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Study on the Influence of Process Parameters on Surface Roughness during the Electrolytic Colouring on Anodized Aluminum

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Abstract*— Aluminum (Al), because of its high strength to weight ratio, has found numerous engineering applications. The natural oxide layer formed is not protective in extreme conditions and it peels off. The anodized layer is thicker than the natural oxide layer and gives better corrosion resistance. Anodization is an electrolytic conversion of the metal surface and does not involve addition of external material. Anodic films are considered sufficiently adherent. The anodization process of metals has been used by industry to protect metal components from corrosion. The electrolytic colouring or "Two Step anodizing" has been developed industrially in the sixties. The process consists of immersing the anodize work in a solution containing metallic salts and to apply and AC voltage. Under these conditions metallic deposit are formed at the bottom of the pores in the interphase between barrier and crystalline layer. The colour depends on the nature of the electrolyte; most metals give a bronze to black colour (Sn, Ni, Co, etc) some as copper gives reds etc.This paper presents a study of parameter optimization of electrolytic colouring on anodized aluminum 7075. The properties of electrolytic finishes are similar to the normal sulphuric and films. The light fastnesses of the finishes produced with most electrolytes are very good.

Index Terms—**ANOVA, S/N ratio.**

I. INTRODUCTION

Aluminum alloys are usually used because they have a low density and quite good mechanical characteristics.[2] To provide specific superficial properties (against corrosion or wearing for example), many surface treatments are available.Anodization is an electrolytic conversion of the metal surface and does not involve addition of external material. Anodic films are considered sufficiently adherent [3]. The anodization process of metals has been used by industry to protect metal components from corrosion. During this electro-chemical process the surface chemistry of the metal is changed, via oxidation, to produce an anodic oxide layer that is thick enough to stifle further oxidation. When aluminum or its alloys are anodized in acid solutions, such as sulfuric acid, phosphoric acid, oxalic acid, or chromic acid, an anodic oxidation film forms on their surface. The film is formless aluminum oxide with a little of 'γ-aluminum oxide [4]. From surface to body the film is composed of a porous layer, resistance layer, and body as in figure 1[1]. Because of the porous structure the oxidation film has good adsorbability The electrolytic coloring process consists of immersing the anodize work in a solution containing metallic salts and to apply and AC voltage.

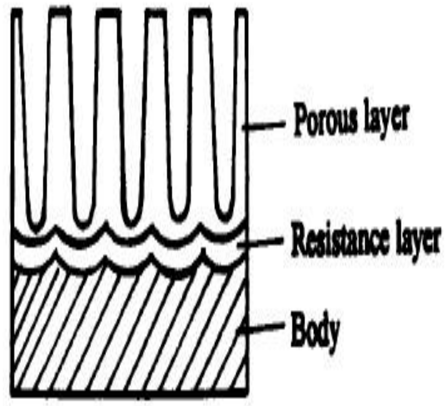

Fig 1: Structure of anodized aluminum

Alternating current is deformed when it goes through the film. The negative current is more than the positive current. When the current is negative, metal ions in the pores are reduced and deposit on the bottom of the porous film as shown in the figure 2. When current is positive, aluminum is continuously oxidized and a little of the metal, which deposits on the bottom of the porous film, is oxidized to metal oxide. The metal or metal oxide selectively adsorbs and diffuses incident light to produce a color effect.

Table 1: Coloring parameters

		Levels and values				Response
Parameter	Unit	1	2	3	4	Surface roughnes s
Time	sec	60	180	300	420	
Voltage	V	10	12	14	16	
Conc.	ml/L	75& 15	90& 18	105 & 22	125 & 25	

This paper presents a study of parameter optimization of electrolytic coloring on anodized aluminum 7075. AA7075 alloy is extremely useful in aircraft fitting gears and shafts, fuse parts, meter shafts and gears, missile parts, regulating valve parts, worm gears, keys, aircraft, aerospace defense applications, bike frames, all terrain vehicle sprockets.AA7075consistsofSilicon,iron,copper,manganese, magnesium,chromium,zinc,aluminium and titanium as its

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components. Many heat treatments and heat treating practices are available to develop optimum strength, toughness and other desirable characteristics for proper application of alloy 7075.

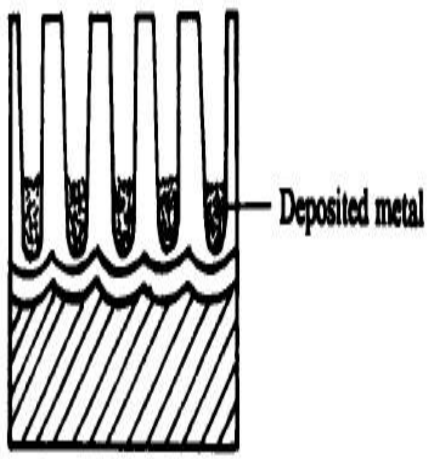

Fig 2: Structure of electrolytic colored aluminum

II. SCHEME OF EXPERIMENT

Disk shaped specimens of AA 7075 having diameter of 25 mm and thickness of 8 mm are selected for the experiment. A through hole of diameter 4 mm is made on the work piece at a distance of 6mm from the center in order to facilitate jigging. The parameters, levels and responses are shown in table1. The settings for each experiment are arrived by suiting the levels in the L16 orthogonal array as shown in Table 2. While preparing the work piece care have been taken to maintain a uniform surface finish. The L16 array with all values selected for the experimental run is shown below in table 2.

III. OUTPUT RESPONSES

Surface roughness is calculated in order to determine the polishing effect of electrolytic colouring. Surface roughness (Ra) values of the specimen can be measured using TESA model 90G shown in figure 3, which has a measuring range of 50mm and measuring span of 1000 µm.

Table 2: Scheme of experiment

Experiment no.	Time(sec)	Voltage(V)	Concentration (ml/L)
1	60	10	75&15
2	60	12	90&18
3	60	14	105&22
4	60	16	125&25
5	180	10	90&18
6	180	12	75&15
7	180	14	125&25
8	180	16	105&22
9	300	10	105&22
10	300	12	125&25
11	300	14	75&15
12	300	16	90&18
13	420	10	125&25
14	420	12	105&22
15	420	14	90&18
16	420	16	75&15

Fig 3: TESA model 90G to determine surface roughness

IV. RESULT AND DISCUSSIONS

S/N ratio

In the experiment, the desired characteristic for surface roughness is lower the better.

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}(y_i{}^2)\right]$$

Where n is the number of measurements in a trial and y_i is the measured value in a trial. Taguchi's method of analyzing means of the S/N ratio using conceptual approach involves graphical method for studying the effects and visually identifying the factors that appear to be significant. The rank indicates the dominant machining parameter [5]. Table 3 summarizes the surface roughness of the colored films and their corresponding signal to noise (S/N) ratios. Surface roughness varies from 0.232 to 0.475 during electrolytic colouring of AA7075.

Table 3: SNRA corresponding to each experiment

Experiment no.	Surface roughness(µm)	SNRA
1	0.397	8.02
2	0.286	10.87
3	0.299	10.486
4	0.271	11.34
5	0.389	8.20
6	0.475	6.46
7	0.301	10.43
8	0.309	10.20
9	0.239	12.43
10	0.232	12.69
11	0.264	11.57
12	0.296	10.57
13	0.291	10.72
14	0.259	11.73
15	0.342	9.32
16	0.281	11.03

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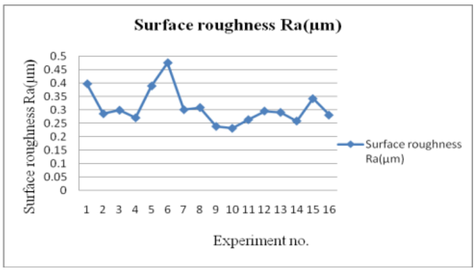

Fig 4 : Plot of surface roughness and experiment number

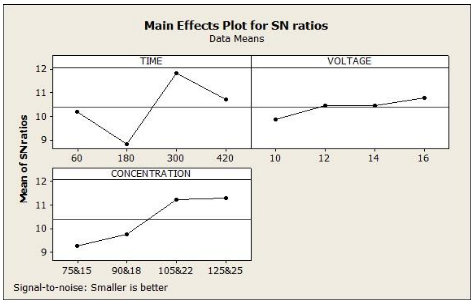

Fig 5: Main effects plot for SN ratios

The variation of surface roughness with experiment number is shown in figure 4 and the main effects plot for S/N ratio is shown in figure 5. Table 4 shows the response table of Signal to Noise ratios for surface roughness. Based on this analysis, polishing behavior is obtained at time (300sec), electrolyte concentration (125&25 ml/L), and voltage (16v). In the analysis, time is shown as the most influencing parameter followed by electrolyte concentration and voltage.

V. ANALYSIS OF EXPERIMENTAL DATA

Statistical analysis of variance (ANOVA) is done to investigate which design parameter significantly affects surface roughness. Based on the ANOVA, the relative importance of the colouring parameters with respect to surface roughness was investigated to determine the optimum combination of the anodizing parameters.

Table 4: Response Table for surface roughness S/Noise Ratios (Smaller is better)

Level	Time	Voltage	Conc.
1	10.181	9.845	9.271
2	8.824	10.441	9.742
3	11.816	10.451	11.213
4	10.700	10.785	11.295
Delta	2.992	0.941	2.024
Rank	1	3	2

All analysis is carried out for a significance level of α=0.05, i.e., for confidence level of 95%. ANOVA table also has probability level that is the realized significance level, associated with the F-tests for each source of variation. The sources with a probability level less than 0.05 are considered to have a statistically significant contribution to the performance measures. Also the percentage of contribution of each source to the total variation indicates the degree of influence on the result by each source[5]. Based on the ANOVA results in Table 5 the percentage contribution of various factors to surface roughness is identifiable. Here, time is the most influencing factor followed by electrolyte concentration.

Table 5: Results of anova

Source	DOF	Sum of squares	Mean of squares	F	P	Contribution (%)
Time	3	18.501	6.1670	4.46	0.057	44.78
Voltage	3	1.838	0.6125	0.44	0.731	4.45
Conc.	3	12.678	4.2261	3.05	0.113	30.68
Error	6	8.300	1.3833			
Total	10	41.317				

The percentage contribution of time and electrolyte concentration towards colouring is 44.78% and 30.68% respectively. Also the probability level of electrolyte concentration is much more than α (0.05) which indicates that voltage has least contribution towards surface roughness.

The optimal combination is:
Time = 300 sec
Electrolyte concentration = 125&25 ml/L
Voltage = 16 v

VI. CONCLUSION

1. Surface roughness varies from 0.232 to 0.475 during electrolytic colouring of AA7075
2. The optimal combination based on S/N ratio and anova are time 300 sec, electrolyte concentration of 125&25 ml/L and Voltage of 16 v
3. The time is the most influencing factor followed by electrolyte concentration and voltage.
4. Amount of metal deposited (depth of colour) is proportional to the colouring time.
5. Coating thickness increases with increase of concentration of electrolyte and applied voltage.

APPENDIX

1. S/N ratio: In the experiment, the desired characteristic for surface roughness is lower the better.

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}({y_i}^2)\right]$$

Where n is the number of measurements in a trial and y_i is the measured value in a trial.

2. Concentration (conc.): In the concentration 125&25ml/L, 125ml/L is the concentration of coloring solution and 25ml/L is the concentration of stabilizer.
3. Electrolyte concentration: Electrolyte is prepared mixing coloring solution and stabilizer as required and 10ml of

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sulphuric acid. The solution is makeup to one litre by adding deionized water.

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