Optimization of Process Parameters of Nickel – Chromium Electroplating for Thickness Variation using Genetic Algorithm

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Abstract: Surface is very critical from quality point of view which affecting the life and the performance of products. Surface properties can be improved by number of methods, but electroplating is preferred because of its enhanced results at lower cost. In this work nickel chrome is selected for experimentation as it is widely used in industry especially in automotive sectors for plating many of the automotive components. The electroplating of nickel chrome not only improves the surface properties but also aesthetics of the component which is also a vital part of automobile requirement. Experiments are planned by Taguchi L16 orthogonal array and effect of density of solutions and time for processes at two levels on thickness variation is studied. Mathematical model were developed by regression analysis for thickness variation. Genetic Algorithm is used for optimization of process parameters. It was observed that the effect of time is more dominating for the thickness variation.

Keywords: ***Surface Engineering, Anodic, Semi Bright, Genetic Algorithm***

1 Introduction

Surface of any mechanical element is important as performance and working life of the element depends on it. The economics of the processing is the main concern of the industry. Surface preparation processes contribute to the cost and durability of the product so it's critical and electroplating contributes a lot in surface properties enhancement than other methods. Depending upon specific requirement, different plating materials are selected such as zinc, nickel, chromium, nickel chrome etc. Nickel chrome is widely used in many applications especially in automotive industries. Nickel chrome plating improves the corrosion resistance, hardness, wear resistance, improve aesthetic look and improve surface properties independent of substrate. Almost 12% of worlds nickel chromium produced is just used for electroplating, justifying its importance in surface improvement so there is continuous need to still improve the process. Many researchers have studied electroplating with different aspect. Nickel zinc electroplating process optimization is done to set factor to optimum value for hydrogen evolution affecting plating [1]. Optimization of nickel, copper and hard chromium coating by multiple electroplating process is done for thickness of plating [2]. Improvement in thickness of deposition for amount and distribution of nickel been plated is done by proper racking and placement of the part in solution and by using theirs shields and auxiliary anode [3]. Effect of time, temperature, current and density on nickel in electroplating characteristics in supercritical CO2 is studied [4]. Improving the throwing power of nickel electroplating baths for improving deposition is studied [6]. Non uniformity leads to thickness variation affecting the functional requirement so more thought is to be given to the thickness variation in electroplating process [7]. In the present work study of thickness variation is done. Experimentation is done by L16 orthogonal array and effect of time and density is studied for thickness variation. Mathematical model are developed using regression for different factor setting at different levels. Genetic Algorithm is used to optimize the process parameters.

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2 Experimental Work

Electroplating is the electrolytic deposition of a metal from a solution onto the surface of substrate immersed in

solution. Part to be plated is submerged in the bath and electric current is applied. The part is in the centre of plating tank as cathode and the anodes of plating material are positioned near the edges of tank, deposition takes place based on Michael Faradays Laws. The set-up used is of Zumtara Electroplating industry. The steps of process are cleaning, rinsing and electroplating. The set- up has a series of tanks with different solution as per the process. The setup of electroplating is as shown in figure 1.

Fig. 1. Setup of Electroplating

Fig. 2. Outer Tube of Shock Absorber

2.1 Material

For the study the experimentation work was performed on the outer tube of shock absorber that is 250 mm in length and 45 mm diameter. The product is as shown in figure 2. The material steel cold drawn containing carbon-0.20 max., Mn- 0.30-0.60, S-0.60 max and P-0.060 max. The plating material deposited on the product is nickel and chromium.

2.2 Technique

Experimentation is carried by Taguchi's L16 orthogonal array. Following the array randomly experimentation was carried out. On the plating jigs number of components to be plated are adjusted and are dip in solutions to carry processes on number of components simultaneously. Three components electroplated are selected randomly for set parameter process and thickness of plating is checked at three different locations per component. The complete process of cleaning, rinsing and plating is a continuous sequential process carried in 8 steps as shown in table 1 with two levels of factor time and density.

Table 1 Factor Setting Values for Two Levels

Factors	Processes															
Levels	Degreasing		Anodic		HCL		H_2SO_4		Semibright		Triplex		Bright		Chrome	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Time(min)	5	8	3	5	2	5	2	3	20	24	3	5	14	16	3	5
Density(g/L)	10	13	6	10	5	10	10	20	19	22	19	24	19	24	19	24

2.3 Thickness testing

Thickness of plating is measured by Smart GEDET tester. This device work on principle opposite to electroplating it remove the coating of material working on coulometric principle. The thickness of plating layers of bottom semi bright is 12 to 14 µm, middle triplex is 2 to 3 µm and top bright layer is 9 to 10 µm. i.e. total nickel chrome electroplating thickness is 24 to 25 µm.

3 Results and Discussion

In order to have more accurate results randomly the experiments were carried out for three times and three different components were checked at three locations in a sample for thickness. Form the reading noted of a component, maximum and minimum value gives thickness variation. Average of three different component thickness variations is taken. The results were analysed to investigate the effects of time and density parameters at two levels for each step of degreasing, anodic, HCL, H2SO4, semi bright, triplex bright and chrome for thickness variation of electroplating.

3.1 Regression analysis

The lower thickness variation is considered as better result. The result of thickness variation due to time and density variation is as shown in table 2 and table 3 respectively.

Table 2 Thickness variation with time of processes

Trail No.	Factor Time (Min.)								Thickness Variation(µm)
	T1	T2	T 3	T4	T5	T6	T7	T 8	
01	5	3	2	2	20	3	14	3	6.765
02	5	3	2	2	20	3	14	5	4.895
03	5	3	2	3	24	5	16	3	6.53
04	5	3	2	3	24	5	16	5	6.66
05	5	5	5	2	20	5	16	3	4.03
06	5	5	5	2	20	5	16	5	5.16
07	5	5	5	3	24	3	14	3	5.3
08	5	5	5	3	24	3	14	5	5.43
09	8	3	5	2	24	3	16	3	6.53
10	8	3	5	2	24	3	16	5	6.86
11	8	3	5	3	20	5	14	3	6.38
12	8	3	5	3	20	5	14	5	6.2
13	8	5	2	2	24	5	14	3	7.1
14	8	5	2	2	24	5	14	5	6.1
15	8	5	2	3	20	3	16	3	5.35
16	8	5	2	3	20	3	16	5	5.65

Thickness Variation versus T1, T2, T3, T4, T5, T6, T7 and T8 i.e. for time of process.
The regression equation for thickness variation = 3.63 + 0.225 T1 - 0.419 T2 - 0.132 T3 + 0.007 T4 + 0.190 T5 + 0.086 T6 - 0.087 T7 - 0.064 T8 (1)

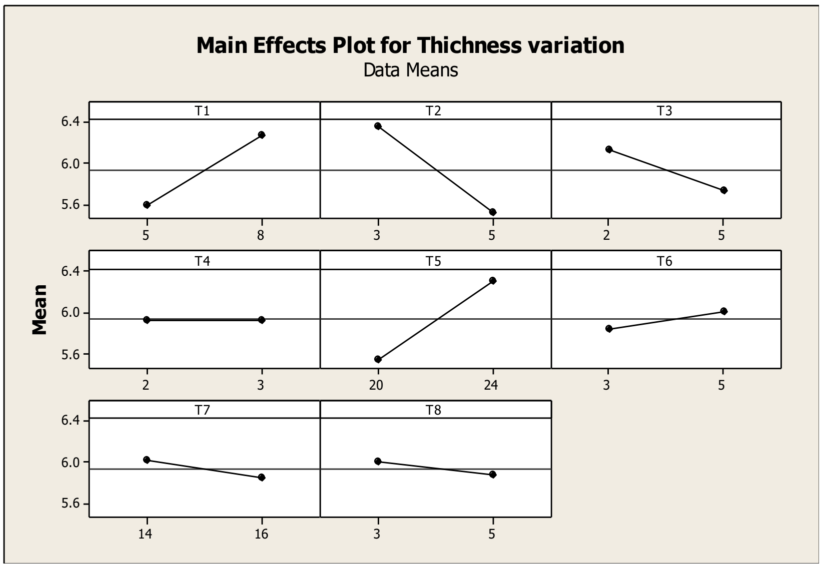

Fig. 3. Main effect plot for thickness variation with time

From the main effect plots as shown in figure 3 it was found that the thickness variation is more affected by cleaning process such as degreasing and anodic with more time of anodic cleaning thickness variation reduces, also semi bright plating is affecting the thickness variation with time as the major thickness of plating is of semi bright i.e. 12 to 14 µm.

Table 3Thickness variation with density solution

Trail No.	Factor Density(g/L)								Thickness Variation (µm)
	D1	D2	D3	D4	D5	D6	D7	D8	
01	10	6	10	10	19	24	24	19	6.766
02	10	6	5	10	19	19	19	24	5.447
03	10	6	5	20	22	24	24	19	6.749
04	10	6	5	20	22	24	24	24	6.690
05	10	10	10	10	19	24	24	19	4.998
06	10	10	10	10	19	24	24	24	4.940
07	10	10	10	20	22	19	19	19	5.269
08	10	10	10	20	22	19	19	24	5.109
09	13	6	10	10	22	19	24	19	6.490
10	13	6	10	10	22	19	24	24	6.790
11	13	6	10	20	19	24	19	19	6.444
12	13	6	10	20	19	24	19	24	6.385
13	13	10	5	10	22	24	19	19	6.504
14	13	10	5	10	22	24	19	24	6.445
15	13	10	5	20	19	19	24	19	5.404
16	13	10	5	20	19	19	24	24	5.459

Thickness Variation versus D1, D2, D3, D4, D5, D6, D7, D8 i.e. density of solutions.
The regression equation for thickness variation = - 0.11 + 0.183 D1 - 0.225 D2 - 0.0344 D3 - 0.0054 D4 + 0.194 D5 + 0.102 D6 + 0.0203 D7 - 0.0229 D8 (2)

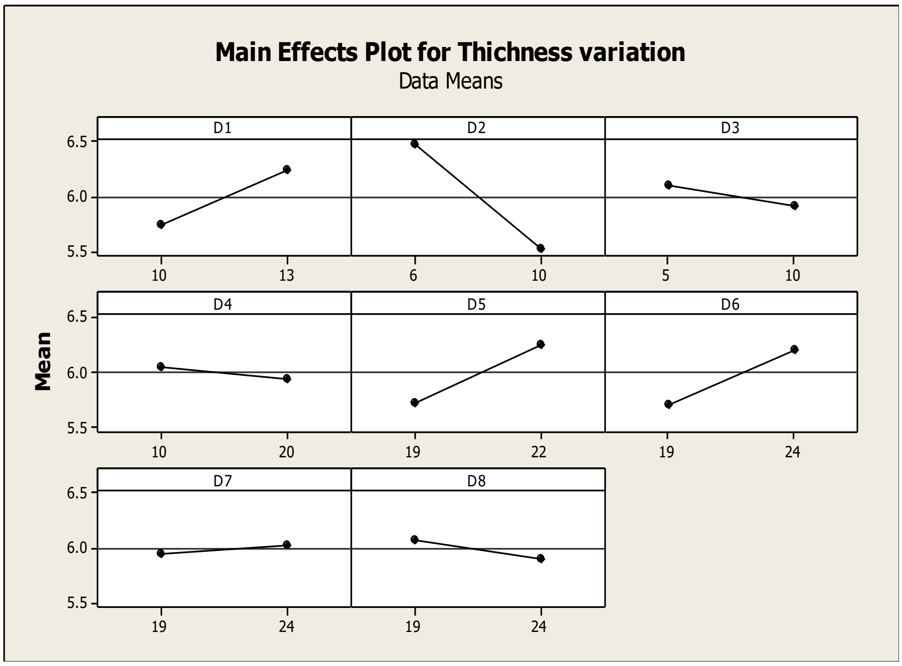

Fig. 4. Main effect plot for thickness variation with density solution

From the main effect plot for effect of density, as shown in figure 4 it is found just like time, with density of solutions cleaning process affect the thickness variation most also in actual plating semi bright and triplex affect the most. Semi bright is base plating layer and triplex is intermediate layer which binds the upper layer with the semi bright layer. At lower density of plating solutions we get minimum thickness variation.

3.2 Optimization

The mathematical model developed with regression analysis is into a MATLAB (R2009a) function and then optimized by GA.
In the objective function f (1) is for thickness variation with time,
function f = singleobjTT(y)
f(1)=1/(1+3.63+(0.225*y(1))-(0.419*y(2)) (0.132*y(3))+(0.007*y(4))+(0.190*y(5))+(0.086*y(6))-(0.087*y(7))-(0.064*y(8))); (3)

In the objective function f (1) is for thickness variation with density,
function f = singleobjDT(y)
f(1)=1/(1-0.11+(0.183*y(1))-(0.225*y(2))-(0.0344*y(3))-(0.0054*y(4))+(0.194*y(5))+(0.102*y(6))+(0.0203*y(7))-(0.0229*y(8))); (4)

Table 4 Details of GA for time and density variation on thickness variation

GA for time variation	GA for density variation
Solver: ga- Genetic Algorithm Fitness function: @singleobjT Number of variables : 08 Lower Bounds: [5,3,2,2,20,3,14,3] Upper Bounds: [8,5,5,3,24,5,16,5] Iteration required: 55	Solver: ga- Genetic Algorithm Fitness function: @singleobjD Number of variables : 08 Lower Bounds: [10,6,5,10,19,19,19,19] Upper Bounds: [13,10,10,20,22,24,24,24] Iteration required: 51

These function was used as input to the GA Toolbox of MATLAB 2009a as the objective function. The upper and lower bounds were specified as per the levels of the parameters and the number of variables was set at 8. The objective function values are obtained for minimum thickness variation. Initial population size of 60 is taken and simple crossover and bitwise mutation with a crossover probability Pc = 0.8, migration interval of 20, migration fraction of 0.2 and Pareto fraction of 0.35 was set for optimization. The details of GA for time and density variation is as shown in table no. 3

According to the algorithm, ranking and sorting of solutions are done and reported in table 5 From the result shown in table optimum value of thickness variation with effect of time is 7.471 µm and for density variation is 7.416 µm. so the effect of time is more dominating for the thickness variation.

Table 5 Details of optimize values

Sr. No.	Factors	Iteration	Degreasing	Anodic	HCL	H_2SO_4	Semibright	Triplex	Bright	Chrome
1	Time	55	7.994	3.019	2.048	2.689	23.997	4.997	14.168	3.082
2	Density	51	12.997	6.088	5.109	12.239	21.99	23.994	23.787	19.064

4 Conclusions

Investigation in nickel-chrome electroplating process is done to study effect of parameters during plating processes on thickness variation. Based on observation following conclusions are drawn:

1. Optimum thickness variation is affected more by time than density of solution
2. Considering time factor, the cleaning process as degreasing and anodic affect more and among the plating semi bright process contributes more to the thickness variation. Thickness variation is less with lower time and it increases with semi bright process time.
3. Considering density factor effect on thickness variation, both cleaning as degreasing and anodic affect thickness variation, anodic affect the most also the semi bright and triplex plating affects with lower density of solutions to lower thickness variation.
4. Most influencing processes during the electroplating that are affecting thickness variation are degreasing, anodic, semi bright, and triplex.

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