Evaluation of Corrosion-Resistant Alloys for Wet Electrostatic Precipitator

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Abstract: We found suitable corrosion-resistant alloys for a wet electrostatic precipitator (WESP) equipped with an intermittent washing function used in power plants that use fuel with a high sulfur content. Using seven types of corrosion-resistant alloys selected in advance, tests were run to compare the four forms of corrosion that occur within the WESP. N06022 or N10276 produced better results when pH was lower than 0.5. In the 0.5 pH to 1.0 pH range, S32053 was found to be the ideal material from the viewpoint of both corrosion resistance and cost. By capitalizing on our wealth of design technologies and know-ledge of materials, we can provide optimum systems for the corrosive environment within the WESP.

Keywords: Wet electrostatic precipitator, SO_3 mist, pH, corrosion-resistant alloys, general corrosion, pitting corrosion, Stress corrosion cracking, crevice corrosion

1 INTRODUCTION

A WESP is installed in the latter stage of desulfurization equipment ($DeSO_x$) to collect fine SO_3 mist. The collected SO_3 mist is washed continuously or intermittently with a water spray installed within the WESP and recovered.

Power plants in Japan mainly use fuel with a low sulfur content. In addition, WESP is continuous-ly washed, and the pH of the water discharged from the WESP is maintained within the 2 pH to 3 pH range. Consequently, relatively inexpensive materials (such as S31703) can be used for the WESP.

On the other hand, many overseas power plants use fuel with a sulfur content as high as 3% to 4%, and the WESP is washed only intermittently. Because the pH of SO_3 mist is around 0.5, the interior of the WESP becomes highly corrosive when washing is not performed, so the materials used for the WESP must be reviewed in such cases.

In this study, corrosion-resistant alloys usable within the WESP, which enters a strongly acidic state, were studied from the viewpoint of both corrosion resistance and cost, and a suitable material was found.

2 TEST MATERIALS AND EVALUATION METHOD

Table 1 lists the corrosion-resistant alloys evaluated [1, 2]. In this paper, UNS numbers are used to represent material codes. Preliminary evaluations were conducted to narrow down the number of materials to seven. The pitting resistance equivalent (PRE) [2] calculated from the mass % of the chemical components (Cr, Mo, N) contained in these materials was used for the evaluation.

PRE = Cr + 3.3 Mo +20 N

The forms of corrosion that may occur within the WESP include general corrosion, pitting corrosion, stress corrosion cracking (SCC), and crevice corrosion. To evaluate the effects of the corrosion on materials, (a) electrochemical measure-ments, (b) SCC tests, and (c) crevice corrosion tests were conducted.

Table 1 Test Materials

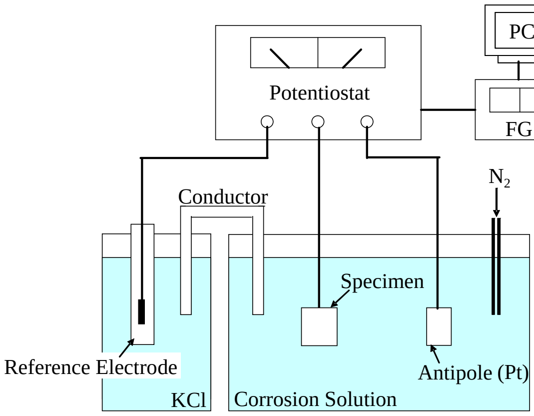
UNS Number	Cost [%]	Mass Rate of Chemical Component [%]					PRE	Corrosion Resistance
		Ni	Cr	Mo	N	others		
S30400	70	8	18	-	-	Fe	18	Low
S31703	100	13	18	4	-	Fe	28	
S32506	100	6	25	3.3	0.15	Fe	32	
S31727	180	15	18	4	0.15	Cu, Fe	39	
S32053	200	25	23	5.5	0.2	Fe	45	
N06022	700	56	22	13	-	Co, W, Fe	65	
N10276	700	57	16	16	-	W, Fe	68	High

A primary material selection was made first by evaluating the results of (a) and (b) comprehensively, and then (c) was conducted to make a final evaluation. The corrosive solution used for these three tests was prepared by simulating the SO_3 mist collected from the WESP. Specifically, chloride ion concentration was fixed to 3% and temperature at 328 K, and by changing the sulfuric acid concentration, the pH of the solution was adjusted to within the 0 to 2 range.

3 EXPERIMENTAL PROCEDURE

3.1 Electrochemical Measurements [3]

The anode polarization curve of each material was measured to evaluate the status of general corrosion and pitting corrosion. Fig. 1 shows the test equipment used. A function generator and potentiostat were connected to a computer. The specimen and the antipole (Pt) were immersed in a corrosive solution, while the reference electrode was immersed in a potassium chloride solution. First, to remove oxygen contained in the test solution, the glass vessel was sealed tightly and then N_2 gas was injected for 30 minutes for replacement. Then the current density of each material was measured with the scan rate kept at 20 mV/min by a function generator. General corrosion was evaluated by the existence or nonexistence of the peak of activity, while pitting corrosion was evaluated with the maximum electric potential exceeding 10^{-4} A/cm^2 regarded as the pitting potential.



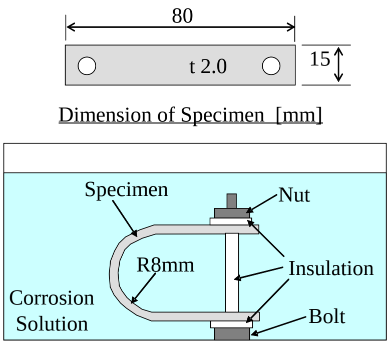
(pH 0, 1, 2 Cl 3% 328K)

PC : Personal Computer FG: Function Generators

Fig. 1 Electrochemical Measurement

3.2 SCC Test [4]

Fig. 2 shows the test equipment used to evaluate general corrosion and SCC. A 2 mm thick, 15 mm wide, and 80 mm long flat plate deformed in a U shape was used as a specimen. To maintain the U shape, both ends of the plate were fastened with bolts. To ensure electrical insulation between the specimen and the bolt, an insulating material was inserted between the specimen and the bolt. The specimen was immersed in the corrosive solution for 500 hours, and then the cracks on its surface were examined.

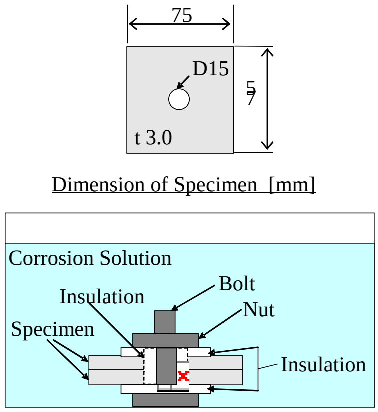


(pH 0, 1, 2 Cl 3% 328K)

Fig. 2 SCC Test

3.3 Crevice Corrosion Test

Fig. 3 shows the test equipment used to evaluate crevice corrosion and general corrosion. A hole 15 mm in diameter was made at the center of the two 3 mm thick, 75 mm wide, and 75 mm long specimens. The specimens were fastened with bolts. As in the case of the SCC test, an insulating material was inserted between the specimen and the bolt. The decrease in thickness of the specimens was measured after 1000 hours.



(pH 0, 0.1, 0.5, 1, 2 Cl 3% 328K)

Fig. 3 Crevice Corrosion Test

4 RESULTS AND DISCUSSION

4.1 Electrochemical Measurements

Fig. 4 presents a typical measurement result of S31703, S32053 and N06022 when the pH was kept at 0. Since there exists an activity peak with S31703 and S32053, it is highly likely that general corrosion occurs with these materials. Meanwhile, since no peak was found with N06022, general corrosion is not considered to occur with this material.

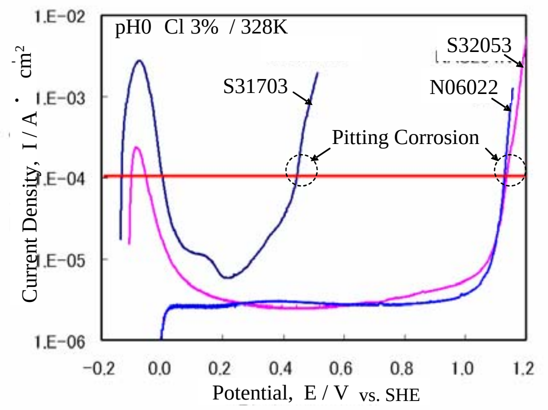


Fig. 4 Result of Electrochemical Measurement

Fig. 5 shows the pitting potential of each material when the pH of the corrosive solution was varied. The lower the pitting potential, the higher the possibility that pitting corrosion occurs. Since the pitting potential of S32053, N06022 and N10276 was as high as 1 V under any conditions, it is unlikely that pitting corrosion occurs.

4.2 SCC Test

Fig. 6 presents the test results of the four materials when the pH was kept at 0. Cracks were found on S32506. Although no cracks were found on S31703, a number of grooves that would have developed into general corrosion upon the occurrence of cracks were found. Consequently, we regarded these grooves on S31703 as cracks. On the other hand, S32053 and N06022 produced good results, with no apparent generation of cracks or grooves.

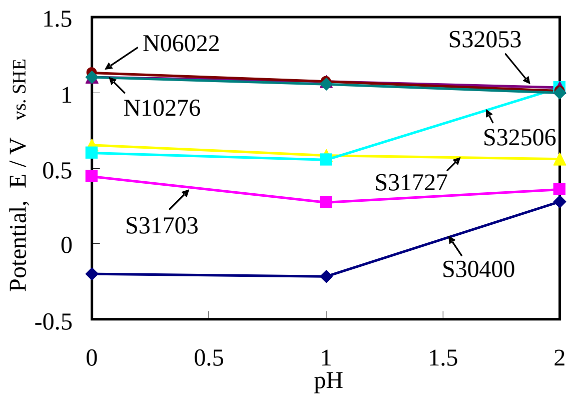
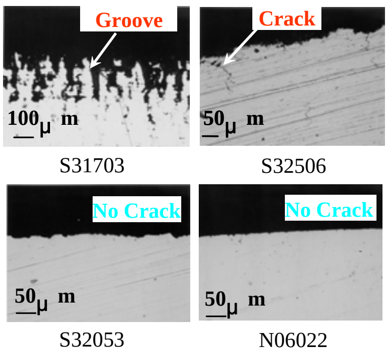


Fig. 5 Potential (for Pitting Corrosion) - pH Curve



(pH0 Cl3% / 328K / 500h)

Fig. 6 Result of SCC Test

4.3 Primary Selection of Materials

Table 2 summarizes the results of the electrochemical measurements and SCC test. Since no corrosion occurred with N06022 or N10276 under any conditions, they were considered to be applicable to the WESP and so were not subjected to the crevice corrosion test. Although electro-chemical measurements suggested that S32053 may develop general corrosion under the condition of pH 0, it was the most promising material in terms of corrosion resistance and cost. Other materials were found to be unusable under pH conditions of 1 or lower. Consequently, S32053 was used for the crevice corrosion test, and the corrosion area that defines the application limit was examined in further detail.

Table 2 Primary Selection of Material

UNS Number	Electrochemical Measurement: No Peak: G / Peak: NG			Potential (for pitting corrosion) Over 1V (vs. SHE): G / Less 1V (vs. SHE): NG			SCC Test: No Cracks: G / Cracks: NG			Judgment
	pH0	pH1	pH2	pH0	pH1	pH2	pH0	pH1	pH2	
S30400	NG	NG	G	NG	NG	NG	NG	G	G	NG
S31703	NG	G	G	NG	NG	NG	NG	G	G	NG
S32506	NG	G	G	NG	NG	G	NG	G	G	NG
S31727	NG	G	G	NG	NG	NG	NG	G	G	NG
S32053	NG	G	G	G	G	G	G	G	G	P
N06022	G	G	G	G	G	G	G	G	G	G
N10276	G	G	G	G	G	G	G	G	G	G

G: Good P: Possible NG: No Good

4.4 Crevice Corrosion Test

Fig. 7 shows the mass loss of the specimens when the pH was varied. To compare the result with that of S32053, the same test was also conducted using S31703. No corrosion was found with S31703 when the pH was 2, but when the pH was decreased to 1 or lower, significant mass loss was found, which indicated that crevice corrosion as well as general corrosion had occurred.

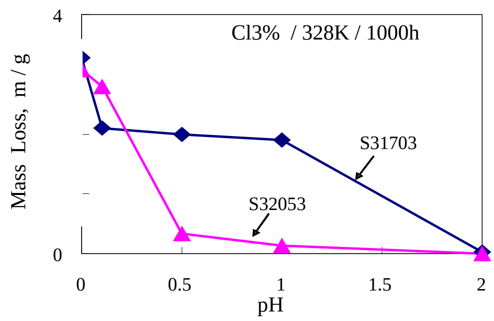


Fig. 7 Effect of pH on Corrosion Mass Loss

Meanwhile, mass loss was rarely found with S32053 when the pH was 1 or higher, indicating that no corrosion had occurred. When the pH was kept at 0.5, mass loss was found, which indicated that crevice corrosion had occurred. When the pH was decreased to less than 0.5, general corrosion as well as crevice corrosion occurred, resulting in significant mass loss. Fig. 8 shows the specimen of S32053 when the pH was kept at 0.5 and 1 respectively. Crevice corrosion was found to have occurred around the bolt hole when the pH was kept at 0.5.

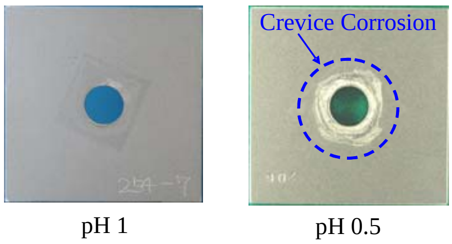


Fig. 8 Crevice Corrosion of S32053

The above results are summarized as follows: although crevice corrosion occurred to S32053 when the pH was kept at 0.5, general corrosion did not occur. To prevent crevice corrosion from occurring, applying a coating material to the joining area is effective. S32053 can be used for areas other than joining areas, where a gap is generated, without taking any additional measures. Consequently, S32053 is considered to be ideal for the WESP in the 0.5 to 1.0 pH range in terms of corrosion resistance and cost.

5 CONCLUSIONS

We studied suitable corrosion-resistant alloys that can be used in a WESP using fuel with a high sulfur content and equipped with an intermittent washing function. The following results were obtained.

(1) When the pH of the SO_3 mist falls within the 0.5 to 1 range, S32053 was found to be an ideal material for the WESP both in terms of corrosion resistance and cost. However, if the pH is kept at 0.5, countermeasures against crevice corrosion must be taken.

(2) When the pH of the SO_3 mist is lower than 0.5, the use of N06022 or N10276 is recommended.

Consequently, we can provide optimum systems for the corrosive environment within the WESP, capitalizing on our wealth of design technologies and knowledge of materials.

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