Effect of Shot-peening on the Passive Film Formation and Corrosion of Carbon Steel in LiBr Aqueous Solution

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1. Introduction

In absorption chillers using LiBr aqueous solution, corrosion problems of carbon steel heat exchangers become more serious as the temperature of the generator increases. To reduce corrosion problems, various surface treatment methods such as a shot-peening process are applied, and corrosion inhibitors are frequently added into the LiBr solution to form passive films on the surface of carbon steel.

A shot-peening process was proven to be beneficial in the fatigue corrosion, however, its effect on corrosion in LiBr aqueous solution at high temperature has been rarely investigated. In our previous study [1], the effect of surface treatment on corrosion of carbon steel in LiBr aqueous solution was investigated. The results showed that the shot-peening process was quite effective in suppressing both the general corrosion and local corrosion including the pitting corrosion.

With a shot-peening process the metal surface experiences the property changes such as an increase in hardness, formation of compressive residual stress in a thin layer, and an increase in surface roughness, which are thought to be favorable in inhibiting the corrosion of steel**.** However, the reason is not yet clear why a shot-peening is effective in inhibiting the corrosion in LiBr aqueous solution.

The compressive residual stress formed in the surface layer is well known to suppress stress corrosion cracking and improve the fatigue life of the metal. Maleki et al. [2] showed that the shot-peening process improved the fatigue life. Also, the enhancement of hardness has been thought as a reason of the corrosion inhibition. Lin et al. [3] studied the hardness and the corrosion resistance of carbon steel using induction heat treatment. Measuring the corrosion potential and corrosion current density, they showed that the corrosion could be reduced by increasing the hardness of steel surface. The corrosion resistance according to surface roughness was studied by Toloei et al. [4]. The surface of mild steel was abraded using SiC papers with different grades, and the corrosion characteristics of steel in H_2SO_4 solution were investigated. Their results showed that a higher surface roughness of carbon steel was more effective in suppressing the corrosion.

Since the experimental conditions of our previous study in which the surface roughness was increased by shot-peening, it was supposed that the surface roughness could play a great role in the formation of the passive film. In this study, therefore, a simple test was carried out to figure out the effect of shot-peening process on formation of Fe_3O_4 passive film on the surface of carbon steel.

2. Experimental

SS400 carbon steel was used in the experiments. The chemical compositions except Fe are shown in Table 1, and the size of a steel specimen is 25 mm x 5 mm x 3 mm. To compare the effect of shot-peening, two kinds of surfaces were tested. One was untreated surface and another was shot-peened. Two surfaces (25 mm x 5 mm) of a specimen were shot-peened.

First, the surface of the specimens was chemically cleaned to remove the impurities. The chemical cleaning was carried out by ASTM G1-03 method [5]. The blackening process, the formation of Fe_3O_4 film, was performed by the hydrothermal method using hydrazine hydrate proposed by Hongliang et al. [6]. The blackening solution was made by adding 0.14 g of iron sulfate hydrate ($FeSO_47H_2O$), 0.08 g of sodium hydroxide (NaOH), and 0.03 g of hydrazine monohydrate ($N_2H_4H_2O$) to 100 mL of deionized water. The cleaned specimens were immersed in the blackening solution and put into a high temperature oven set at 150℃. After 4 hours, the specimens were taken out of the oven, and rinsed using deionized water several times. The specimens were cooled naturally at room temperature for 1 hour. After the test, the Fe_3O_4 film on the surface was observed using a field emission scanning electron microscope (FE-SEM), and analyzed by comparing the oxygen element content using an energy dispersive spectroscopy (EDS) mapping.

Table 1 Chemical composition of carbon steel specimens (wt%).

C	Si	Mn	P	S
0.1941	0.010	0.230	0.0106	0.0047

3. Results and discussion

Figure 1 shows FE-SEM images of the surface of each specimen for untreated and shot-peened specimens. In the figure, (a) indicates the chemical cleaned and (b) indicates the blackened specimen, respectively. In Fig. (a) the structural difference due to the shot-peening process can be observed. The shot-peened surface is rougher than the untreated one. The blackened specimens (Fig. (b)) showed darker color than the cleaned ones. Especially, it can be seen that the color of the shot-peened specimen is darker than that of the untreated one, which indicates more Fe_3O_4 film was formed on the shot-peened specimen.

The oxygen element contents observed at the same magnification using EDS are shown in Table 2. In case of the chemically cleaned specimens, very low oxygen contents were observed. After blackening process, the specimens showed higher oxygen contents than the cleaned ones. The oxygen content of the shot-peened specimen (7.02%) was found to be quite higher than that of the untreated one, which means more passive film was formed in the shot-peened specimen. The results agree well with that of Toloei et al. [4], and indicate that a shot-peened surface offers a favorable condition for the Fe_3O_4 passive film formation.

Although the present study was carried out using a blackening solution, a similar effect is expected in LiBr aqueous solution. Another experiments using LiBr aqueous solution are currently being carried out, and the results are to be reported in the near future.

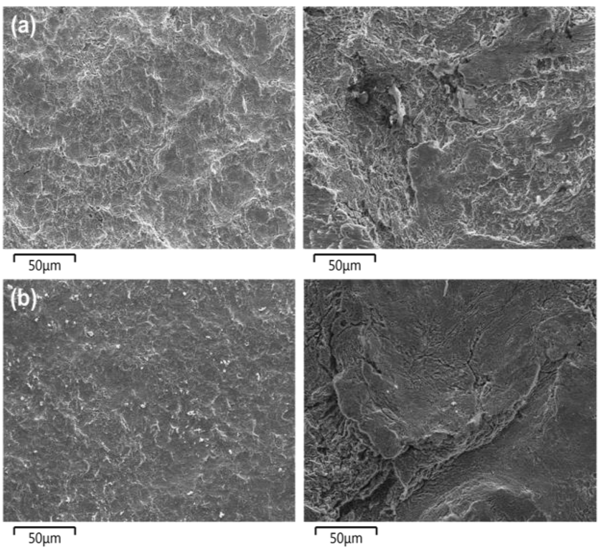

Fig. 1 FE-SEM image of untreated(left) and shot-peened specimen(right):
(a) chemical cleaned specimens
(b) blackened specimens

Table 2 Oxygen element content (wt%).

	Untreated specimens	Shot-peened specimens
Chemical cleaned	0.96	1.59
Blackened	2.51	7.02

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