

STUDIES ON THE CHARACTERISTICS OF WATER SOLUBLE ACRYLIC RESINS USED FOR ELECTRODEPOSITION

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[Received: 1 November 1995 Accepted: 11 July 1996]

Electrodeposition of paint has become a widely accepted technique for application of paint coating and is being adopted for coating a variety of metal articles for corrosion protection as well as for decoration. Several resin systems have been used for this purpose depending on the specific application for which the coating is used. For example for excellent corrosion protection, primer coatings based on epoxies and polybutadiene are used. Acrylic coatings have not very good fade resistance properties and can be used for decorative applications over different metallic substrates. This paper deals with some of the studies made mainly on the bath characteristics of the acrylic system. The main parameters studied include the effect of conductivity of the solution on deposition characteristics, the throwing power at different operating parameters and coulombic efficiency with and without pigmentation. Some of the physical properties like bond strength of cured coatings, hardness, abrasion resistance and also corrosion resistance are also reported in this paper.

Keywords: Acrylic resin and electrodeposition.

INTRODUCTION

Electrodeposition of resins and pigmented resins has become a versatile paint application technique and presently it is being used in several countries due mainly to the various advantages it possesses over the conventional application techniques [1]. The method can be used for primer application or one coat finish application [2,3]. A number of paint systems are used for deposition purposes and the choice is made depending on the purpose for which the coating is applied whether for corrosion protection or decoration etc. [4]. Some of the properties of the electrodeposited coating can be changed by incorporating certain addition agents [5]. Acrylic coatings are well known for their colour retention and non-yellowing properties [6] and because of this they are used as finish coats. Electrodeposited acrylic coating can be used both for protective and decorative purposes and several water soluble acrylic systems based on different acrylic monomers are reported for electrodeposition purposes [7].

EXPERIMENTAL

Water soluble acrylic resin was prepared by reacting appropriate quantities of butyl acrylate, styrene, acrylic acid,

butyl cellosolve and n butanol till the acid value reached 45-50. The resulting resin was water solubilized by means of triethanol amine to acquire the required pH value. Deposition was carried out anodically over the test specimens using mild steel as cathode.

Throwing power of the bath was determined using the Tawn and Bery method [9]. The pigment migration efficiency which is the ratio of the pigment/binder in the film to that in the bath was determined by separating the pigment from the film after curing the deposited film for 10 minutes at 383 K. The flexibility test for the coating was carried out as per ASTM D.522 (60), hardness testing by the scratch hardness tester as per IS 101, abrasion resistance by using the Taber abrasion tester as per ASTM D 4060- 84. Salt spray test was conducted as per ASTM B 117-73 and immersion test as per ASTM 1647. Bond strength was determined by sandwich pull off test using MONSANTO Tensometer with araldite as the standard adhesive.

RESULTS AND DISCUSSION

Electrical conductivity

Table I gives the variation of conductivity of the solution with concentration of the resins and also the nature of the deposit obtained. The conductivity of the solution increases

TABLE I: Effect of resin concentration on the conductivity and nature of deposit

Sl No	Resin concn wt%	Conductivity $\mu\text{m cm}^{-1}$	Nature of coating produced at 100 V
1.	5	1300	Thin deposit
2.	10	1750	Uniform and smooth
3.	15	1950	Uniform and smooth
4.	20	2260	Uniform and smooth
5.	25	2540	Uniform
6.	30	2480	Rough

with concentration upto 25 % and then there is a tendency to decrease.

Resin concentration

As already indicated in Table I, the nature of the deposit varies with the concentration of resin in the solution. At 100 V the deposit is very thin at 5 % concentration where as from 10 to 20 % the coating is very smooth and uniform. The coating tends to become rough from a concentration of 25 % and 30 % it is highly rough. The nature of the current-time relationship shown in Fig. 1 also indicates the same behaviour. Up to 20 % the curve is smooth but beyond this there is a tendency to deviate, the minimum current not touching near zero, thus showing that the deposit is porous.

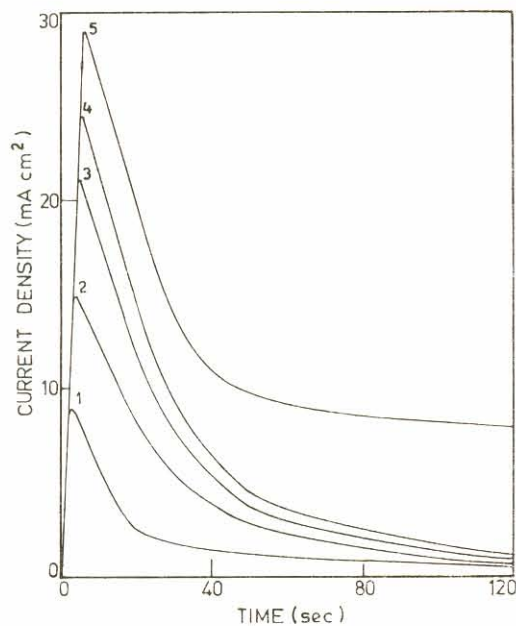


Fig. 1: Effect of concentration resin on current-time behaviour applied voltage 100 v (1) 5% (2) 10% (3) 15% (4) 20% (5) 30%

Applied voltage

Voltage upto 200 V for a solution with 10 % resin concentration gives smooth coating. Higher voltage produces rough deposits. Fig. 2 shows the variation of current with time at different voltages above 250 volts film get ruptured resulting in high values of current. The main reason for breaking the film can be attributed to the heat development at the metal/resin interface under such high voltage conditions.

pH and temperature

The optimum pH for getting a good coating is found to be 7.5 - 8.5 and the temperature range is 293-308 K. At pH less than 7.5 a tendency for coagulation of the resin particles was observed due to charge neutralization where as at high pH excessive gas evolution resulted in thin and porous coatings. Similarly baths at temperature below 293 K and above 308 K yielded coatings with undesirable properties, lower temperature yielding too thin coatings and higher temperatures giving porous coatings.

Characterization of electrocoating bath

Throwing power

Throwing power of both bare resin solutions and TiO_2 pigmented baths were determined by using Tawn and Bery method. The values are given in Table II and III. Both the systems are found to have very good throwing power. The

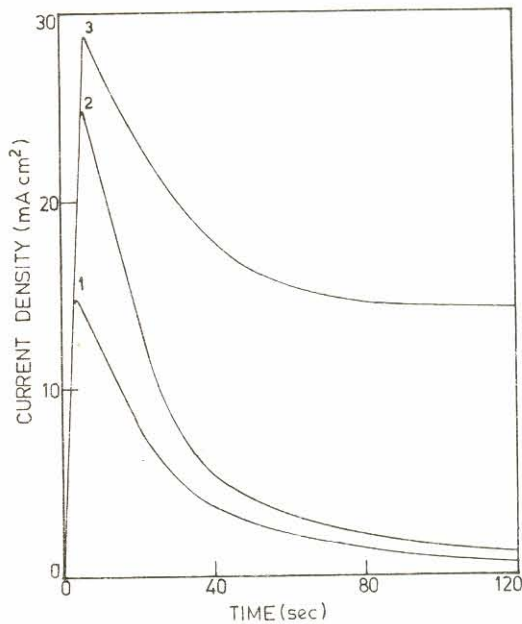


Fig. 2: Effect of voltage on current-time behaviour concentration 10% (1) 100 v (2) 200 v (3) 250 v

**TABLE II: Throwing power of acrylic resins solution
pH = 8.0**

Sl No	Resin concn wt%	Voltage volt	Throwing power %
1.	5	50	94.5
2.	10	50	98.5
3.	15	50	98.5
4.	20	50	98.5
5.	30	50	94.5
6.	10	100	98.5
7.	20	100	98.0
8.	10	200	98.0
9.	20	200	98.0

**TABLE IV: Columbic yield of acrylic resin bath
with and without pigmentation
Applied voltage = 100 V pH 8.0**

Sl No	Resin concn wt%	Pigment concn wt%	Columbic yield
1.	5	0	8.2
2.	10	0	9.9
3.	15	0	10.1
4.	20	0	10.1
5.	10	5	10.2
6.	10	10	10.5
7.	10	20	10.6
8.	10	30	10.8

maximum throwing power for pigmented bath is found at a concentration of 10 % TiO₂ to 10 % resins. At very high pigment concentration the T.P. gets reduced considerably.

Columbic yield

Columbic yield of the acrylic resin bath with and without pigmentation is shown in Table IV. With pigmentation there is slight increase in the value when compared with the value of bath containing resin alone. When the pigment concentration is increased keeping the resin concentration constant, the coulombic yield is found to be increasing to a slight extent. But the optimum is to be fixed because beyond a certain limit of the pigment concentration the coating becomes highly porous.

Pigment migration efficiency

Pigment migration efficiency (PME) was determined using the formula

$$PME = \frac{\text{Pigment-binder ratio in the coating}}{\text{Pigment-binder ratio in the bath}} \times 100$$

This value gives an indication of the extent of pigment concentration in the coating when a particular pigment binder ratio is used in the bath.

The pigment dispersed in the electrodeposition bath gets charged by virtue of the absorption of the charged resin particulars as to the pigments particles. Though it is expected that the pigment and resin distribution in the coating will be the same as in the depositing solution as it can be seen from Table V. That it varies with different parameters of deposition e.g voltage and duration of deposition. The PME is an important characteristic as the standardization of this particular factor becomes necessary since the properties of the coating depend on the pigment binder ratio, the pigment volume concentration of the coating.

**TABLE III: Throwing power of TiO₂ pigmented
acrylic resin solutions; Applied voltages = 100 v**

Sl No	Concentration of resin w%	Concentration of TiO ₂ wt%	Throwing power
1.	10	5	98.5
2.	10	10	98.5
3.	10	20	96.5
4.	10	30	96.0
5.	20	10	96.5
6.	20	30	92.0

**TABLE V: Pigment migration efficiencies of
acrylic resin concentration 10%**

Sl No	TiO ₂ concn wt%	Voltage volts	Time secs	PME
1.	3	50	120	106
2.	4	50	120	108
3.	5	50	120	115
4.	5	20	120	110
5.	5	30	120	112
6.	5	40	120	114
7.	5	100	120	120
8.	5	150	120	130
9.	5	100	60	118
10.	5	100	90	120
11.	5	100	180	120

TABLE VI: Bond strength of anodic acrylic coatings with and without pigmentation over different substrates

Sl No	Substrates	PVC %	Bond strengths Kg cm ⁻²
1.	Mild steel	0	258
		5	267
		10	270
		15	275
		20	278
		25	278
2.	Phosphated mild steel	0	260
		10	275
		30	265
3.	Aluminium	0	208
		10	210
		20	217
		25	217
		30	210
4.	Zinc	0	255
		10	265
		20	276
		25	278
		30	272

TABLE VII: Physical and corrosion resistance properties

Sl No	Property	Resin coating (10% resin)	TiO ₂ pigmented coating (PVC 25%)
1.	Scratch hardness (kg cm ⁻²)	2100.00	2300.00
2.	Flexibility (cm)	0.30	0.30
3.	Impact resistance (cm)	21.00	21.00
4.	Abrasion loss (mg/100/rev/ 500 g load)	5.10	3.60
5.	Salt spray resistance in 5% NaCl (hrs)	456.00	504.00

resistance of the coatings as seen in the conventional paint systems.

Corrosion resistance — Salt spray and immersion test

Results of salt spray test indicates that the pigmented coating starts corroding after 600 hrs. Alkali causes damage to the coating after 408 hrs. Attack occurs earlier for simple resin coating confirming that pigmented electro-coatings perform better in corrosive environments.

CONCLUSION

Amine solubilised water acrylic resins can be used as good systems for electrodeposition. They give very good electrocoating with excellent adhesion to different substrates, corrosion resistance, flexibility impact resistance, hardness and abrasion resistance.

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Evaluation of the properties of the coating

Bond strength

Adhesion values of the cured acrylic coatings with and without pigmentation on different substances are given in Table VI. There is not much difference in the values for different substrates expect for aluminium where the value is much lower. This may be due to the part played by the anodic film formed on aluminium surface. However even in the case of aluminium the values obtained are well within the satisfactory limit. In the case of phosphated mild steel the adhesion values are more or less similar to the bare mild steel substrate. This can be attributed to the fact that phosphate layer also is getting slightly dissolved during deposition.

Other physical properties

Properties like hardness, flexibility, impact resistance and abrasion resistance have been evaluated for acrylic resin coatings (25 μm) with and without pigmentation over mild steel and results are given in Table VII. Generally it is found that pigmentation improves the hardness and abrasion