Investigation of Pineapple as Addition on the Electrode Position of Zn-nAl_2O_3 on Carbon Steel in Acidic Medium

Kadhim F. Alsultani and Lubna Muneer Tajaldeen

***Abstract*—The performance effects of pineapple Juice Extract as addition agents on the electroplating of zinc on mild steel in acid chloride solution were experimentally investigated. The experiments were performed under different corrosive media. The zinc electroplating on mild steel was performed using a direct current (DC)–supply at defined operating parameters. The surface of the plated steel was examined using scanning electron microscopy (SEM) for surface morphology. The corrosion resistance of the plated surface was determined by potentiostatic polarization method. To evaluate the performance of coatings types in general and oxides, which exist on metal and alloys surface in a special way, were examined by thermal shock test. The quality of the electro-deposition of zinc was good as indicated by the microstructural feature of the plated surface. The electrodeposition process was sensitive to changes in additive concentration and plating time. Variations in the plating parameters produced entirely new and different surface morphology.**

***Index Terms*—Electrodeposition, pineapple, steel, acid chloride, corrosion, surface characteristics.**

I. Introduction

Nowadays, application of steel in product manufacturing has gained much interest because of its unique properties such as low cost, recyclability and excellent mechanical characteristics. However, low corrosion resistance of this material is the most important problem. One of the most common approaches to overcome this problem is the application of protective coatings to enhance the life span of this material. In this regard, various materials have been used as coating such as zinc, cadmium, synthetic and/or extracted organic compounds, modified polymers, resins and alloys [1].

Pure zinc coatings suffer from poor mechanical properties and the incorporation of a second hard phase during the electrodeposition process (e.g. ceramic nanoparticles) would normally permit to enhance them [2].

Co-electrodeposition is a simple and low cost technique to produce metal matrix composite coatings which have been widely used in automotive and aerospace [3].

Composite coatings consist of a metal or metal alloy matrix containing a dispersed phase of non-metallic particles. Such coatings have been developed for improved material properties with regard to corrosion stability, wear resistance, friction protection, self-lubrication, high temperature stability, electrical contacts and improved catalytic activity. The metals providing the matrix are mainly nickel, cobalt, copper, silver, zinc or gold. The list of particles embedded into the metal matrix ranges from carbides (e.g. SiC, WC, TiC), oxides (e.g. Al_2O_3, TiO_2) [4], [5].

Nanostructured coatings offer great potential for various applications due to their superior characteristics that are not typically found in conventional coatings. Because of the novel properties and various potential applications, nano composite materials with typical grain sizes <10 nm are attracting increasing attention from researchers all over the world. Because of the small grain size of these materials and consequently the large volume fraction of atoms in or near the grain boundaries, these materials exhibit properties that are often superior and sometimes completely new, in comparison with those of conventional coarse-grained materials [6].

Though the commercially available proprietary additives have now been used for some years, the need to develop other environment–friendly non-commercial proprietary additives for the acid chloride bath has been generating increased research interest including the present investigation. The present interest in further research necessitates the need to develop other environment-friendly non-commercial proprietary additives for the acid sulphate baths. The importance of electrodeposition (electroplating) in engineering products/facilities and in our daily lives is further made significant by the need to prevent corrosion and toxicity, and to enhance the aesthetic value of steel components in the automotive, construction, electronics, electrical appliances, recreational and.

Materials handling industries are in our daily lives. This has, in addition, led to an enlarged interest in the field of electrodeposition.

In recent works [7], surface characterisation of the effects of organic additives on the electrodeposition of zinc on mild steel and the influence of organic additives on the surface characteristics of zinc electrodeposition on mild steel in acid-chloride solution under different conditions were performed. The use of pineapple under different experimental working parameters/conditions in this study is an attempt to further extend these previous investigations.

Two types of non-cyanide zinc plating solutions are in use – mildly acid solution using chloride or sulphate anions, and alkaline-zincate solutions. The mild baths generally consist of zinc chloride dissolved in solution of excess ammonium chloride .Chloride zinc solution does not only eliminate cyanide in plating, it also gives improved bath efficiency and exceptional brightness. Moreover, zinc baths are used where it is desirable to have a high plating rate and low cost. Chloride zinc plating offers considerable advantages over

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cyanide-based systems, although it is not without its share of routine operating problems [8].

The use of local plant, pineapple juice, as addition agent in zinc electrodeposition from acid based solution, in this work, makes this study significant. Pineapple juice is obtained from the plant. Pineapple is a tropical fruit, which grows in countries, which are situated in the tropical and sub-tropical regions. Scientifically, it is known as *pineapple and* belongs to the family of *Bromeliaceae,* of the genus; pineapple and grows on the ground. It can grow up to 1m in height and 1.5m wide.

Raw pineapple juice is high in vitamin C, manganese, and vitamin B [9], [10]. Pineapple mainly contains water, carbohydrates, sugars, sucrose, fructose, glucose, ash, vitamins A, C and phytonutrients such as carotene-ß and crypto-xanthin-ß. In addition, the juice contains also, protein, fat, dietary fiber, other vitamins such as folates, niacin, pyridoxine, riboflavin, thiamin, vitamin E, vitamin K. It also contains electrolytes like sodium and potassium and other minerals such as calcium, copper, iron, magnesium, manganese, phosphorus, selenium and zinc.

Pineapples contain antioxidants namely flavonoids, vitamin A and C (already mentioned above). These antioxidants reduce the oxidative damage such as that caused by free radicals and chelating metals. The juice also contains the enzyme bromelain, which is a natural digestive enzyme with anti-inflammatory properties. Bromelain contains peroxidase, acid phosphate, several protease inhibitors and organically bound calcium and is found in peak concentration within the pineapple rind [11].

II. Experiment

Mild steel plates, with a nominal composition of 0.13% C, 0.54 Mn, 0.06 Cr and the remainder Fe. Were cut with dimensions of (100, 80,20) mm length, width and thickness respectively. The test specimens were immerse for 2 minutes with an alkaline degreasing chemical, and then removed from the solution, rinsed in distilled water, immersed in methanol, and air-dried. The specimens were, in turns, etched for 2 minutes in 10% HCl, rinsed in distilled water, immersed in methanol, air dried and stored in a desiccator for further experimental process. For the preparation of solutions, distilled water was used. Plating bath compassion shown in Table I. Electrodeposition of zinc on steel was performed by partially immersing the steel specimen and the zinc electrodes in the plating solution through the rectangular hole made on prepared Perspex cover for the 250ml beaker used as the plating bath.

The pH of the bath solution was adjusted with 10% hydrochloric acid or sodium carbonate solution. Zinc plate of 99.99% purity was added as anode. The anode was activated each time by immersing in 10% HCl followed by water wash. The deposits were obtained at a constant current density from the optimized solution.

The steel specimen was connected to the negative side of a DC supplier while the zinc electrodes were also connected with a wire to the positive side, Fig. 1. The plating solutions were put in turns into the beaker. After plating experiment, the plates were subjected to bright dip in 1% nitric acid for 2 s followed by water washes. The specimens were stored in a desiccator for further analysis. Polarization curves were measured in tap water, 3.5% NaCl and 3% HCl at room temperature. The sweep rate of potential was set at 1 mV/s. The potential was changed from cathode to anode values in the range of E_0 ± 200 mV. Corrosion currents were determined by the Tafel extrapolation method. SEM photomicrographs were taken to know the nature of deposit in the presence of addition agents. To evaluate the performance of coatings types in general and oxides which exist on metal and alloys surface in a special way were determined by thermal shock test.

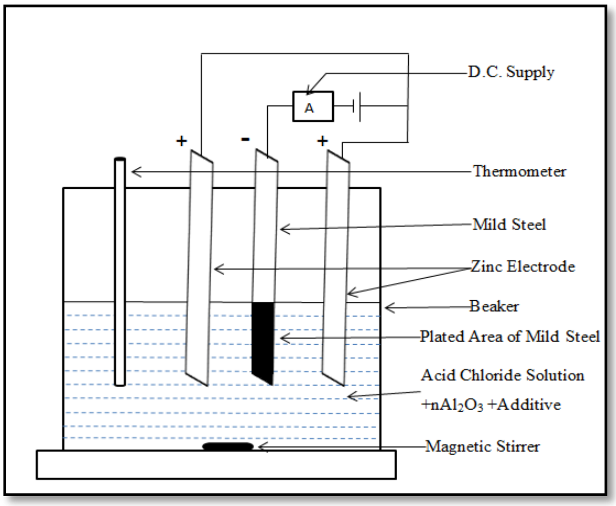

Fig. 1. Schematic diagram of experimental set-up.

III. Results and Discussion

A. Effect of Pineapple Juice Extract

Basic bath solution gave coarse dull deposit between the current density range of 1 and 2 A/dm^2 at 1A cell current. To improve the nature of deposit pineapple juice extract was added to the bath solution. With increase in the concentration, the nature of deposition improved and at a concentration of 50ml of ananascomosus (pineapple) juice extract, the plating cell panels were bright between the current density range of 0.5 and 4 A/dm^2.With further increase in the concentration of ananascomosus (pineapple) juice extract, the nature of the deposit became burnt at higher current density region. Therefore, on the basis of the above observations, the concentration of pineapple juice extract was kept at 10 ml/l as optimum.

B. Effect of pH

To know the effect of pH, the pH of the bath solution was varied from 2-5.At higher pH, the plating cell panels showed burnt deposit at high current density region. At pH 3.8, satisfactory deposit was obtained. At lower pH (<3.8), the specimens had dull deposit at low current density region. From the above observations, the pH of the bath solution was kept at 3.8 as optimum.

C. Effect of Deposition Current

The plating cell experiments were carried out at different cell currents (1–3A) for 10 min using optimum bath solution. It was found that at a cell current of 1A the deposit was bright in the current density range of 0.5-4 A/dm^2. At a cell current of 2 A, the deposit was bright in the current density range

0.5-8 A/dm^2. At a cell current of 3 A the deposition was bright over the current density range 0.5-8.5 A/dm^2. Above 8.5 A/dm^2, a burnt deposit was observed. Through the above observations, it was found that the optimized bath produced a bright deposit in the current density range of 1-8.5 A/dm^2.

TABLE I: BASIC BATH COMPOSITION AND OPERATING CONDITIONS

Bath composition	Concentration	Operating conditions
$ZnCl_2$	30 (g/l)	Plating time: 20 min
NH_4Cl	150 (g/l)	Temperature: 25^{0}C
H_3BO_3	20 (g/l)	Anode:Zinc metal(99.99)
Al_2O_3	30(g/l)	Cathode: Mild steel
pH	3-4.5	Cell constant in Ampere:1A
pineapple juice extract	10ml/l	

A known amount of pineapple juice extract was added to the bath solution. The bath solution was stirred for 30 min and then used for the plating cell experiments.

IV. Surface Morphology Study

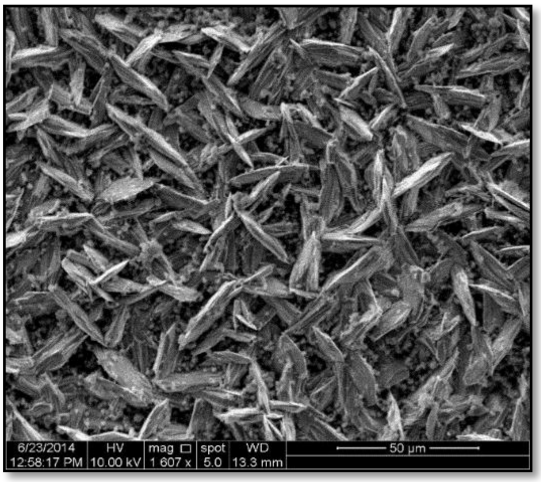

Fig. 2a. SEM photo micrographs obtained in the absence pineapple juice extract.

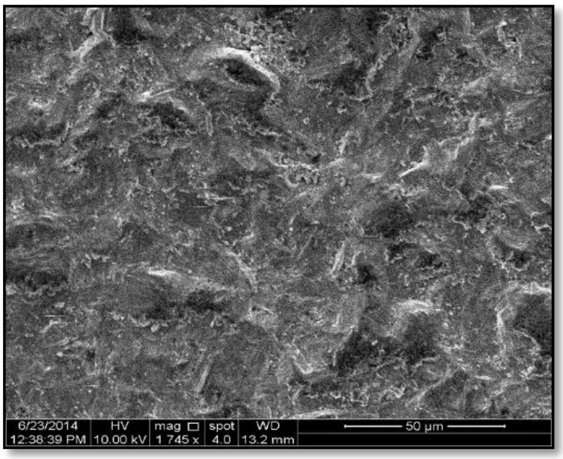

Fig. 2b. SEM photo micrographs obtain in the presence of pineapple juice extract.

The natural growth in the presence and the absence of pineapple juice extract was explained with the help of SEM photomicrographs Fig. 2. In the Fig. 2a, the crystal growth is not uniform, the basic bath produced deposit having different and slightly larger crystal size. However, in the presence of pineapple juice extract in the optimized bath showed uniform arrangement of crystals, refinement in the crystal size and hence gave a bright deposit Fig. 2b.

V. Corrosion Behavior

The polarization curves of Zn-A_2O_3 without additive and Zn-A_2O_3 with additive (pineapple) in tap water, 3.5% NaCl and 3% HCl are shown in Fig. 3a-Fig. 3f. The related corrosion current densities and corrosion potentials are listed in Table II. The results illustrate in this table shown that for all medium, tap water, salt solution (3.5% NaCl) and acid solution (3%HCl), the corrosion rate decrease when addition the 10% pineapple.

TABLE II: CORROSION POTENTIAL(E_{CORR}), CORROSION CURRENT DENSITY(I_{CORR}), CORROSION RATE OF THE COATING

No.	Zn-A_2O_3	E_{corr}(mv)	i_{corr}(μm/cm^2)	Corrosion Rate(mpy)
1	Without additive in tap water	-599	17.84	11.328
2	With additive in tap water	-558.6	10.75	6.827
3	Without additive in 3.5%NaCl	-1073.7	46.30	25.597
4	With additive 3.5%NaCl	-1038.4	22.33	14.178
5	Without additive 3%HCl	-1032.6	79.51	50.485
6	With additive 3%HCl	-1008.2	51.41	32.643

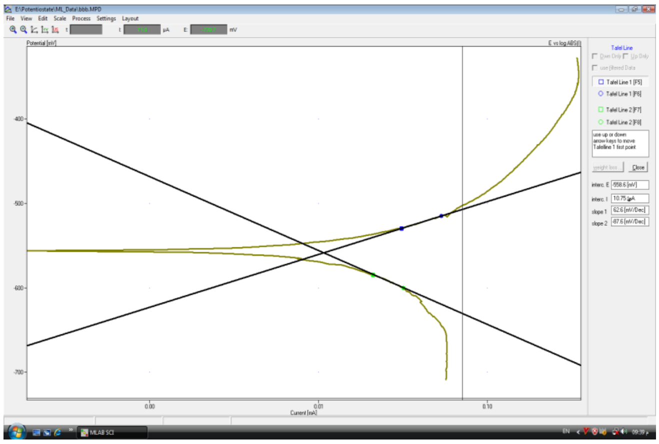

Fig. 3a. Polarization curve for Zn-Al_2O_3 without additive in tap water.

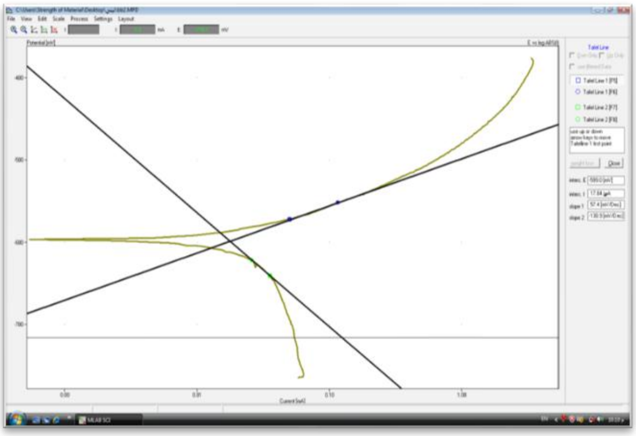

Fig. 3b. Polarization curve for Zn-$Al_2O_3$with additive in tap water.

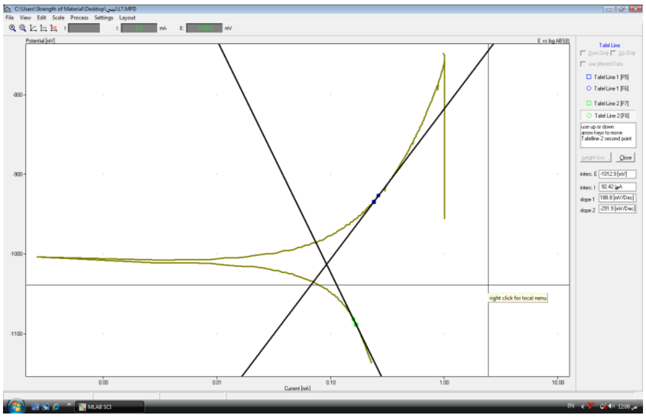

Fig. 3c. Polarization curve for Zn-Al_2O_3 without additive in 3.5%NaCl.

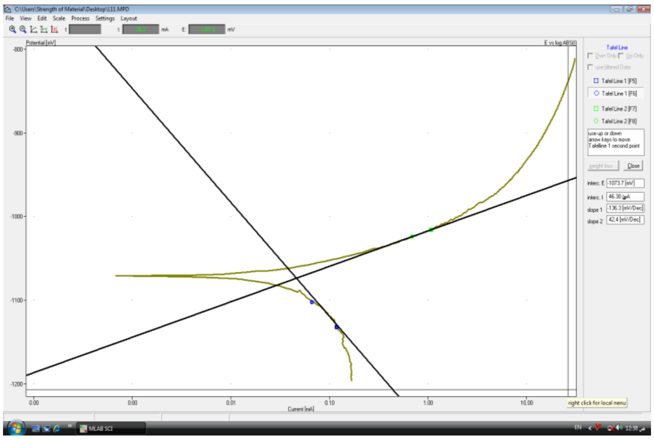

Fig. 3d. Polarization curve for Zn-Al_2O_3 with additive in 3.5%NaCl.

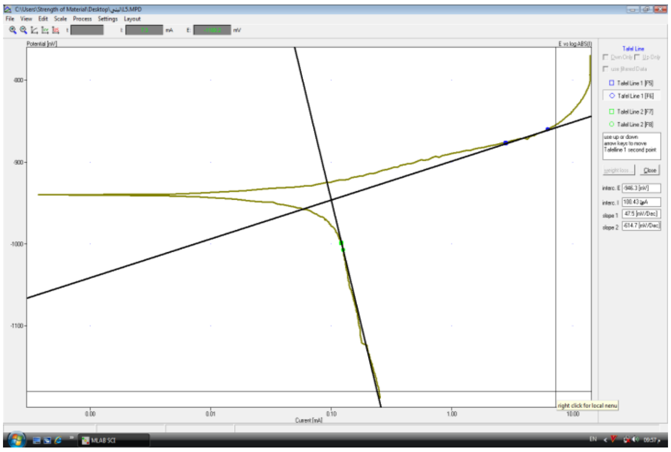

Fig. 3e. Polarization curve for Zn-Al_2O_3 withoutadditive in 3% HCl.

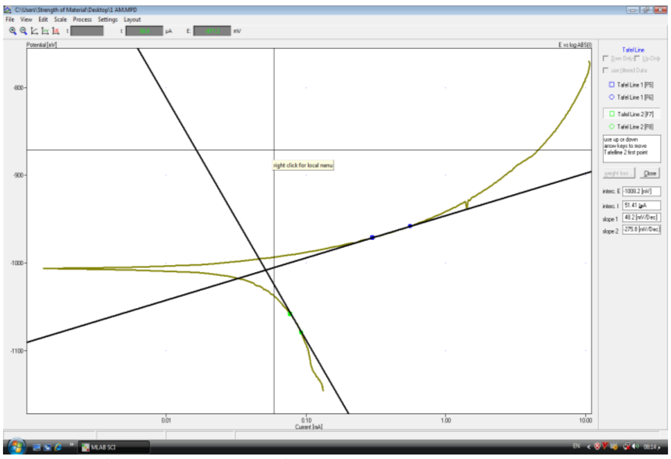

Fig. 3f. Polarization curve for Zn-Al_2O_3 withadditive in 3% HCl.

VI. Thermal Shock Test

The plating layer (Zn- Al_2O_3) without additive we noticed that there is some slight weight loss in temperature (100^{o}c) after wise the stability is obtained in weight to temperature of (500^{o}c) and also starts to flake in temperature of (600^{o}c) but when adding pineapple juice extractplating layer (Zn- Al_2O_3) was stable to temperature (400 ^{o}c) and starting toflake with temperature of (600^{o}c) as shown in Fig. 4.

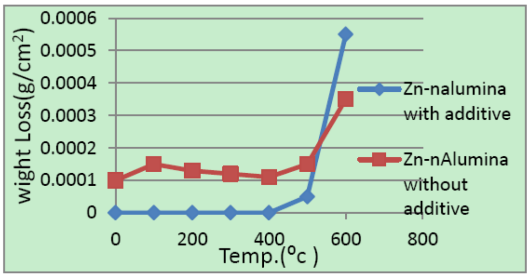

Fig. 4. Shows effect of thermal shock on weight loss of plating layer.

VII. Conclusions

1) A good zinc-alumina electrodeposition on mild steel surface could be obtained in the acid zinc chloride solution using the pineapple juice extract as the addition agent.
2) Charactrerisation of the zinc-alumina plated surface of the mild steel substrate showed different surface features depending upon the plating conditions.
3) The plated samples were found to exhibit good corrosion resistance in salt solution test when compared with the unplaited samples and thus confirming their protective capability as expected.
4) The particle size is very much reduced in the presence of additive.
5) The plating produced very fairly bright deposition. Though not as bright as the cyanide bath, the surface structures obtained indicate that the plating can serve several useful protective purposes that could be technologically and economically viable.
6) The additive was a natural product that is environment friendly.

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