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Study on the Behavior of Impingement Erosion – Corrosion for Thermal Sprayed Coating on Mild Steel in Acidic Environment

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This paper was studied on the behavior of impingement erosion-corrosion for Cu-Ni and Ni-Cr thermal sprayed coating on mild steel in pH 1.5 and 4.5 solutions. Due to increase of air pollution substance, such as SO_2, SO_3, H_2S, CO, HCl, Cl_2 and so on, the operating environment of mechanical equipment and facilities, such as generating plants, ships, boilers, refrigerating air-conditioning system etc, are acidified. Because of accelerating fluid velocity and mechanical device's RPM, these devices using fluid occur the impingement erosion by liquid jet impacting surface. In acidic environment, mechanical impingement erosion and electrochemical corrosion occur together, resulting the decrease of machine efficiency and damage of machine devices. The behavior of erosion-corrosion for SS 400, Cu-Ni and Ni-Cr thermal sprayed coating was considered. Also, impingement erosion-corrosion mechanism in acidic environment was investigated.

Keywords : *thermal sprayed coating, impingement erosion-corrosion, acidic environment, volume loss rate*

1. Introduction

As energy consumption increased, influence of air pollutive substance like SO_2, SO_3, H_2S, CO, HCl, Cl_2, is being accelerated. And addition to this, every kind of facilities and mechanical device is coming to be high speed and high power, and so, there occurs impingement erosion-corrosion so often to the mechanical device. In case that there happen impingement erosion-corrosion at the same time, the synergy effect causes less efficiency and makes the life span of device shorten. So, to prevent the damage by impingement erosion-corrosion in corrosive liquid, the way to coat on cheep mild steel with anti-corrosive metal or alloy is widely used.[1-5]

In this study, the impingement erosion test was carried out on the mild steel(SS 400) with Cu-Ni power and Ni-Cr power. And, based on the test result, the erosion-corrosion behavior of base metal(SS 400), Cu-Ni coating and Ni-Cr coating was observed, and the mechanism of erosion-corrosion in acidic environment was searched.

2. Experimental apparatus and method

The base metal used in this study is SS 400, and thermal sprayed coating powder is Cu-Ni and Ni-Cr which is passive alloy. Table 1 shows the chemical compositions of these coating powder.

In impingement erosion-corrosion experiment, the test sample was made by thermal spraying Cu-Ni powder and Ni-Cr powder to base metal and the shape is shown in Fig. 1.

The effective exposure area was 10 cm^2 and the other area was electrically isolated by silicon resin. And coated

Table 1. Chemical compositions of Cu-Ni powder and Ni-Cr powder (wt%)

Cu-Ni powder composition						
Cu	Ni	Si	B	P	Fe	C
Balance	22	1.5	1.2	1.3	0.2	0.03
Ni-Cr powder composition						
Ni	Cr	Cu	Si	Fe	B	C
Balance	13	5.3	3.8	3.6	3.1	0.6

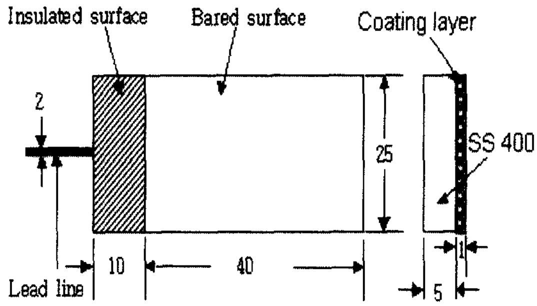

Fig. 1. Shape and dimension of impingement erosion-corrosion test sample (unit : mm).

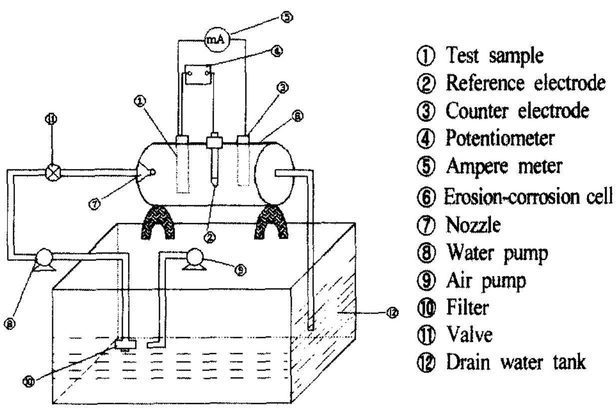

Fig. 2. Schematic diagram of impingement erosion-corrosion test apparatus.

wire was connected to observe the behavior of electro-chemical erosion-corrosion.

The impingement erosion experimental apparatus was designed and made by referring to the ASTM G73-82,[6] "Liquid impingement erosion testing", as shown in Fig. 2. To produce impingement erosion-corrosion phenomenon, after installing Teflon parallel nozzle of 3 mm diameter on pipe line of 25 mm, corrosive liquid about 10l was jetted every minute with 20 m/s velocity. And the jetted corrosive liquid was collided with test sample far away 100 mm from the front side of nozzle. In all pipe line and materials for experimental apparatus, electrically isolating materials like plastic, teflon, acryl were used, and to prevent occurring corrosive by-product, the isolating filter was installed on the pipe line. Corrosive liquid was made by adding H_2SO_4 to distilled water to control pH as 1.5 and 4.5, and covered with lap to restrain contacting air as soon as possible.

3. Results and discussion

3.1 Erosion-corrosion behavior of thermal sprayed coating

Fig. 3 shows the volume loss of base metal(Ss 400), Cu-Ni coating, and Ni-Cr coating by impingement erosion-corrosion in pH 1.5 solution with time passing. The velocity is 20 m/s.

The volume loss of Cu-Ni coating and Ni-Cr coating in pH 1.5 solution is much less than base metal. And the loss of Cu-Ni is less than Ni-Cr coating. Therefore, in strong acid solution, base metal which is mild steel is most sensitive to hydrogen evolution corrosion, and the next is Ni-Cr coating, and Cu-Ni coating is least sensitive to hydrogen evolution corrosion.

Fig. 4 shows the volume loss of base metal(SS 400), Cu-Ni coating, and Ni-Cr coating by impingement erosion-corrosion in pH 4.5 solution with time passing. The velocity is 20 m/s.

The volume loss of base metal and Cu-Ni, Ni-Cr coating in pH 4.5 solution is similar with the behavior in pH 1.5 solution.

Fig. 5 shows the volume loss of base metal, Cu-Ni coating, and Ni-Cr coating after impingement erosion-cor rosion test per 96 hours with changing pH. The velocity

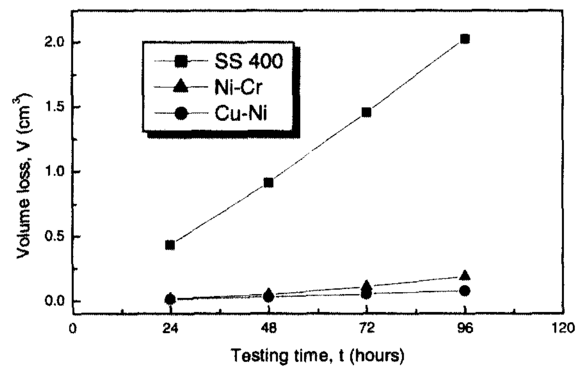

Fig. 3. Volume loss of SS 400, Cu-Ni coating, and Ni-Cr thermal sprayed coating by impingement erosion-corrosion in pH 1.5 solution (V=20 m/s).

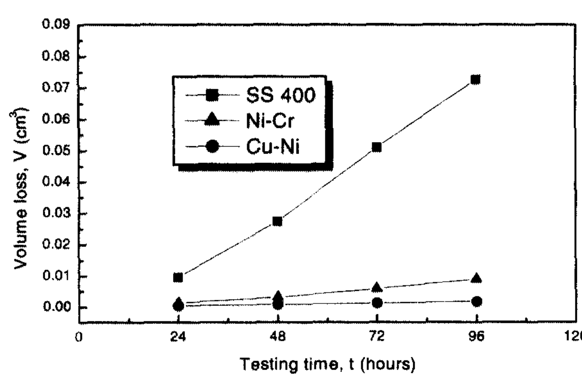

Fig. 4. Volume loss of SS 400, Cu-Ni, Ni-Cr thermal sprayed coating by impingement erosion-corrosion in pH 4.5 solution (V=20 m/s).

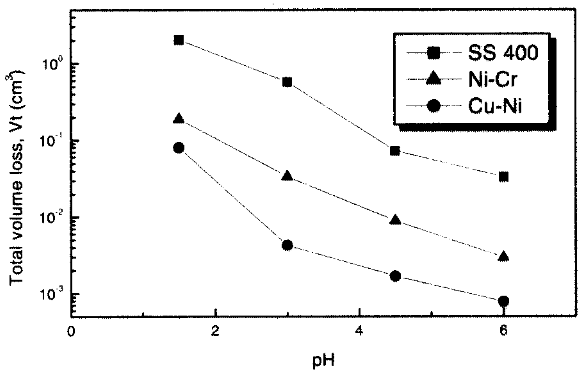

Fig. 5. Total volume loss of SS 400, Cu-Ni, and Ni-Cr thermal sprayed coating by impingement erosion-corrosion vs. pH (t= 96 hrs, V= 20 m/s).

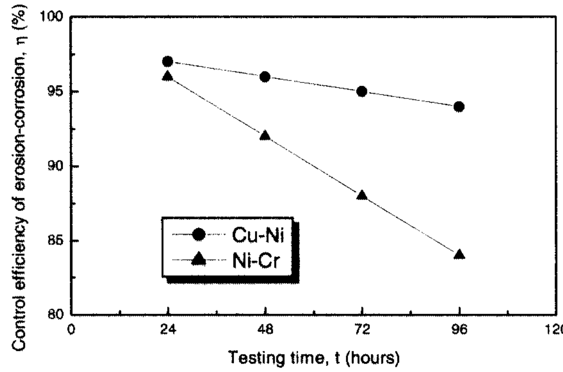

Fig. 6. Control efficiency of erosion-corrosion for Cu-Ni and Ni-Cr thermal sprayed coating to SS 400 depending on the testing time in pH 1.5

is 20m/s. The total volume loss of base metal, Cu-Ni coating, and Ni-Cr by impingement erosion-corrosion shows increasing tendency as pH lowed. This result might be owing to active hydrogen evolution corrosion at low pH. Especially, rapid volume loss of Cu-Ni coating corrosion is observed between pH 3 and pH 1.5. And it may be owing to active hydrogen evolution corrosion at pore of Cu-Ni coating which occur at the boundary between base metal and Cu-Ni coating.

3.2 Control efficiency of erosion-corrosion

Control efficiency of erosion-corrosion about base metal, Cu-Ni coating, and Ni-Cr coating is calculated as percentage of weight change rate between before and after impingement erosion-corrosion test.

$$\eta_e(\%) = \frac{weightdecreaseofcoating}{weightdecreaseofbasemetal} \times 100 \quad (1)$$

Fig. 6 shows the control efficiency of impingement erosion-corrosion of Cu-Ni coating and Ni-Cr coating to the base metal in pH 1.5 solution.

In pH 1.5 solution, the control efficiency of erosion-corrosion of Cu-Ni coating to base metal is higher than that of Ni-Cr coating. And as time passed, the control efficiency of coating is coming to be low. The reason about low control efficiency seems that the defect area on base metal caused by active erosion-corrosion is filled with solution and it has the role to make impact low.

3.3 Modeling of impingement erosion-corrosion

Fig. 7 shows the modeling of impingement erosion- corrosion based on macro erosion-corrosion aspect of mild steel(SS 400) in acid solution.

Jetted solution from nozzle impacts to the center area C and a. Owing to this impact, there occur bubble at around

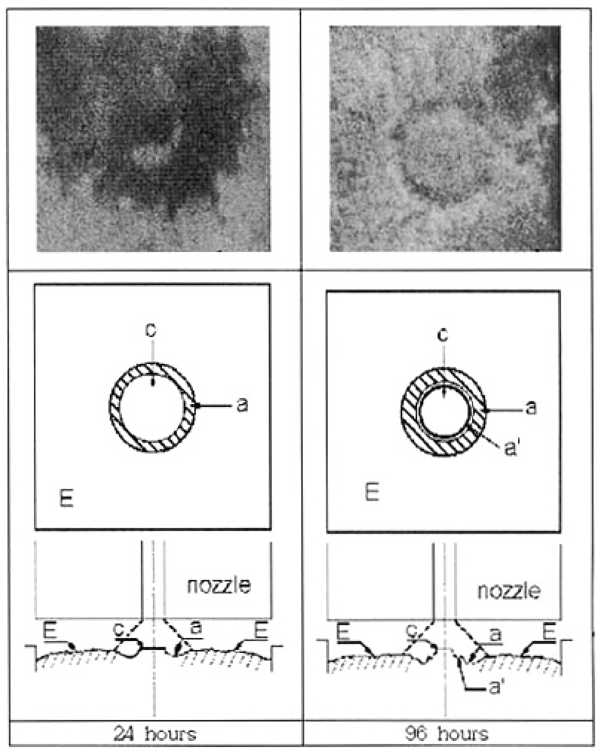

Fig. 7. Modeling on damage surfaces in acid solution according to testing time for SS 400.

area E and collapse of bubble seems to cause erosion-corrosion damage to area E. Especially, the oxygen concentration of area C and a is lower than around area E, and it cause oxygen concentration cull which makes area a and a' to anode and so, lead to active galvanic corrosion with erosion caused by collapse of bubble. So, most severe damage by erosion-corrosion occurs at area a because of synergy effect of galvanic and erosion-corrosion but as time pass, the damage area comes to move to area a' which is inside of round.

Fig. 8 shows the modeling of impingement erosion-

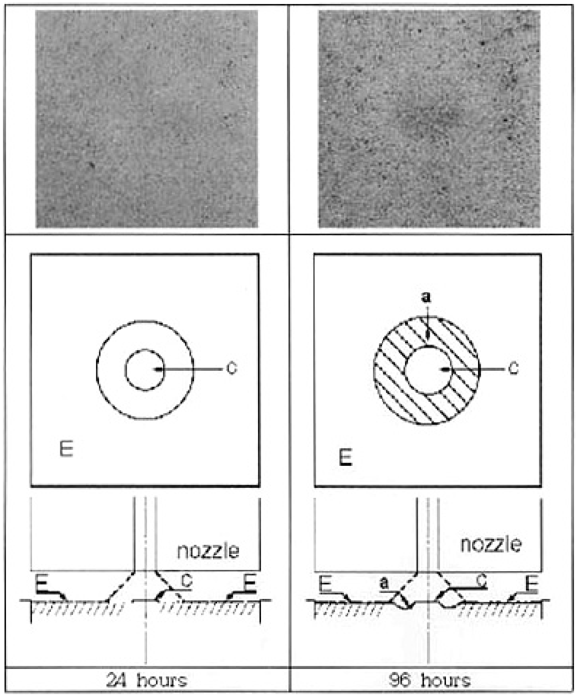

Fig. 8. Modeling on damage surfaces in acid solution according to testing time for Cu-Ni thermal sprayed coating

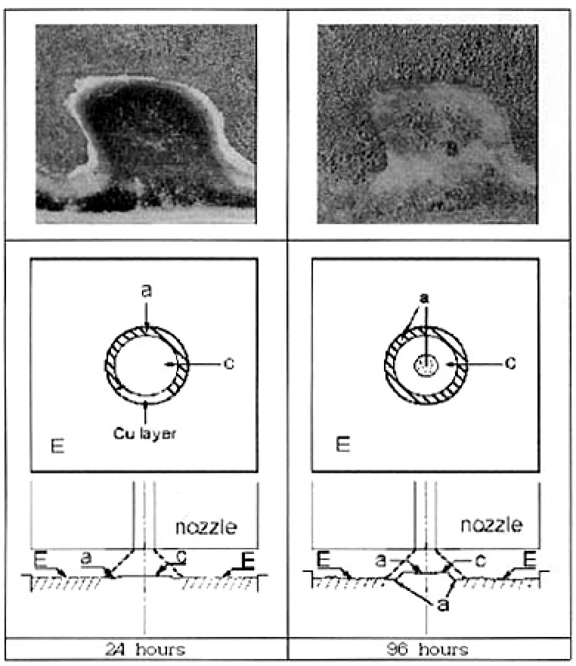

Fig. 9. Modeling on damage surfaces in acid solution according to testing time for Ni-Cr thermal sprayed coating

corrosion of Cu-Ni coating based on macro erosion-cor rosion aspect in acid solution. Like base metal shown in Fig. 7, most severe damage occurs at area a because of synergy effect of galvanic and erosion-corrosion but in case of a' area, there is little damage because Cu-Ni coating has anti-corrosive characteristics.

Fig. 8 shows the modeling of impingement erosion- corrosion of Ni-Cr coating based on macro erosion-corrosion aspect in acid solution.

Like base metal and Cu-Ni coating shown in Fig. 7 and Fig. 8, there occurs most severe damage at area a. But the different point with base metal and Cu-Ni coating is that Cu coating layer come to be separated and cause damage to area c as well as area a.

As shown in Fig. 7, Fig. 8, and Fig. 9, impingement erosion-corrosion is developed to the depth way by synergy effect of galvanic corrosion and erosion-corrosion even though there is a little difference depending on materials and corrosion environment.

4. Conclusion

The test results on erosion-corrosion behavior, control efficiency of erosion-corrosion, and the mechanism of mild steel, Ni-Cr coating, and Cu-Ni coating are as follows:

1) The erosion-corrosion damage to SS 400, Cu-Ni coating and Ni-Cr coating is increased with pH coming to low.
2) In acidic solution, the control efficiency of erosion-corrosion of Cu-Ni coating and Ni-Cr coating come to be low as time passed.
3) Erosion-corrosion damage in acidic solution propagates to the depth way by synergy effect of galvanic corrosion and erosion-corrosion.

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