A Look at the Deposit Distribution in Acid Copper Plating

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As an electrodeposit, copper has wide range of applications (1-4), including electroforming and occasionally for salvaging wornout components. Another interesting application of copper deposit is on the electrode of many flame arcs (5), and on the carbon rods of all high intensity arcs, which are to carry DC currents upto 100 amps. Usual range of dimensions of the arc carbons are : 0.6 to 2.5 cm. in diameter and 15 to 60 cms. in length. The copper deposit increases the electrical conduction so that the current could travel the entire length of the carbon rods between the holder and the arc.

Copper plating for the purpose is done from acid copper bath known for its low throwing power. Therefore, it is of interest to study the distribution of copper particularly on jobs of the type of high intensity carbon rods.

EXPERIMENTAL

(a) Cine arc carbon rods of 0.70 cm. dia. and 35.5 cms. length were copper plated in Vats of 450 litres capacity. The bath employed (6-8) had the composition:

Copper Sulphate (Cu_2SO_4, $5H_2O$)	:	250 g/l
Sulphuric acid	:	50 g/l
Cathode Current density	:	2.6 A/Sq.dm.
Temp.	:	Ambient. (30°)
Anode/Cathode	:	1.5/1
Duration of plating	:	2 hours

The bath was contained in PVC lined Vats. The chemicals were of technical grade. Anodes were of cast copper of 99.8% purity.

The carbon rods were held in jigs, made out of PVC with suitable stay rods. Each jig carried 40 rods and 7 such jigs were used in each vat. Intercathode distance and interanode distance were 0.6 - 0.8 cm. and 14 cm. respectively. The bottom of the anode/jig were nearly 19 cms. away from the tank bottom and the job protruded 1 cm. above bath level, for electrical contact purposes. Rectifier constituted the source of direct current.

The sequence adopted for copper plating was :-

i) Manually clean/wipe with wet cleaning powder;

ii) Swill (in tap water) and rinse in deionised water;

iii) Dip in 5% (by volume) sulphuric acid solution

iv) Swill and rinse;

v) Load in the jigs and copper plate under the conditions indicated above;

vi) Swill and rinse;

vii) Give a neutralising dip in 5% (w/v) sodium carbonate solution;

viii) Swill, rinse and dry.

(b) In order to have a ready method of assessing the thickness of copper deposit on the carbon rod, voltage drop (IR drop) method was chosen. A few rods were plated in a 40 litres bath to varying thicknesses. 'A probe' with a span of 11 cms. was fabricated (photo 1) so that it can be easily

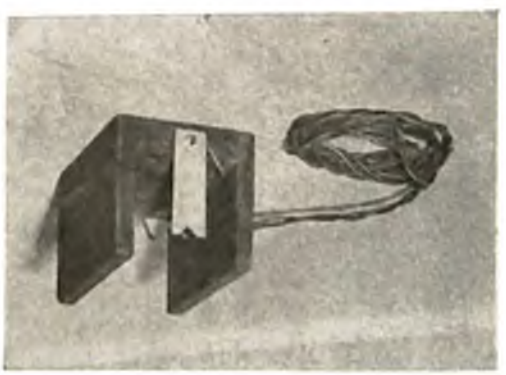


Fig. 1 'Probe' for measuring IR drop on carbon rods.

moved over the job. With this probe and by passing a direct current of 2 amp. from a constant current unit, the IR drop was measured with a VTVM (photo 2). This was related to the actual copper deposit weight, assessed by gravimetry. This relationship constituted the reference for all further work.

(c) To study the deposit distribution on the carbon rods from various loads, a sampling

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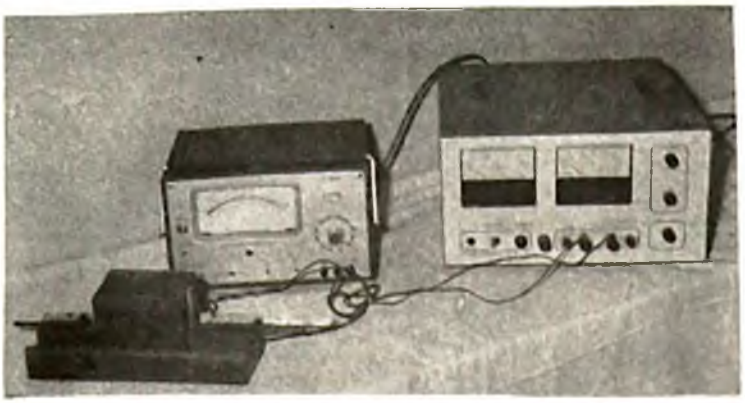


Fig. 2 'Probe' in use.

procedure was decided upon. As per this, groups of plated rods, each containing 2-4 rods per group were picked out, from each of the jigs and each of the vats. Alternative locations in each jig were chosen - two end positions (A & E), a middle one (C) and two intermediary places (B & D). In the final tallying, 60% of the groups carried three rods, 31% contained four rods and 7% of them consisted of 2 rods.

(d) Circumferential deposit distribution was checked by physically stripping off the deposit on a few plated rods in a sheet form and measuring the copper deposit thickness by a micrometer.

(e) The physical look of the deposit on each of the plated rods was noted visually in terms of smoothness and roughness.

RESULTS AND DISCUSSION

(1) OPTIMIZING THE PLATING TIME

IR drop values were measured at 3 locations on each rod employing the 11 cm probe. The IR drop measured on unplated graphite was 3.95 V. With a deposit of 3.5 g cm over the rod (which corresponds to 50 μm thick copper plates) the IR drop was found to be 4.0 mV. By making measuremets with different weights of cu, it was found that IR drop is lineraly related to the reciprocal of deposit weight. The product of IR drop and weight of copper was found to be 13.8.

In a plating bath containing carbon rods in 7 rows, smaples were collected from rows 1,4 and 7. The weights of deposited copper on a large number of rods are calculated. The results are presented in Table 1. Time of deposition has been varied and distribution of copper deposition in each case is computed and included in the same table.

It is seen that:

i) Considering the weight range 3.15 - 4.9 gms. copper as acceptable, maximum production of 65% is possible at 90 mts plating;

ii) 22% and 41% of the plated rods consititute underplated rods at 90 mts and 80 mts respectively; these rods may be segregated during chekcing of the IR drop values and may be replated;

iii) Replating of the under-plated rods would require 34 mts and 43 mts repectively, when the entire load is acceptable towards production; and

iv) In a 8 hour shift, taking 105 rods as a batch for plating, the following is roughly possible -

at 120 mts plating per batch - 4 loads yielding 420 acceptable rods;

at 90 mts plating per batch - 5 loads + 1 load for replating, giving 515 acceptable rods;

at 80 mts plating per batch - 5 loads + 2 loads for replating, giving 520 acceptable rods.

It can thus be seen that plating for reduced time of 90 mts or 80 mts a higher production by 24% is

TABLE 1

EFFECT OF DURATION OF PLATING ON % OF ACCEPTABLE COPPER PLATED RODS

Duration of Plating (Mins)	Weight of copper on the carbon rods (grams.)					% of Acceptable rods**	Total weight of Copper (grams)
	7.0	6.5 - 5.3	4.9 - 4.0	3.85 - 3.15	3.05		
	No. of rods						
120	14 (13.3)*	35 (33.3)	42 (40.0)	12 (11.4)	2 (2.0)	98	543
90	--	14 (13.3)	24 (22.9)	44 (41.9)	23 (21.9)	78	407
80	--	8 (7.6)	17 (16.2)	37 (35.2)	43 (41.0)	59	362
60	--	--	6 (5.7)	13 (12.4)	86 (81.9)	18	271

* % value ** Rods with 3.15grams and higher amounts of copper.

* Figures in the brackets indicate the % of the rods with the deposit in the specified range.

TABLE 2

FREQUENCY DISTRIBUTION OF CURRENT DENSITY ZONES IN 1, 4, 7 ROWS OF ALL VATS

Current Density region	IR Drop Range (mV)	Location in the Vat				
		A	B	C	D	E
High	2.5 & below	7, 6, 7½ * (6.8)	2½, - 3½ (2.0)	8, 5, 7 (6.7)	1, 2, 2 (1.7)	8½, 8, 7 (8.0)
Medium	2.7 - 3.4	4, 4½, 3½ (4.0)	9½, 9, 6½ (8.3)	4, 4½, 4 (4.2)	11, 7, 9 (9.0)	3½, 3, 4½ (3.7)
Normal	3.6 - 4.4	1, 1/2, 1 (0.8)	-, 2, 2 (1.3)	-, 1 1/2, - (0.8)	-, 2, 1 (1.0)	-, 1, 1 - - -
Low	4.6 & above	-, 1, -	-, 1, -	-, 1, -	-, 1, -	-, -, -

* 1. Where the IR drop for a plated rod happens to fall between two current density regions, it is taken as representing both the regions, and in counting, half unit is assigned to each location.
2. The three values successively under each location corresponds to the 3 loads repectively.
3. The figures in the brackets are the mean values.

possible with the same plant, besides a saving in copper by 22% (on an average).

(2) CURRENT DISTRIBUTION TREND IN THE VATS

Samples were taken from 1,4,7 rows of each of the vats and from all the loads. For rods from each location, IR was measured. For convenience of understanding, a code as indicated in Table 2 was followed to depict the picture.

From the summary in Table 2, the following are the broad conclusions -

i) By and large, in each of the loads and in each position/location in the jigs, the frequency of occurence of a given type of current density is of the same order (within limits), indicating that a certain behavioural pattern, specific to the locations themselves, exists.

ii) An over all picture in the vats is that at locations A, C and E, high and medium c.ds prevail, while at positions B&D, predominantly medium c.d. exists.

iii) The c.d. pattern in 1,4, 7 rows (details not included - only summary of observations are given) 1 in row 1, predominantly medium and to a lesser degree high c.d. exists (except in vat 2); in row 4, high c.d. prevails,slightly more than medium c.d. (except in vat 4); and in row 7, the trend is just the reverse to the one obtaining in row 4 (except in vat 4, once again).

3 (a) LONGITUDINAL DISTRIBUTION OF COPPER DEPOSIT ON THE CARBON RODS

i) General: The copper plated rods from load A were scanned with the probe at three places. The % variation of the end mV drop values with respect to the middle value was caluculated in each case and % deviations were grouped for convenience as under -

'p' range (difference); 3% and below-(most uniform plating).
'q' range - 5 to +5% (includes -4, -6, +4 & +6).
'r' range - -10 to +10% (includes values ±6 to ±11%).
's' range - beyond -10 to +10% (includes values beyond -11 and +11%)

Based on the above, the observations on the copper plated are presented in Table 3. It may be seen

TABLE 3

LONGITUDINAL DISTRIBUTION OF COPPER DEPOSIT ON CARBON RODS
Samples are taken from Load A

Samples	No. of plated rods in the range			
	'p'	'q'	'r'	's'
(i) 1,4,7 rows of Vat 1	26.1	26.1	21.7	26.1
(ii) 1 - 7 rows of Vat 1	21.4	23.2	22.3	33.1
(iii) 1,4,7 rows of Vat 1-4	22.4	15.9	28.4	33.6
Mean of (i), (ii) and (iii)	23.2	21.7	24.1	30.9

that 31% (mean value) of the plated rods have a longitudinal distribution of copper deposit along

the rods with a tolerance in excess of 10%, in other words, highly non-uniformly plated rods are produced. Further, 24% of the rods are plated with 10% tolerence. There is scope to improve the uniformity of copper deposit on these rods, so that they can be taken into the fold of 'p' and 'q' ranges.

ii) Pattern of the non-uniformity of deposit distribution:

The copper plated rods with a deposit thickness of tolerance of 10% and above, were scrutinised further to assess the trend of nonuniformity, as for instance, whether the tendency is to deposit more at the bottom of the rod, or its top position, or both ends. About 320 rods have been examined. The possible types of variation of deposit thickness at the top and bottom portions of the carbon rods, can be (based on mV drop values and hence weight of copper) as indicated in Table 4 and schematically in Fig. 3.

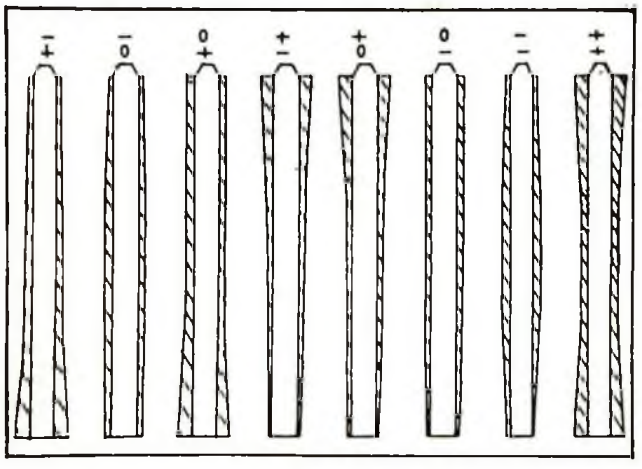


Fig. 3 Non-Uniformity of distribution of copper deposit

It is noticed that (i) 49% of the plated rods with a non-uniform deposit carrying low thickness at the top and high thickness at the middle and bottom portions of the carbon rods; (ii) that the reverse is true with 30% of the plated rods; and (iii) 21% of the plated rods carry either low or high quantity of copper at the top and bottom

TABLE 4

PATTERN OF THE NON-UNIFORMITY OF DEPOSIT DISTRIBUTION ON COPPER PLATED CARBON RODS

Load No.	No.of copper plated rods with deviation			
	+ + 0 / - 0 -	- - 0 / + 0 +	+ + / - -	- / -
I	65	26	32	5
II	58	49	14	8
III	70	45	11	11
Mean value	64	40	19	8
%	48.9	30.5	14.5	6.1

+, + or 0 Indicating a copper plated carbon rod with low thickness of copper at the top portion with respect to the middle and bottom portions.

-, - or 0 Indicating a copper plated carbon rod with high thickness of copper at the top portion with respect to the middle and bottom portions.

\+ / + Indicating low thickness of copper at the top portion with respect to the middle and bottom portions.

\- / - Indicating high thickness of copper at the top and bottom portions with respect to the middle portions.

segments when compared with the middle part of the carbon rods.

3 (b) CIRCUMFERENTIAL DISTRIBUTION OF COPPER DEPOSIT

A few plated rods were stripped of their copper into a sheet form and the thickness variation along the breadth of this strip (corresponding to the circumference of the plated rod) was assessed. The data is given in Table 5. From it, it is evident that (i) the deposit thickness is non-uniform across the circumference; and (ii) the number of regions with a specific variation depends on the overall thickness of the copper deposit on the carbon rod. For example, in a 77µm thick deposit, 78% of the plated surface has a thick variation 1.0 - 1.2; but this is only 59% at 51µm, as one can except at a lower thickness.

(4) NATURE OF SURFACE FINISH OF COPPER DEPOSIT

The details presented in Table 6 show that amongst the plated rods 33% are smooth, 55% are slightly

TABLE 5

CIRCUFERENTIAL DISTRIBUTION OF COPPER DEPOSIT ON THE CARBON RODS

Thickness of Copper deposit, µm.	mV drop	Number of regions on the plated rod with the ratio of copper deposit on successive protions as -							
		1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
77	2.6	10	7	8	3	1	2	--	1
	%	31.2	21.9	25.0	9.4	12.5	12.5	12.5	12.5
51	4.1	8	7	4	3	3	2	2	3
	%	25.0	21.9	12.5	9.4	9.4	12.5	12.5	9.4

rough and the balance are very rough. Vat 2 carries nearly equal number of each type of rod. In vat 3, one notes large % of rough rods - 69% slightly rough and 24% very rough.

The overall picture from Table 6B) prevailing in all 3 loads is that 27% of the rods are smooth, 52% are slightly rough, and the rest are very rough. Once again, load A nearly represents the overall picture.

(5) CONCLUSION

In this work on copper plating of carbon rods, the observations may be summarised as follows:

(i) A practically useful relationship between IR drop and copper weight is reported for a thickness range of 40-120 µm, employing a probe.

(ii) A sampling procedure is arrived at to represent the picture in all the plating vats. As per this 15 rods are chosen from each jig at 5 places - two end protions, a middle place and two intermediary locations. It is established that it would suffice if the plated rods from rows 1,4,7 are picked out and that would represent the entire production from the vat.

iii) A frequency distribution study shows that only 52% of the plated rods can be accepted and 44% are under-plated. It is demonstrated that by reducing the plating duration , production from a vat can be raised by 24%, in addition to 22% saving of the coper metal.

iv) It is found that the extreme and middle locations in a vat are prone to high and medium c.ds. while in the intermediary positions, medium c.d. prevails. Among the jigs predominantly medium c.d. exists in row 1; slightly high c.d. prevails in row 4; and the trend in row 7 is just the reverse to row 4.

v) Scanning of the deposit thickness lengthwise on the plated rods indicates that 45% of the rods have a variation of 5% and below, 24% a variation

TABLE 6A

NATURE OF SURFACE FINISH OF COPPER DEPOSIT ON CARBON RODS

a - smooth b - slightly rough c - very rough

picture in Vats in Load A (1,4,7 rows)

Samples	Nature of surface finish		
	a	b	c
Vat 1	13(29.5)*	25(56.8)	6(13.6)
Vat 2	14(31.1)	15(33.3)	16(35.6)
Vat 3	4(7.8)	35(68.6)	12(23.5)
Vat 4	19(36.5)	28(53.9)	5(9.6)

* % value

TABLE 6B

NATURE OF SURFACE FINISH OF COPPER DEPOSIT ON CARBON RODS

Overall picture in all the loads (1,4,7 rows of Vats 1-4)

Samples	Nature of Surface finish		
	a	b	c
Load A	50	103	39
Load B	45	87	76
Load C	67	122	11
Mean value	54	104	42
%	27	52	21

of 10% and the rest beyond 10% difference, from end to end. They are non-uniform along a Circumference also.

vi) A majority (45%) of the plated samples carried low thickness at the top and high thickness at the middle and bottom portions of the carbon rod, whereas reverse is the trend in 24% of the production. The rest of the plated rods carry either low or high deposit thickness at the top and bottom segments versus the middle region of the carbon rod.

viii) The over all picture regarding the surface finish of copper deposit on plated rods is that 27% of the rods are smooth, 52% are slightly rough and the rest are very rough.

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