistry Guidelines for Operators and Chemisit. EPRI, Palo Alto, CA: 2009.1015657.
[2] Pressurized Water Reactor (PWR) / Pressurized Heavy Water Reactor (PHWR) Secondary Side Filming Product (FP) Application: Effect of Filming Products on General Corrosion under Simulated Secondary-Side Lay-Up Condtions. EPRI, Palo Alto, CA: 2023.3002026095.