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IMPROVING THE DEPOSIT DISTRIBUTION DURING ELECTROFORMING OF COMPLICATED SHAPES

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Electroforming involves the deposition of metals to higher thicknesses so that the deposit itself stands as a separate article for use in various functional applications. In this process considerable amount of metal is deposited at the projections, corners and edges and hence the wastage of metal is of the order of 100-200% over and above the requirement. This is due to the inherent nature of the electrodeposition process namely nonuniform current and metal distribution. Ions are invisible to man and their propulsion and manipulation through electrolytes is not nearly so controllable as that of electrons through metals and semiconductors at least relative to the purpose to be achieved. Modifications of the deposit distribution pattern can be achieved by changing the geometry of the part, by using auxiliarly anodes or shields or by changing the rack design. Good throwing power is that property of the plating solution which produces a relatively uniform distribution of metal upon a cathode of irregular shape. In the present study a slotted Hull Cell has been used to study the distribution of metal on a plate kept at an inclined position with respect to the anode. It has been concluded from the study that metal distribution is as uniform as possible when metal ions are injected through narrow slots due to the scattering of electric field in the deposition cell.

Keywords: Electroforming, Hull Cell, current distribution

INTRODUCTION

Physical and mechanical properties are largely related to electroplating conditions, particularly the current density. In practice the thickness of the deposit varies even on flat cathode placed parallel to a flat anode. The actual current density is higher at the corners and edges and correspondingly lower in the middle of the cathode. Current density at sharp corner end of a flat cathode is still higher than at the edges. The current is even less uniformly distributed over intricately shaped items which have pronounced protuberances and recesses. Hence, the technical specifications usually indicate not the average but the local thickness of the deposit on critical areas of the job. On intricate shaped articles the nonuniformity of deposits is primarily due to the resistance between anode and different parts of the cathode and thus different current densities on those parts.

Current will flow between two identical parallel electrodes in such a way that not only along the principal lines of force, which are perpendicular to both electrodes, but also along other lines of force. This depends on the location of the electrodes in the bath and electrical conductivity of the electrolyte in relation to the sidewalls, the bottom of the tank and surface of the electrolyte. Metal distribution mainly depends on primary and secondary current distribution. The primary current distribution depends only on the dimensions of the electrodes and distance between them in the electrolyte. However, electrodeposition of metal is accompanied by a change in the cathodic potential, corresponding to the current density at different parts of the cathode. Hence primary current distribution never occurs and would be undesirable from the aspect of obtaining a deposit of uniform thickness. The secondary current or actual current distribution depends on the composition of the electrolyte and on the operating conditions. In any electrolyte the secondary current distribution is more uniform than the primary current distribution. Metal distribution aids such as shields, robbers, thieves and conforming anodes are proposed in the literature and are being widely employed for achieving uniformity of deposits [1-10].

In the present study, the Hull Cell is modified by way of providing hole opening in between anode and cathode. Our idea is to study the influence of hole opening on deposit distribution at the Hull cathode which is kept at an inclined position with respect to the anode. Conventional Hull Cell is used to control the electroplating solutions and achieve optimum parameters such as metal concentration, pH, temperature, current densities, by direct measurements and also smoothness, brightness, porosity of the deposit by indirect measurements.

The shape of the Hull Cell is shown in Fig. 1(a). It is trapezoidal, the parallel sides being insulators, the normal side-the anode and the inclined side-the cathode was developed from practical considerations of manufacture and usage. The plain shape gives an anode-cathode spacing of 46 to 125 mm with a flat cathode panel of 101 x 62.5 mm. The depth of the cell controls its volume, thus 50 mm deep gives a volume of 267 ml. It is usual to take measurements at a mid-height line of the Hull Cell panel so as to minimise

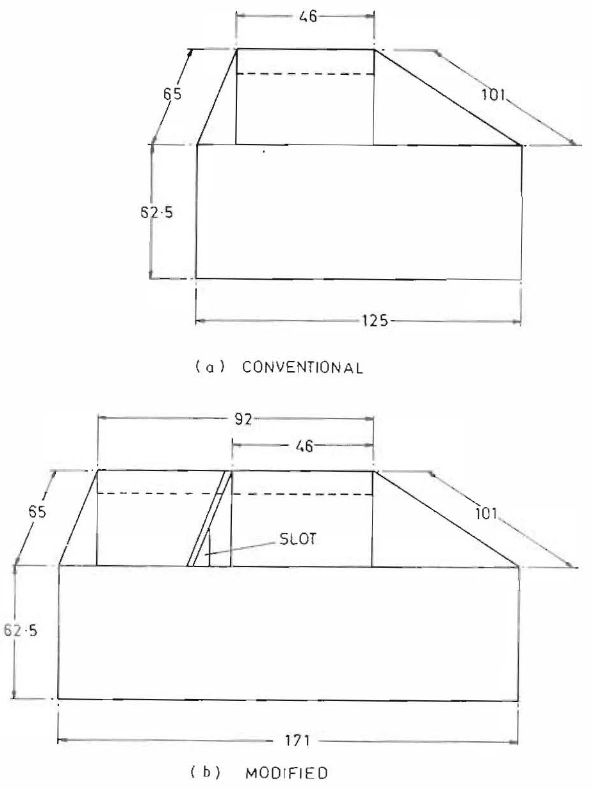

Fig. 1: Hull cell

stagnation effects at the bottom of the cell and over emphasise natural convection near the meniscus. The panel, from left to right demonstrates high, medium and low current density appearances or typically burned/nodular, semibright/bright/levelled to dull or no deposit zones.

Modified Hull Cell

A number of modified cells have been devised as shown in Table I. Each intended to overcome one or other shortcomings. 'Lu' achieved a very wide range of current densities by using four types of cells. They are (i) rotating disk cathode and a stationary cylinder anode, (ii) rotating cone cathode and a stationary disk anode, (iii) rotating cone cathode and a stationary cylinder anode and (iv) rotating cylinder cathode and a stationary washer shaped anode.

In this paper the authors have fabricated a slotted Hull Cell. This cell is nothing but of conventional Hull Cell with slot opening on the wall of anode side as shown in Fig. 1b the anode side of the normal Hull Cell is extended to a distance of 46 mm and slot opening with varying areas is provided in the vertical wall. Anode is placed at the end of the cell so that the metal ions are projected/guided through the slot. Due to the provision of slot, the resistance between the anode and cathode is increased considerably and hence the effect of solution resistance is minimised. This artificial creation of increased resistance between anode and cathode provides as nearly a uniform current density as possible at the cathode.

TABLE I: Modification of Hull cell

Mohler (3), Skwirzynski and Huttley (4)	Hanging Hull cell to be suspended in the electroplating vat. Assumes vat conditions of agitation etc.
Gilmont and Walton (5,6)	Flat cathode at the long side and short anode yields linear CD/L relationship
Dimon (3)	Circulating electrolyte is pumped along the cathode plate at a controlled velocity
Tena cell (8)	Segment of a concentric cell with cathodes at either end and variably spaced intermediate anode
Po yen Lu (10)	Rotating cathode and stationary anode reproducible mass transfer effects on deposit properties and throwing power

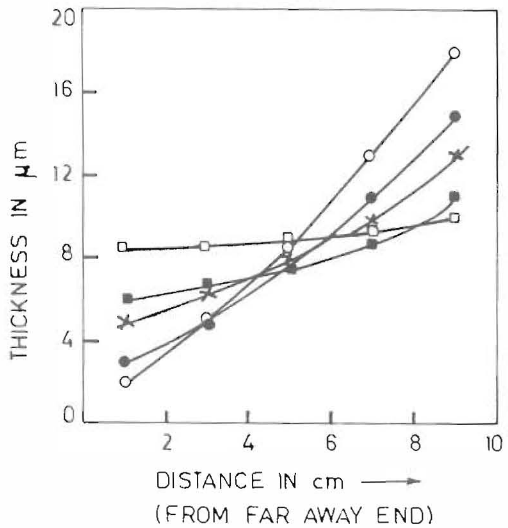

Fig. 2: Thickness of the deposit on Hull cell cathode and slotted Hull cell cathode with different hole openings
(1) Conventional hull cell
Slotted Hull cell hole opening
(2) 0.25 cm^2 (3) 0.50 cm^2
(4) 1.0 cm^2 (5) 2.0 cm^2

EXPERIMENTAL

Different slot areas of 0.25, 0.5, 1 and 2 cm^2 were employed and the metal distribution studied on the Hull Cell panel using the following electroforming solution:

Nickel sulphamate: 300 g/l
Nickel chloride: 10 g/l
Boric acid: 35 g/l

The Hull Cell panels were prepared by employing the conventional cleaning procedures and the electrolyte was prepared using LR grade chemicals and purified by using conventional procedures.

RESULTS AND DISCUSSION

Deposit thickness variations on the Hull Cell cathodes are shown in Fig. 2 for various slot openings. It could be seen that the thickness variation is too much for the conventional Hull Cell due to large variation in current density along the cathode. But in the case of slotted Hull Cell, as the hole opening is decreased from 2.0 cm^2 to 0.25 cm^2 the deposit distribution is almost uniform. With wider hole openings there is some change in the thickness distribution of the deposit. The uniformity of the deposit on the inclined cathode is achieved due to the realignment of the current lines because of the presence of a physical barrier between the anode and cathode. The physical barrier favourably alters the movement of the metal ions and thereby promoting the formation of uniform deposit. The resistance offered by the physical barrier is much greater than the resistance of the solution. Due to the presence of the slot opening in the cell, the voltage required for the passage of a given current is higher for the slotted cell in comparison to the Hull Cell. This sort of hole opening has been employed in photography to generate pointed light source which will have uniform intensity of light all over the area.

CONCLUSION

In order to obtain uniform deposit thickness on indicated shapes it is essential to provide a plastic mask with distributed holes so as to project or guide the metal ions for deposition. By doing so, the resistance between the anode and cathode is increased considerably and hence the effect of solution resistance is very much minimised. This artificial creation of increased resistance between anode and cathode provides as nearly a uniform current density as possible at the cathode and there by promotes uniform deposition of metal.

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