CORROSION OF CADMIUM PLATED STEEL COUPLED TO DIFFERENT TYPES OF ALUMINIUM ALLOYS

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ABSTRACT

In many applications of the aircraft industry, aluminium alloys and steel components may come into electrical contact. In order to reduce the resulting danger of galvanic corrision of aluminium alloys, steel components are often coated with a metal or an alloy which is more active than the steel. Cadmium electroplatings are currently used to perform this function in the Egyptian aircraft industry. Some of the special characteristics that recommend the use of cadmium platings are the good lubricity, solderability and corrosion resistance. However, it is claimed that the service life of cadmium as a protective plating is relatively short. In this paper the main function of cadmium plating of providing cathodic protection for the coupled aluminium alloys is tested. Cadmium plated steel substrates of different plating thicknesses have been connected to 7075-T6,2024-T3 and 5056 aluminium alloys in 3.5% Na cl salt solutions. Galvanic corrosion current measurements have shown that cadmium platings accelerate the corrosion of the 7075-T6 aluminium alloy and cathodically protect the 2024-T3 and 5056 alloys for short periods.

1. INTRODUCTION

Cadmium platings have been widely used for the sacrificial corrosion protection of steel components used in aircraft. The platings also provide cathodic protection for the aluminium alloys of the aircraft structure when they come into electrical contact with the plated steel components in the presence of a corrosive medium |1|. However, it has been claimed |2,3| that cadmium platings have a relative short service life and replacement coatings with greater durability have to be found.

In this work the effective lifes of cadmium platings of different thicknesses coupled to three different aluminium alloys 7075-T6,2024-T3 and 5056. have been measured. A zero resistance ammeter and voltage follower similar to those described by Lauer and Mansfeld |4| have been constructed and used for galvanic corrosion current and potential measurements. Fig.1 shows the circuit diagram of both apparatus. For the zero resistance ammeter one of the electrodes of the couple is earthed whereas the other is connected to the negative input of a high gain operational amplifier. The output of this amplifier V_o is propertional to the passing galvanic current I_g between the couple :

$$V_o = I_g R_f$$

where R_f is the feedback resistance. The voltage follower comprises the same type of amplifier and its positive input is connected to a reference electrode immersed in the salt solution. In this way the output voltage is the same as the input voltage of the galvanic potential.

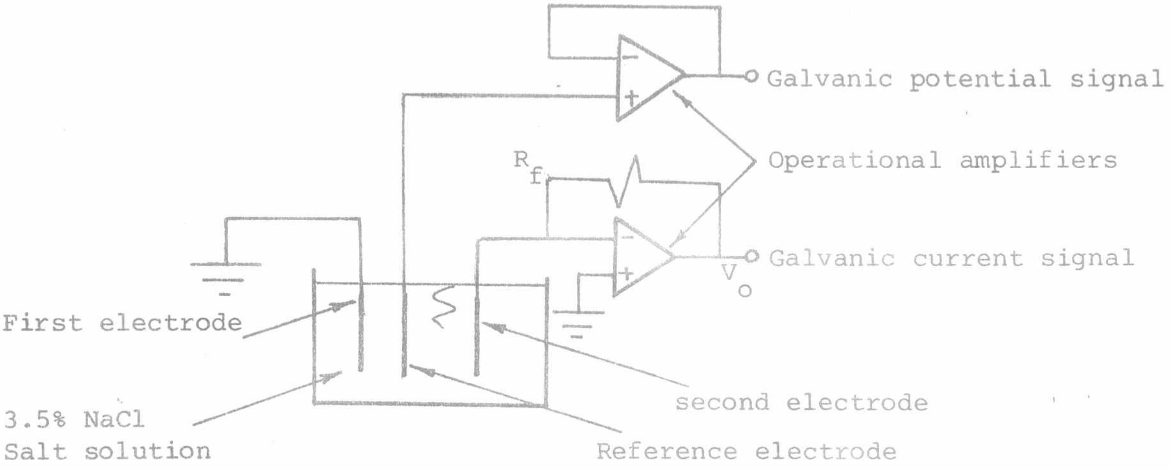

Fig.1. Zero resistance ammeter and voltage follower arrangement.

The effective life of a cadmium plating has been taken as the period during which the plating is anodic to the coupled aluminium alloy. Once the polarity of the galvanic cell is changed the plating accelerates the corrosion rate of the aluminium alloy.

2. EXPERIMENTAL

2.1 Electroplating

A mild steel vat with a temperature regulating equipment (15°C-30°C) was used in the cadmium electroplating procers. Before plating 30x30x4 mm mild steel samples were degreased and rinsed in water. Samples were then activated (hydrocloric depassivated), rinsed in water and immersed directly in the cadmium plating bath. Table 1 shows the composition of the solution that was used for cadmium electroplating |5|. a cathodic current density of 2 Amp/dm^2 was used and a plating time of 25 minutes was required to produce 10 μm thick coatings.

Table 1. Composition of the solution used for electroplating

Brown cadmium oxide	20 ± 1 gm/ℓ
Sodium cyanide	80 ± 5 gm/ℓ
Caustic soda	10 ± 1 gm/ℓ

2.2 Galvanic Current and Potential Measurements

After electroplating, samples were coupled to the aluminium alloys through the zero impedence ammeter. Table 2. shows the chemical composition of the coupled 7075-T6, 2024-T3 and 5056 aluminium alloys. Both the aluminium alloy sample, (30x30xvariable thickness) and the cadmium plated samples were degreased, rinsed in water and alcohol then hot air dried before they were immersed in a 3.5% Na Cl salt solution. The separating distance between the two samples was 4cm. The corrosion potential of each of the two uncoupled samples was followed for 15 minutes immediately after immersion |all potentials refer to the saturated calomel Electrode (SCE)|. After coupling, the output of the zero impedence ammeter which is proportional to the galvanic current I_g was measured by a millivoltemeter. The galvanic potential ϕ_g was also measured by means of another millivoltemeter. After 48 hours of testing the couple was disconnected and the corrosion potential of each sample was followed for 15 minutes.

Table 2. Chemical composition (weight percent) of the coupled aluminium alloys.

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	T_i	Al
7075-T6	0.50	< 0.7	1.2-2.0	0.3	2.1-2.9	---	5.1-6.1	< 0.2	Bal.
2024-T3	0.08	0.21	4.29	0.56	1.5	<0.01	0.05	0.03	Bal.
5056	< 0.4	< 0.5	<0.1	0.1-0.6	4.5-5.6	<0.2	< 0.2	< 0.2	Bal.

3. RESULTS AND DISCUSSION

The time behaviour of the galvanic current I_g and galvanic Potential ϕ_g for aluminium alloys 7075-T6, 2024-T3 and 5056 coupled to cadmium electroplatings are shown in Fig.1,2 and 3 respectively. The corrosion Potentials of the coupled samples before and after each test are also shown in the same figures.

Fig.1 shows that, before coupling, the corrosion potential of the aluminium alloy 7075-T6 is more negative than that of the coupled cadmium plating while Fig.2 and Fig.3 show that the opposite is true for the alloys 2024-T3 and 5056 respectively. This means that on coupling the aluminium alloys to cadmium platings in the 3.5% Nacl salt solution, the corrosion of the alloy 7075-T6 is expected to be accelerated whereas the cadmium plating is expected to cathodically protect the coupled 2024-T3 and 5056 alloys. This expectation is verified by observing the direction of the galvanic corrosion current on coupling the aluminium alloys to the cadmium platings.

The polarity of the galvanic cell does not change at the end of the test in case of coupling to the 7075-T6 alloy whereas it does during the period of coupling to the 2024-T3 and 5056 alloys. Similar results have been reported by MC Loughlin |6| indicating the change of plarity of the galvanic cell in case of coupling cadmium platings to the 7075-T6 alloy in acidified (Ph=3) 5% NaCl salt solution. Thus, although the 2024-T3 and 5056 alloys are cathodically protected by the cadmium plating at the begining of the test it takes only 30 hours of coupling for the galvanic cell to change its polarity in case of coupling to the 2024-T3 alloy and about one hour to do so in case of coupling to the 5056 alloy. This change of polarity leads

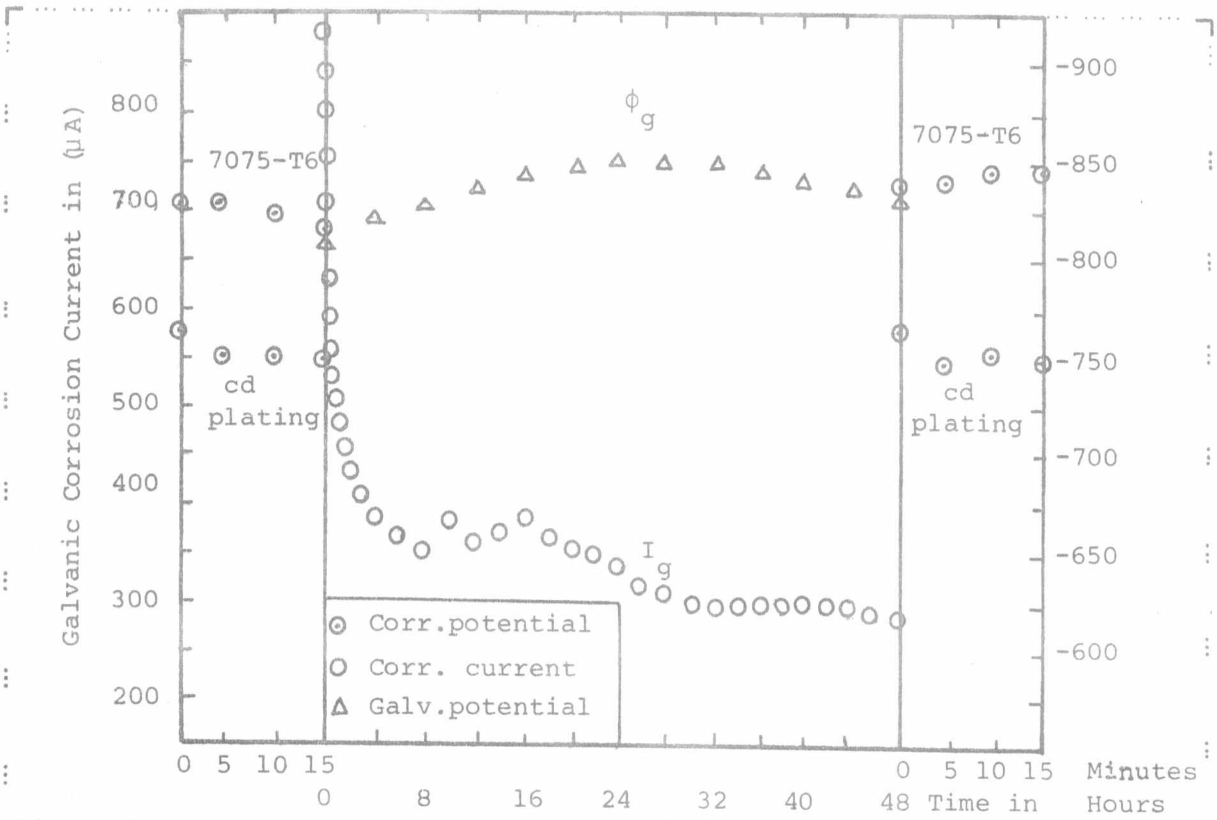

Fig.1. Corrosion current and potential of the coupled cadmium plating and aluminium alloy 7075-T6 versus time.(plating thickness=4 μm)

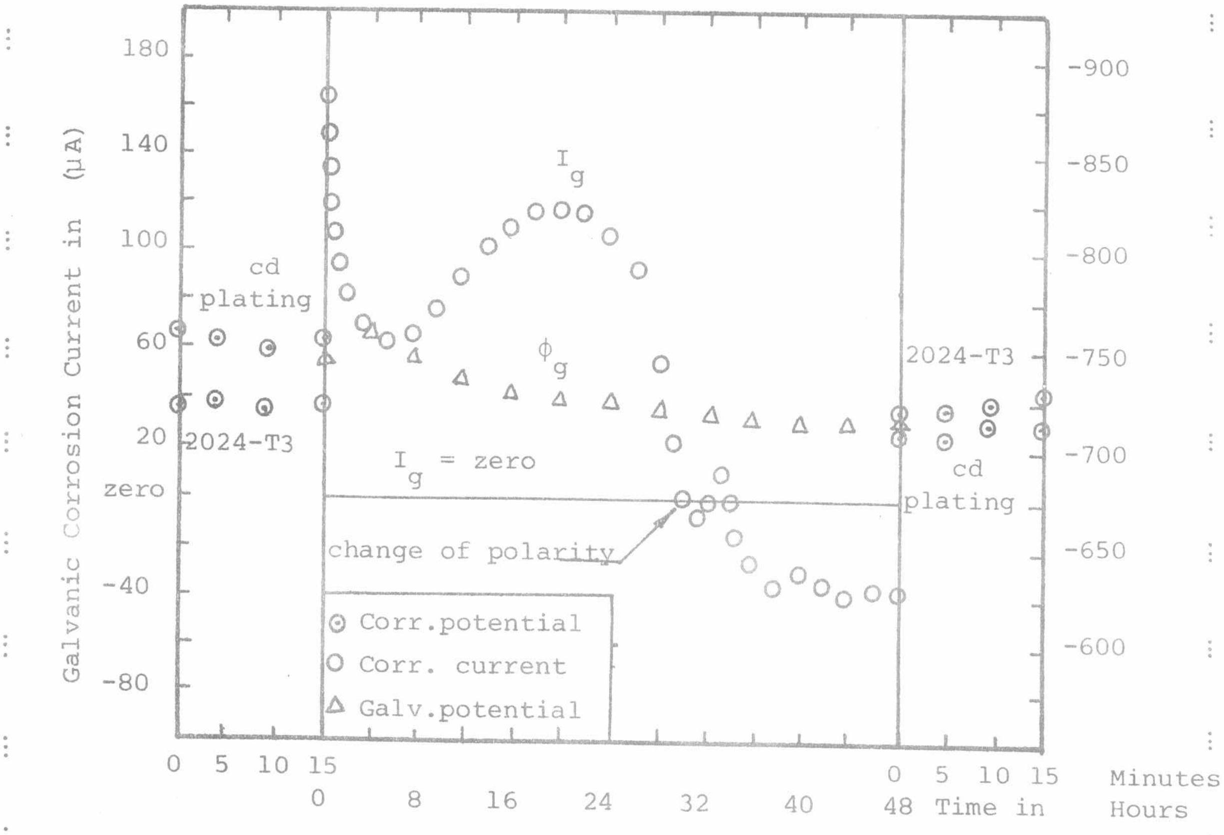

Fig.2. Corrosion Current and Potential of the coupled Cadmium plating and aluminium alloy 2024-T3 versus time.(plating thickness= 4 μm)

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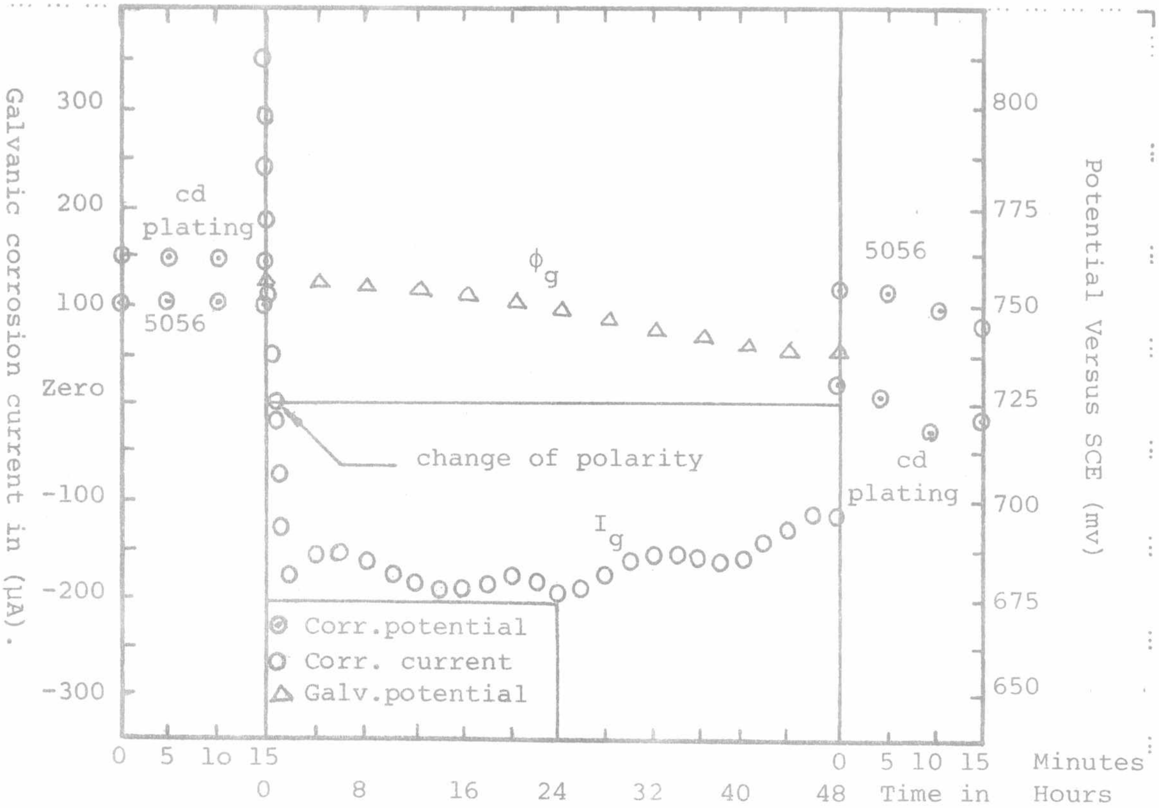
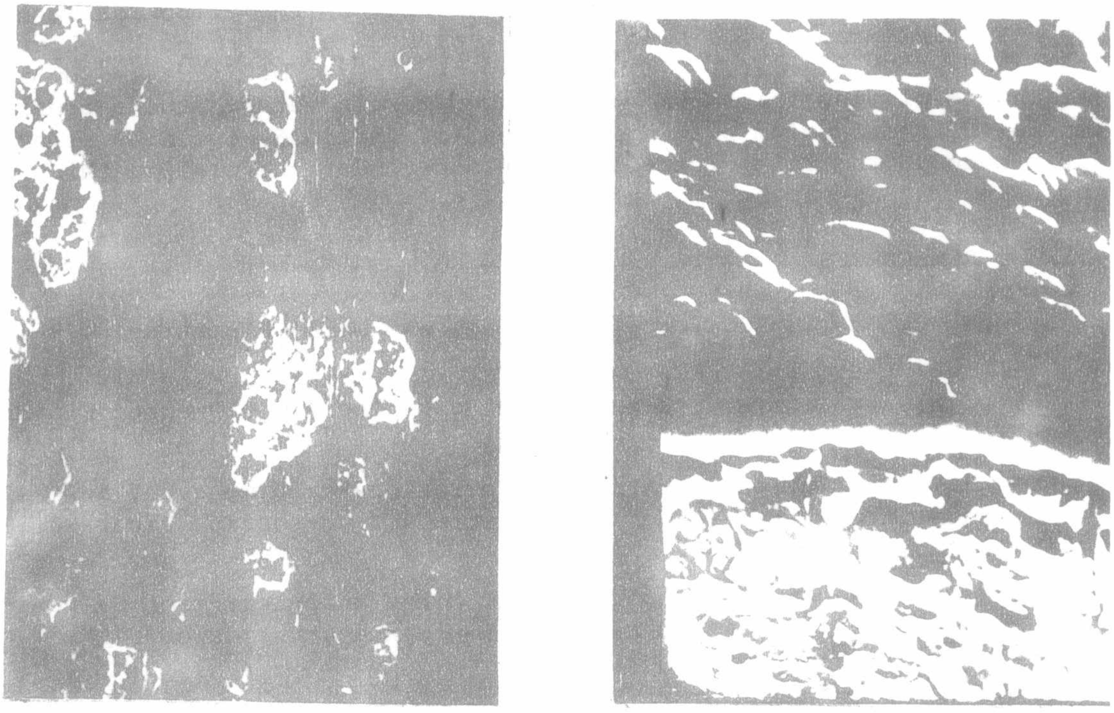


Fig.3. Corrosion current and potential of the coupled cadmium plating and aluminium alloy 5056 versus time.(plating thickness=10 μm).



(a) (b)

Fig.4. (a) Typical corrosion pits suffered by the three aluminium alloys coupled to cadmium coatings (the photograph is for aluminium alloy 7075-T6). (b) Surface and fracture of 10 μm thick cadmium coating.

to accelerating the corrosion of the coupled aluminium alloy which becomes the anode of the galvanic cell. Fig.4-a shows a photomicrograph for typical corrosion pits suffered by the three aluminium alloy coupled to cadmium platings as a result of accelerating the corrosion of the alloys. Two factors can change the polarity of a galvanic cell; the first is the consumption of the plating to expose the underlying steel which is cathodic to the aluminium alloy, the second is the formation of a corrosion product layer on the cadmium surface which shifts the potential in the noble direction. The 30 hours of testing after which the polarity changes in case of coupling to the 2024-T3 alloy suggests that both factors are behind this polarity change whereas the rapid change of polarity in case of coupling the 10 µm thick cadmium plating to the 5056 alloy indicates that the formation of a corrosion product layer is the main reason for that change. However the existance of any porosities in the 10 µm thick plating may reduce the effective coating thickness and lead to a rapid consumption of the plating and hence a polarity change. Therefore scanning electron examination of the surface and fracture section of the cadmium plating is helpful. Fig.4-b shows a photomicrograph illustrating the surface and fracture section of a 10 µm thick cadmium plating. The plating has a columnar growth structure with dome shaped coarse grains. However no porosities are observed in the plating which eliminates the possibility of the plating consumption as a reason for change in polarity in case of coupling to the 5056 alloy.

4. CONCLUSION

Cadmium electroplatings accelerate the corrosion of the electrically coupled 7075-T6 aluminium alloy. The platings cathodically protect the coupled 2024-T3 aluminium alloy for a limited time which may be increased by increasing the plating thickness. The narrow margin between the corrosion potential of the cadmium platings and that of the 5056 aluminium alloy greatly reduces the life of the platings and render the plating thickness of no value in increasing its life.

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