

# CORROSION RESISTANCE BEHAVIOUR OF HARD CHROMIUM COATINGS WITH ZINC UNDERCOAT

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*Hard chromium plating is being used for a number of industrial applications especially to resist wear and tear with a view to increase the life of the component. When the life of the component increases the hard chromium coating is also expected to withstand corrosion for increased life. But some of the hard chromium coated components fail because of low corrosion resistance. A suitable undercoat can improve the corrosion resistance behaviour of hard chromium coating. In this paper the authors discuss the effect of zinc undercoat in improving the corrosion resistance behaviour of hard chromium coatings. Mild steel plates with different thick chromium deposits and with an undercoat of zinc were subjected to salt spray and the results are presented.*

*Keywords: Hard chromium, effect of zinc and mild steel*

## INTRODUCTION

Hard chromium serves virtually every manufacturing industry by making equipment and tools work more effectively while greatly extending their service life [1-2]. Hard chromium electrodeposits resist the chemical attack by a great number of chemicals [3], the atmospheric corrosion [4] and the high temperature [5]. Hard chromium is usually coated on iron and steel from a hexavalent chromium plating electrolyte in preference to the trivalent chromium based plating baths [6-9]. Though chromium coating is electronegative to iron and steel, it is found in practice that, due to passivity the chromium electrodeposit is electropositive. Since chromium electrodeposit behaves cathodically in this combination it is essential that the deposit should be free from porosity along with good adhesion [10]. The variations in the structure and crack density of the chromium electrodeposit modify the behaviour in corrosive conditions [11]. Microcracks are a three dimensional network, they occur periodically but they are not involved in a single plane which alter the corrosion resistance behaviour of hard chromium to a considerable extent [12]. Moreover the corrosion resistance of

hard chrome deposit decreases as hydrogen is removed by heat treatment due to the enlargement of crack network.

In general a matt chromium electrodeposit offer a better resistance in salt spray test than bright deposits and also a chromium deposit produced at low current density and with high plating bath temperature is reported to offer higher corrosion resistance [3]. Hard chromium electrodeposits which are used to resist wear and tear with a view to increase the life of the component sometimes fail because of low corrosion resistance. The corrosion resistance behaviour of hard chromium coatings can be increased by suitable undercoats of nickel, copper or bronze [3].

In this paper the authors have tried zinc as undercoat to hard chromium and the results are reported.

## EXPERIMENTAL

Electrodeposition of zinc was performed at various current densities on 7.5 x 5.0 x 0.03 cm cold rolled steel cathodes and with zinc anodes (7.5 x 5.0 x 0.3 cm) placed on either side of the cathode in a suitable type of zinc plating bath of the following composition.

Zinc sulphate 240 g/l  
 Sodium acetate 30 g/l  
 Aluminium sulphate 30 g/l  
 Temperature 303 K

A regulated power supply system served as the source of DC with less than 1% AC ripple. From the mass gain of each plated specimen data on cathode current efficiency, rate of deposition and nature of deposit were collected.

Electrodeposition of chromium was also carried out separately at various densities on cold-rolled mild steel specimens (7.5 x 5.0 x 0.03 cm) with lead-tin alloy (93:7) anodes of the same dimensions as that of the cathode on either side of the cathode. A regulated power supply system with AC ripple less than 1% was used as the current source and the chrome bath of the following composition was used for chrome deposition.

Chromic acid 250 g/l  
 Sulphuric acid 2.5 g/l  
 Temperature 323 K

In order to prevent the dissolution of zinc plated surfaces during chrome plating, the zinc plated surfaces were initially passivated in a solution of the following composition for a duration of 30 seconds at 303 K.

Sodium dichromate 200 g/l  
 Sulphuric acid 9 ml/l

The passivated zinc coated samples were then chrome plated from a conventional bath operated at 303 K and at 15.5 A.dm<sup>-2</sup> for a duration of 3 mts before regular chrome plating to the required thickness. The process employed for chromium plating on steel and chromium plating on zinc plated steel is given as in Fig. 1.

For the determination of corrosion resistance behaviour of the chrome plated steel specimens and chrome plated steel specimens with zinc as

**Process employed to coat chromium on steel**

Solvent degreasing



Electrocleaning



Washing & Rinsing



Strike chrome plating



Chromium plating



Washing and drying

**Process employed to coat chromium on zinc plated steel**

Solvent degreasing



Electrocleaning



Washing & Rinsing



Zinc plating 10/20 μm



Washing and Rinsing



Passivation dip in passivation solution



Working and Rinsing



Chromium plating at 303 K for 3 mts at 15.5 A.dm<sup>-2</sup>



Chrome plating at 323 K to the required thickness



Washing and Drying

Fig. 1

**TABLE I: Current efficiency and rate of build up of the zinc plating bath employed for zinc undercoat**

Bath composition (g/l)	Temp K	Current density A.dm <sup>-2</sup>	Current efficiency %	Rate of build up $\mu$ m/ h	Nature of the deposit
ZnSO <sub>4</sub> 240					
CH <sub>3</sub> COONa 30					
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> 30	303	1.0	99.0	17.0	Grey
" " "	"	1.5	99.2	25.6	Grey
" " "	"	2.0	99.2	34.1	Grey
" " "	"	2.5	98.9	42.1	Grey

undercoat, salt spray test was employed. A 5% solution of sodium chloride with pH adjusted to 3.1 by acetic acid was sprayed in a salt spray apparatus and data on the time taken for the initiation of white rust, red rust and 100% red rust formation were collected.

### RESULTS AND DISCUSSION

The results of the experiments carried out on zinc plating is presented in Table I. From the table it is clear that an efficiency of about 99% could be obtained from the bath employed at all current densities. The rate of build up increases linearly with increase in current density and the bath produces grey coloured deposits under all conditions studied. From this study it was decided to carry out zinc plating at 2 A.dm<sup>-2</sup> and at 303 K in order to obtain either 10 or 20  $\mu$ m thick deposit which will serve as an undercoat for chromium deposition.

The results of the experiments carried out on chromium plating from a conventional type of chrome bath is given in Table II. From the result it may be seen that the cathode efficiency increases with increase in current density at 323 K. It may also be seen from the results that

the bath produces satin type of deposits at the normal current densities. From the results obtained it was decided to operate the chrome bath at 323 K and at 31 A.dm<sup>-2</sup> in order to obtain 15,20 and 30  $\mu$ m.

The results of the salt spray test carried out to assess the corrosion resistance behaviour of i) 15,20 and 30  $\mu$ m direct chrome plated cold-rolled steel specimens, ii) 15,20 and 30  $\mu$ m chrome plated cold-rolled steel specimens with 10  $\mu$ m zinc undercoat and iii) 15,20 and 30  $\mu$ m chrome plated cold rolled steel specimens with 20  $\mu$ m zinc as undercoat are given in Table III. From the results it may be clearly seen that the application of zinc undercoat for chromium plating enhances the time taken for the initiation of red rust to a very high extent. The time taken for the formation of red rust on 50% of the area plated also increases to a very high extent by the application of zinc undercoat. It may be seen from the table that a 15  $\mu$ m chrome plated steel exhibits red rust even within 24 hours whereas a 15  $\mu$ m chrome plating on a 10  $\mu$ m and 20  $\mu$ m zinc coated steel exhibit red rust only after 144 hours and 484 hours respectively. This clearly indicates that an undercoat of zinc improves the corrosion resistance

**TABLE II: Current efficiency and rate of build up of the chrome plating bath employed for chrome plating**

Bath composition (g/l)	Temp K	Current density A.dm <sup>-2</sup>	Current efficiency %	Rate of build up $\mu$ m/ h	Nature of the deposit
CrO <sub>3</sub> 250					
H <sub>2</sub> SO <sub>4</sub> 2.5	323	7.5	7.7	2.6	Bright
" " "	"	15.5	13.1	9.1	Stain
" " "	"	31.0	15.4	21.4	Stain
" " "	"	46.5	18.0	37.6	Stain

TABLE III: Salt spray (NaCl 5% pH adjusted to 3.1 with acetic acid) data on the corrosion of electrodeposits

Deposit details		No of hours for the initiation of white rust	No of hours for the initiation of red rust	No of hours for 50% red rust formation	No of hours for 100% red rust formation
Chromium	15 $\mu$	—	< 24	24	48
Chromium	20 $\mu$	—	24	48	72
Chromium	30 $\mu$	—	48	72	96
Zinc	10 $\mu$ &				
Chromium	15 $\mu$	72	144	456	>634
Zinc	10 $\mu$ &				
Chromium	20 $\mu$	72	484	634	>634
Zinc	10 $\mu$ &				
Chromium	30 $\mu$	72	484	>634	>634
Zinc	20 $\mu$ &				
Chromium	15 $\mu$	72	484	>634	>634
Zinc	20 $\mu$ &				
Chromium	20 $\mu$	72	484	>634	>634
Zinc	20 $\mu$ &				
Chromium	30 $\mu$	72	634	>634	>634

behaviour of thick chrome deposits and with increase in thickness of zinc undercoat the corrosion resistance behaviour of chrome deposits also increases. The anodic behaviour of zinc in a sandwich system is mainly responsible for this high corrosion resistance. Thus it may be seen that wherever a high corrosion resistance of chrome deposits is needed along with wear resistance a zinc undercoat of about 10-20  $\mu\text{m}$  may be considered.

#### CONCLUSION

A zinc undercoat (10-20  $\mu\text{m}$ ) improves the corrosion resistance of thick chrome deposits to a great extent. The zinc undercoated specimens are to be passivated in a passivation solution and then chrome plated in a conventional type of chrome bath operated at 303 K for a duration of 3 mts at 15.5 A.dm<sup>-2</sup> before regular chrome plating to the required thickness.

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