ELECTROPOLISHING OF STAINLESS STEEL

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Three different electropolishing baths were formulated in H_3PO_4 –H_2SO_4 medium with mono, di and triethanolamines as additives for polishing of stainless steel panels. For each bath, the polishing current densities were fixed through Hull Cell experiments. The effect of varying current density, temperature and electroplating duration were studied for these baths. The specular reflectance measurements were made to assess the extent of polishing under different experimental conditions. A detailed analysis of the experimental results is presented.

INTRODUCTION

Electropolishing is an electrochemical process wherein preferential dissolution takes place from macro and micro peaks that appear on the surface. Elimination of the large scale irregularities (> 1 μm) causes smoothening of the surface while the removal of the smaller irregularities (< 0.01 μm) results in brightening.

Innumerable reports on the electropolishing compositions based on phosphoric acids and non-phosphoric acid solutions containing organic substances are available [1-5]. These baths contain higher amount of H_3PO_4 and hazardous chemicals. The present paper deals with the development of H_3PO_4 - H_2SO_4 electropolishing baths containing ethanol amines for AISI 304 stainless steel. The extent of polishing was assessed by specular reflectivity measurements.

EXPERIMENTAL

The stainless steel specimens (0.8% max. carbon, 18-20% chromium, 8-11% nickel and remaining iron) of size 2.5 x 2.5 x 0.1 cm were cut and the sides of the specimens were ground to remove the burrs. They were degreased with benzene or trichloroethylene and electrocleaned cathodically in an alkaline solution (10%

caustic) at 323 K for 2 minutes at 7-8 A.dm^{-2}. The specimens were washed in running water and rinsed in deionised water and then dried. Table I presents the composition of various baths used.

Hull cell studies

The Hull cell of volume 267 ml was used. The polishing solution was poured into the cell upto the brim. Hull cell patterns were obtained using lead as a cathode and stainless steel as anode. The cell currents of 1, 2 and 3 A.dm^{-2} were used for 5 minutes. Experiments were carried out at 333, 343 and 353 K.

TABLE I: Composition of various electropolishing baths

Bath	Constituent	Concentration (ml/litre)
A	H_3PO_4	500
	H_2SO_4	360
	Monoethanolamine	20
B	H_3PO_4	500
	H_2SO_4	360
	Diethanolamine	20
C	H_3PO_4	500
	H_2SO_4	360
	Triethanolamine	20

Fig. 1: Hull cell pattern for different cell currents and temperatures 333, 343 and 353 K for bath A
(1) Very bright; (2) Bright; (3) Dull bright; (4) Dull

Reflectivity measurements

The stainless steel specimens were electropolished at 333 K using 15.5, 31 and 46.5 A.dm^{-2} at different time intervals. They were washed in running water and dried. The reflectivity of the specimens were measured using ML 4B gloss/reflectance meter.

Weight loss measurements

The specimens were kept at different anodic polishing current densities for specified time intervals at desired temperatures in the polishing bath using lead cathode. The changes in weights were recorded.

Fig 2: Hull cell pattern for different cell currents and temperatures 333, 343 and 353 K for bath B
(1) Very bright; (2) Bright; (3) Dull bright; (4) Dull

RESULTS

Hull cell studies

In Hull cell experiments, a specified current is passed for a duration of five minutes. The current density at a specified point on the specimen is

$$A = I \, (5.102 - 5.24 \log L) \qquad (1)$$

where A is the current density (A.dm^{-2}), I is the current passed through the cell and L is the length of the polishing region from the nearest end of the anode.

Various cell currents (1-3 A.dm^{-2}) were passed at different bath temperatures.

Monoethanolamine

At all temperatures mostly dull region dominated followed by a dull bright zone when 1 and 2 Amp currents were passed. At 353 K the passage of 3 Amp has resulted in a very bright region to a considerable extent (Fig. 1).

Diethanolamine

At 333 K very bright polishing regions were seen when 1- 3 Amp. currents were passed. At 343 K and 3 Amp. current, very bright polishing was obtained at the nearest end of the anode. Again at 353 K, only at higher currents very bright polishing could be obtained (Fig. 2).

Triethanolamine

At 333 and 343 K bright polishing was obtained at 2 and 3 Amp. Very bright polishing was seen at the nearest end of the anode at 353 K when 2 or 3 Amp currents were passed (Fig. 3).
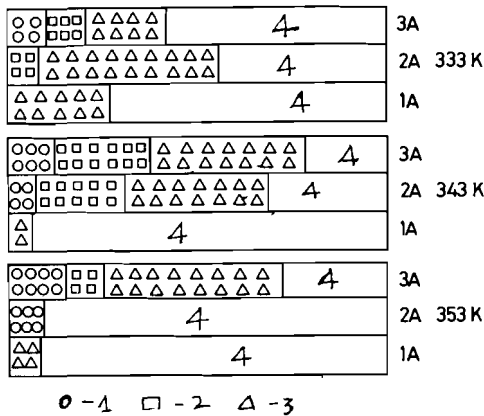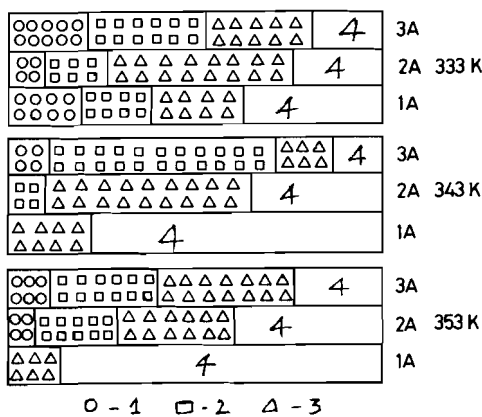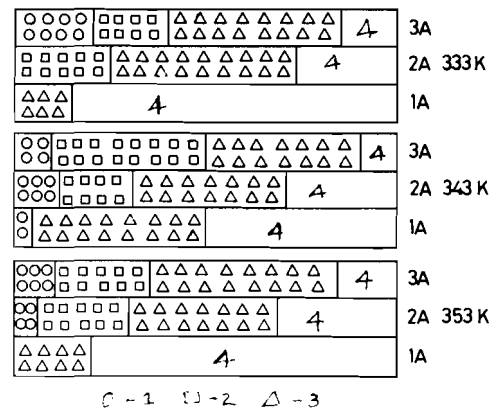

Fig. 3: Hull cell pattern for different cell currents and temperatures 333, 343 and 353 K for bath C
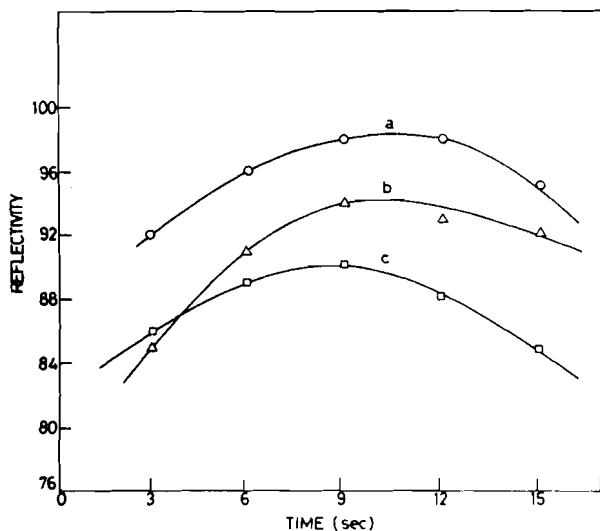*(1) Very bright; (2) Bright; (3) Dull bright; (4) Dull*

Fig. 4: Relationship between specular reflectivity and time of electropolishing at current densities 15.5, 31.0 and 46.5 A.dm^{-2} at 333 K for bath A

Reflectance studies

Bath A

A maximum reflectance of 98% was obtained at 333 and 353 K when a current density of 15.5 A.dm^{-2} was passed through the cell for 9 minutes (Fig. 4). However at 343 K it was found that the current requirement is 31 A.dm^{-2}.
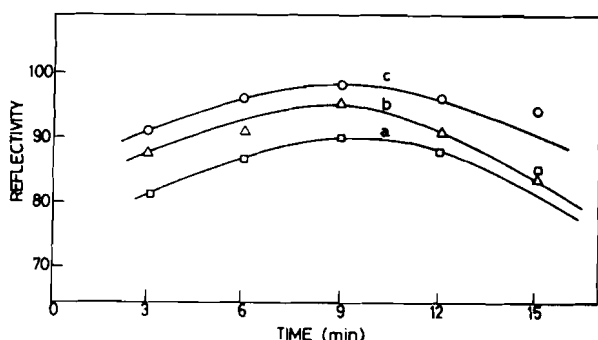
Bath B

At 333 K maximum reflectance was seen only at 46.5 A.dm^{-2} (Fig. 5). Both at 343 and 353 K maximum reflectance was observed at lower current density of 31 A.dm^{-2}.

Bath C

At 333 K maximum of 99% reflectance occurred at the end of 12 minutes when 15.5 A.dm^{-2} was passed (Fig. 6). At 343 and 353 K, the maximum reflectance occurred at the same current density but at lower polishing time of 9 minutes.

To conclude, at 333 K both the baths A and C were found to be better than bath B from the current requirement points of view. Among the two, bath A is superior to achieve maximum reflectance in 9 minutes. For 343 K, bath C is the best among the three and the maximum reflectance is achieved at the end of 9 minutes. For 353 K bath A is superior from current requirement and electropolishing time points of view.

Weight loss measurements

At a constant polishing time of 5 minutes, the specimens were anodically kept at different current densities. Losses in weight of anodes were calculated. It was found that losses in weight were linearly related to the applied current density and time of electropolishing (Fig. 7).
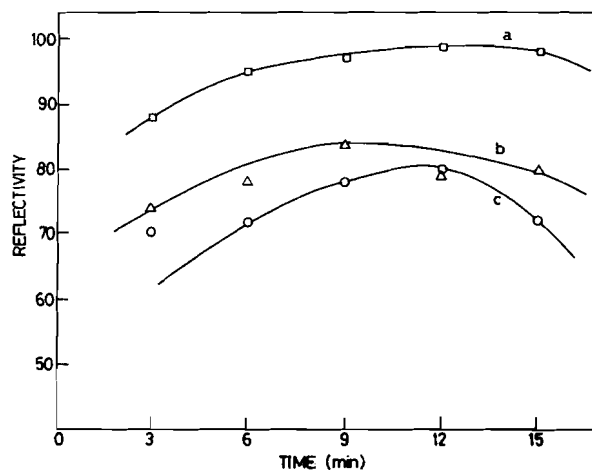

Fig. 5: Relationship between specular reflectivity and time of electropolishing at current densities 15.5, 31.0 and 46.5 A.dm^{-2} at 333 K for bath B

Fig. 6: Relationship between specular reflectivity and time of electropolishing at current densities 15.5, 31.0 and 46.5 A.dm^{-2} at 333 K for bath C
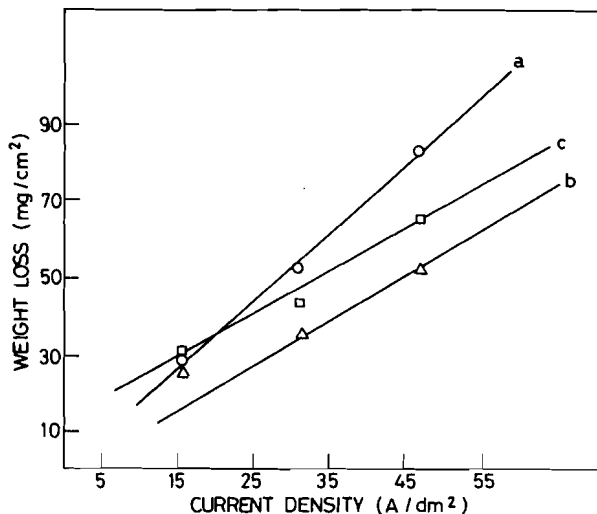
Fig. 7: Typical relationship between current density and weight loss at constant time of 5 minutews for bath A

TABLE II: Reflectivity of electropolished specimens — Effect of bath ageing at 333 K Time duration 1 hour

Bath	Current (A)	Reflectivity (%)
A	1	86
	2	89
	3	94
B	1	83
	2	87
	3	93
C	1	83
	2	84
	3	86

Ageing of the bath

To study whether the electrolyte is stable during the experimental conditions of electrolysis, electropolishing experiments were carried out at different currents of 1-3 for a longer duration of electrolysis namely one hour against the normal requirements of 3-15 minutes of polishing time. The results are presented in Table II.

DISCUSSION

When an anodic current passes through the solution, a liquid layer of anodic dissolution products is formed on the surface. This layer has a higher viscosity and a greater electrical resistivity than the bulk of the solution. The layer thickness is greater on crevices than on projections. Due to the non-uniform current density, metal from the projection dissolves more rapidly than from crevices, which produces a surface levelling effect. The preferential dissolution may be due to [6-9]

¤ differences of the metal ion concentration in peaks and crevices (or)

¤ differences in resistivities of peaks and crevices (or)

¤ concentration of the electric field lines on peak in the rough surface which leads to a change in the surface tension of the films covering the peaks.

When organic compounds viz., ethanolamines are added, the adsorption of these compounds on the peaks of the

surface takes place. The adsorption on the surface of crevices was hindered due to the existence of the thick electrolyte layer. The inhibition of metal dissolution from the peaks of the surface causes levelling. The passive films on the crevices are stable and the uniform rate of dissolution from crevices and from the peaks causes the appearance of bright surface.

CONCLUSION

Hull cell studies, reflectivity measurements and weight loss measurements revealed that electropolishing bath containing monoethanolamine offered very bright surface at all temperatures compared to di and triethanol amines. This electropolishing bath offered maximum reflected surface with minimum electrical power consumption.

REFERENCES

1. J Edwards, *J Electrodep Tech Soc*, **28** (1952) 133
2. P A Jacquet, *C R Acad Sci*, **202** (1936) 402
3. P Michel, *Met Ind*, **26** (1949) 2175
4. P A Jacquet, *Metal Finishing*, **47** (1949) 6
5. H E Zentler-Gorden, *J Electrodepositors Tech Soc*, **26** (1950) 55
6. P A Jacquet, *Metal Finishing*, **47** (1949) 5-10; **48** (1950) 1-2
7. W C Elmore, *J Appl Physics*, **10** (1939) 724; **11** (1940) 797
8. J Edwards, *J Electrochem Soc*, **100** (1953) 7; **189c** (1953) 8; 223 c
9. G S Vozdvizhanskii, *Dan SSSR*, **59** (1948) 1587