Zinc-Aluminum Alloy Deposition on Mild Steel

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Summary: Zinc-aluminum alloy was electrodeposited on mild steel from non-cyanide chloride bath at current density 3-3.5 A/dm^2, plating voltage ~ 1.25 V, temperature 18-20°C, for fifteen minutes. The effect of aluminum chloride on the rest potentials of golden, colorless and non-chromated zinc-aluminum alloy deposits was observed. It was found that rest potential was slightly increased with the increase in concentration of aluminum chloride; only in case of golden chromating. The rest potential of colorless chromated zinc-aluminum deposits on mild steel have no correlation with aluminum chloride concentration. The abrasion resistance of colorless chromated zinc-aluminum mild steel plates was better than golden chromating.

Introduction

Zinc has traditionally been the metallic material most widely used to protect steel against atmospheric corrosion. Due to its low cost, zinc has been the predominant coating [1,2]. Recent demands for higher quality finishes, and, more specifically, longer lasting finishes, have prompted a move to alloy zinc deposits. Several different alloy zinc systems have been introduced, giving deposits of somewhat different properties. Although these coatings present some advantages over zinc, they are not able to cathodically protect steel substrates in all types of natural atmospheres. The differences come not only from the choice of alloying metal, but from the electrolyte system used as well. Except for the tin, which is typically an alloy of 70% tin and 30% zinc alloy, zinc comprises from 85 to 99% of the alloy deposit. Analogous to conventional zinc, each of the alloys requires a chromate conversion coating to obtain improved corrosion resistance. Indeed, the chromate in this case is more effective on the alloy deposits than on the pure metal [1]. Aluminum and aluminum-rich alloy coatings (55% aluminum/zinc) provide cathodic protection to the steel substrate only in atmospheres that are highly contaminated with chloride ions (>100 mg Cl^- m^{-2} day^{-1}) where these coatings become active [2].

Chromate conversion coatings produce a good corrosion resistance on zinc and also make the use of zinc in many decorative and industrial application possible [3-5]. Steel sheets are successively formed with chromate films and zinc or zinc alloy plating on steel, where chromate films have (refractive index) X (film thickness) 180-280 nm [6]

The surface of zinc-(25-75%) aluminum alloy layer formed on a steel sheet is coated with a chromating solution having a Cr^{6+}/(total chromium) molar ratio of ≥ 0.55, dried, coated with a processing liquid containing a resin emulsion, and dried to give a composite coating containing a chromate layer at 5-40 mg chromium/m^2 and a top coating with 0.8-4.0 g resin/m^2. The processing liquid may additionally contain Cr^{3+} [7]. It is difficult to carry out conventional chromate treatment on the surface of steel plated with an aluminum-zinc alloy containing 55% aluminum. A novel chromating solution containing an additive which acts as a comprehensive agent in wetting, activating, oxidizing and sealing the surface is effective in forming a dense chromate film for the protection of such surfaces [8].

Most of the zinc-aluminum coatings on the steel sheets are produced by hot dipping galvanizing [9,10]. We deposit the zinc-aluminum alloy on mild steel by electroplating. This work was carried out to investigate the effect of concentration of aluminum trichloride on the zinc-aluminum alloy deposition and on the rest potential of golden, colorless and non-chromated zinc-aluminum alloy deposits.

Results and Discussion

Mild steel specimens were electroplated with zinc-aluminum alloy. The concentration of aluminum chloride was varied from 0-25 g/L. The change in pH of the plating bath by varying the concentration of aluminum chloride was also noted, Figure 1. Figure 1 showed that with the increase in concentration of

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aluminum chloride pH of the plating bath decreased gradually.

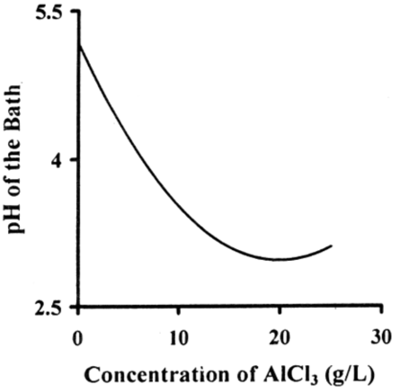

Fig. 1: Influence of concentration of aluminum chloride on the pH of the bath

The zinc-aluminum coated mild steel specimens were divided into three groups: in first group, the plates were not chromated. In second group, the plates were immersed in golden chromated solution of composition potassium dichromate 125-150 g/L and sulphuric acid 2.0-2.5 g/L at pH 1.25-1.3 at temperature 18-20°C for one minute. The third group plates were colorless chromated in solution comprising chromium trioxide 5-6 g/L, sodium fluoride 5-6 g/L and concentrated nitric acid 2-3 ml/L at pH 1.77 at 18-20°C for one minute.

Effect of aluminum chloride concentration on rest potential for golden, colorless and without chromated zinc-aluminum alloy deposits were observed and summarized in the form of tables.

Measurement of Rest Potential

Two sets of measurements of rest potential were recorded. In one case the contact between the two electrodes was closed for a short period of time, and the rest potential on multimeter display was noted. In some cases, this method gave wide dispersion in the rest potential presumably only due to manual procedure for recording the rest potential. The rest potential was measured vs. mild steel. The results obtained are shown in Table 1.

In second case, the contact between the electrodes was closed for a finite period of time i.e. ten seconds and the stable value of rest potential vs.

Table 1: Influence of concentration of aluminum chloride on rest potential vs. mild steel in 5% sodium chloride solution

Concentration of aluminum chloride (g/L)	Rest potential for golden chromating (mV)	Rest potential for colorless chromating (mV)	Rest potential without chromating (mV)
0.0	246.3	482.0	443.0
2.5	434.5	477.5	450.0
5.0		454.5	485.0
7.5	485.5	495.8	507.0
10.0			
12.5	506.0	500.6	459.5
15.0	485.0	488.0	498.5
17.5	521.5	499.3	470.0
20.0	485.3	448.3	465.0
22.5	522.6	471.3	494.5
25.0	531.0	490.3	469.0

Table 2: Influence of concentration of aluminum chloride on rest potential vs. platinum in 5% sodium chloride solution

Concentration of aluminum chloride (g/L)	Rest potential for golden chromating (mV)	Rest potential for colorless chromating (mV)	Rest potential without chromating (mV)
0.0	762	381	641
2.5	767	724	534
5.0	790	504	552
7.5	810	348	409
10.0	812	540	400
12.5	820	729	398
15.0	826	593	497
17.5	782	631	798
20.0	824	655	694
22.5	855	676	654
25.0	830	634	618

platinum electrode after this interval was noted, shown in Table 2.

Table 1, shows that with the increasing concentration of aluminum chloride from 0-5 g/L, the rest potential for golden chromating first rises slowly and then nearly remains constant with further addition of aluminum chloride, column 2. There is no correlation between the rest potential for colorless chromating and the concentration of aluminum chloride, column 3 of Table 1. Rest potential of without chromating zinc-aluminum alloy electroplated vs. mild steel, also remains constant with the increasing concentration of aluminum chloride, column 4 of Table 1.

The relation between the concentration of aluminum chloride and the rest potentials for golden, colorless and plates non-chromated vs. platinum electrode are shown in Table 2. There is a slight increase in rest potential for golden chromating with the increasing concentration of aluminum chloride, column 2 of Table 2. There is no correlation between the rest potential for colorless chromating and the concentration of aluminum chloride, column 3 of Table 2. In case of plates without chromating, the rest potential slightly decreases with increase in concentration of aluminum chloride, up to 12.5, in plating bath. After 12.5 g/L aluminum chloride, rest potential nearly remains constant with increase in aluminum chloride concentration, column 4 of Table 2.

The appearance of the plates was good enough. Bright alloy deposits were obtained. Abrasion resistance of golden chromating was very poor as compared to the abrasion resistance of colorless chromating.

Experimental

Chemicals used for the electrodeposition of zinc-aluminum alloy; zinc chloride, aluminum chloride, sodium chloride, and for the electrolytic cleaning sodium hydroxide, sodium silicate, sodium phosphate, ethanol and sodium carbonate, were of a technical grade. While those used for the chromating; chromium trioxide, sulphuric acid, potassium dichromate, nitric acid, sodium fluoride were analytical grade reagents and were used without further purification. Additives, maintenance, 2222, DICO, Germany; and wetting, 1111, DICO, Germany, were added in the plating bath to obtain smooth and bright deposits.

For the electrodeposition of zinc-aluminum on mild steel, zinc-aluminum bath was used. Bath was prepared from zinc chloride, aluminum chloride, and sodium chloride. The composition of the bath is shown in Table 3. The concentration of aluminum trichloride was varied from 0-25 g/L. The deposition was carried out current density 3-3.5 A/dm^2, voltage 0.75-1.25 V, temperature 30-35°C for fifteen minutes.

Table 3: Composition of zinc-aluminum bath

Chemical	Concentration
Zinc chloride	150 g/L
Sodium chloride	200 g/L
Aluminum chloride	0-25 g/L
Maintenance	1 ml/L
Wetting	30 ml/L

The pH of the bath was measured with the help of digital pH/mV instrument (TOA HM-20S, Japan). pH measurements were carried out at room temperature.

Two plates of 99.9% pure zinc metal, 6×2.5 in^2, were used as anodes. The surfaces of anodes were covered with glass wool to avoid any oxide developed at anodes to enter into plating bath.

Mild steel test specimens 2×1 in^2 were employed as cathode.

Surface preparation of cathode

Before plating, specimens were polished, buffed, degreased with ethanol, electrolytic cleaned, rinsed, pickled and rinsed thoroughly [11-13].

Chromate Coatings on zinc-aluminum deposited mild steel

After plating, the samples were rinsed with distilled water, immersed in 10% nitric acid for few seconds, thoroughly rinsed in distilled water and immersed in the chromating solutions [11-13].

Golden chromate

The golden chromate film was formed when zinc-aluminum plated sample was dipped in the bath containing potassium dichromate 125-150 g/L and sulphuric acid 2.0-2.5 g/L, at pH 1.25-1.3 at 18-20°C for one minute.

Colorless chromate

Colorless chromate film was formed when zinc-aluminum plated sample was dipped in a bath containing chromic acid 5-6 g/L, sodium fluoride 5-6 g/L, and concentrated nitric acid 2-3 ml/L, at pH 1.77 at 18-20°C for one minute [13].

Rest potential

Rest potential of colorless chromated zinc-aluminum deposited plates, golden chromated zinc-aluminum deposited plates, and non-chromated zinc-aluminum deposited plates were measured vs. mild steel specimen and platinum electrode in 5% sodium chloride solution [12].

Conclusions

Results show that: **a-** abrasion resistance of colorless chromating is more than golden chromating; **b-** the rest potential of golden chromated zinc-aluminum deposits was increased slightly with increase in aluminum chloride concentration; **c-** rest potential for colorless chromated zinc aluminum deposits have no correlation with aluminum chloride concentration; **d-** rest potential of non-chromated zinc-aluminum deposits on mild steel specimen is maximum at aluminum chloride 17.5 g/L; **e-** the appearance of the deposits was good.

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