Scientific Journal Impact Factor (SJIF): 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

OPTIMIZATION OF NICKEL – CHROMIUM ELECTROPLATING PROCESS FOR CORROSION RESISTANCE USING GENETIC ALGORITHM

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Abstract— Electroplating process holds a good share in plating industries as its gives good results and it is very much cost effective. The process is the continuous sequential high productive process. The electroplating of Nickel- chromium metals finds wide applications. It is used to improve the appearance and life by increasing corrosion resistance, hardness and wear resistance in chemical, electronic, automobile industries. This work is carried out to study the effect of time and density on corrosion resistance. Process parameters are optimized to improve corrosion resistance. In this work, the nickel-chromium plating was done on cold draw electric resistance butt welded steel tubes (CEW) to prepare test workpiece. Taguchi's L16-orthogonal array was used to design experiments with output quality characteristic as corrosion resistance. Regressions modelling method has been used to developed the mathematical model which establishes the relation between input and output parameter. Process parameters were optimized by genetic algorithm (GA) and optimum values are found. It was observed that a time is more dominating factor than a density of the solution.

Keywords— Electroplating, Surface Engineering, Bright Nickel, Semi Bright Nickel Plating, Genetic Algorithm

I. INTRODUCTION

Human life is at ease and comfort due to development in technology. Demand for good quality and durable product at economical rates is increasing day by day. Surface engineering helped a lot for full filling this desire. Generally surface is subjected to wear and tear, due to contact with other parts. Surface properties are more critical because mostly failure propagates from surface. Surface engineering is growing industry as it increases product performance, durability, reliability, reduce cost, control and improvement in surface properties independent of substrate. Surface engineering can introduce the desired properties in the surface such as increasing wear resistance, corrosion resistance, fatigue strength, heat resistance, alter frictional characteristics, rebuilt worm surface, improve aesthetic look of surface. There are different surface engineering techniques to improve properties of surface such as surface treatment by surface hardening, case hardening, mechanical finishing also coating by plating, thermal spray, thin film coating etc. Among different methods electroplating holds a greater share in surface engineering as it is highly productive and most economical method. Specially electroplating of nickel chrome is most widely used almost to 12% world's production of nickel and also chromium is used just for electroplating process. Till now there is no alternative to nickel and chromium plating due to the properties it gives and cost with which it can be carried out. Researchers stated the importance of the process and Optimization of process to find optimum combination of factor for hydrogen evolution in zinc-nickel deposit [1]. Non-Uniform electrodeposition could result in an unevenly deposited coating that cannot meet functional and dimensional requirements. The ability to control the non-uniformity of electro deposition is studied by finding the reasons and effects of various factors on uniformity of coating [2]. Experiments were performed to find out the effects of temperature, current density and time on nickel, copper and hard chromium coating produced by a multiple electroplating process to optimize the process parameters for better yield. [3] Studied the effect of temperature and pressure on nickel electroplating characteristics in supercritical CO_2 on thickness by varying time, temperature, current and density. [4] Researchers found that improving the throwing power of nickel electroplating baths, enhances the rate of deposition [5]. In nickel electroplating the thickness of deposit at the cathode and the distribution of the coating can be controlled by proper racking and placement of the part in solution by using theirs shields and auxiliary anode [6]. The product functions and last longer due to electroplating which has improved the life of product. Still there is scope to improve the process by optimizing the process parameters.

II. EXPERIMENTATION

In this work the experiments were performed as per Taguchie's L 16 orthogonal array and effect of time of different processes and density of liquid solution used on corrosion resistance of plating is investigated. Regression analysis was used to develop mathematical equation which gives relation of dependent variables with the independent variables at different levels. The result of experiment is optimized by genetic algorithm giving best point in the population, approaching an optimal solution.

2.1. Material

The outer tube of shock absorber was selected for experimental work shown in figure no. 1. It is a cylindrical tube of 250 mm in length and 45 mm diameter. It is having a hook welded to it at top.

Figure no.1. Sample Outer Tube of Shock Absorber

The material of tube is cold drawn electric resistance butt welded steel tube which is referred by standard IS-3074: 1979. The content of steel is carbon-0.20 maximum, Mn-0.30-0.60, S-0.60 maximum and P-0.060 maximum Material has good surface finish, superior machinability, good dimensional tolerances and high strength to weight ratio. The plating material deposited on the product is nickel and chromium. Nickel chromium plating has application in various industries such as automobile, chemical, nuclear, telecommunication, consumer electronics and computer.

2.2. Method

Experimentation were carried out in Zumtara Press Chrome Pvt. Ltd., Aurangabad. Experiments were designed with L16 orthogonal array .The electroplating process consists of three steps such as cleaning, rinsing and electroplating. Cleaning is done by mechanical, chemical and electrolytic methods. The rinsing removes the attached solution of initial tank so that it is not carried forward to next processing tanks and it is washed away in rinsing. Michael Faraday in early nineteenth century has developed the basic laws that governs electro deposition. The weight of a material deposited at an electrode is proportional to the amount of current passed through the cell. The complete process is continuous in steps as degreasing, anodic, HCL, H_2SO_4, semi bright, triplex, bright and chrome. These factors are considered for variation of time for each process and density of solution for each step at two different levels and corrosion resistance was measured. Experiment design for time is given in table no.1.

Table no. 1 Experiment design for time variation

Factors	Processes															
	Degreasing		Anodic		HCL		H_2SO_4		Semibright		Triplex		Bright		Chrome	
Levels	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(E)	10	13	6	10	5	10	10	20	19	22	19	24	19	24	19	24

2.3. Corrosion resistance measurement

Corrosion resistance was measured by the salt spray in CASS test unit. This is used as accelerated quantity control tests in which acetic acid and copper-accelerated acetic acid-salt spray a corrosive solution in form of spray or fog. Solution is sprayed on products which are to be tested and placed in fog cabinet at temperature around 50^0C. The time of start of test is noted and after 12 hours, specimens are checked for start of pitting or corrosion spot appearance. If not then after every hour this is checked and start of corrosion after how much hour has started is noted down. The Experimental set for corrosion resistance measurement is as shown in figure no. 2.

Figure no. 2 Salt Spray CASS Test Unit

III. RESULT AND DISSCUSSION

The experiments were carried out in three replicates for more realistic approach by L-16 randomly. The results were analyzed to investigate the effects of time and density parameters at two levels for each step of degreasing, anodic, HCL, H_2SO_4, semi bright, triplex, bright and chrome for electroplating.

3.1 Regression analysis

In Electroplating process, the higher corrosion resistance are considered as better result of plating process. The effect of time and density variation on corrosion resistance is as shown in table no 2 and table no 3 respectively.

Table no. 2 Corrosion resistance with time variation

Trail No.	Actual Factor								Corrosion Resistance
	1	2	3	4	5	6	7	8	
1	5	3	2	2	20	3	14	3	20
2	5	3	2	2	20	3	14	5	18
3	5	3	2	3	24	5	16	3	27.6
4	5	3	2	3	24	5	16	5	18.6
5	5	5	5	2	20	5	16	3	22
6	5	5	5	2	20	5	16	5	18.6
7	5	5	5	3	24	3	14	3	23.3
8	5	5	5	3	24	3	14	5	21.6

9	8	3	5	2	24	3	16	3	23.3
10	8	3	5	2	24	3	16	5	21.6
11	8	3	5	3	20	5	14	3	24
12	8	3	5	3	20	5	14	5	18.3
13	8	5	2	2	24	5	14	3	24.3
14	8	5	2	2	24	5	14	5	22
15	8	5	2	3	20	3	16	3	21.3
16	8	5	2	3	20	3	16	5	20.3

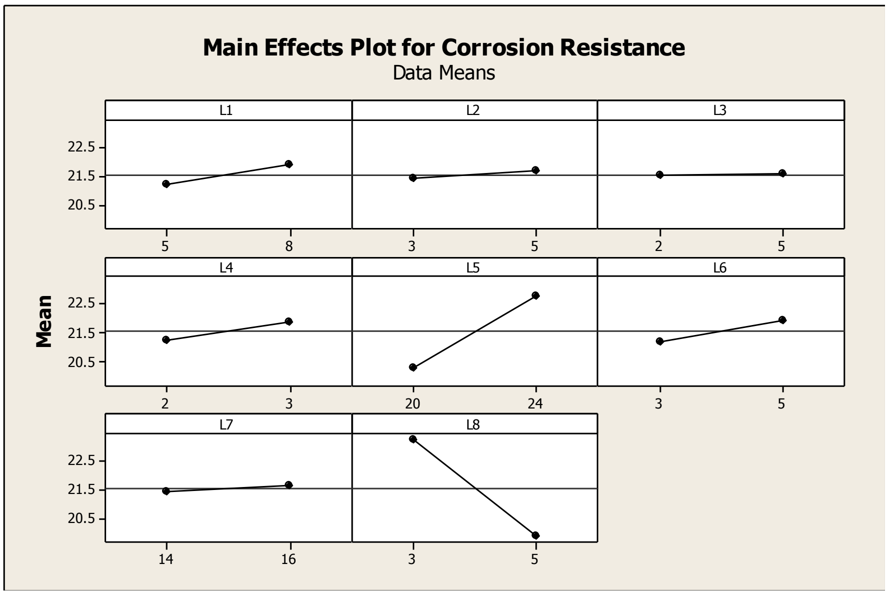

Figure no. 3 Main effect plot for time variation

Corrosion resistance versus L1, L2, L3, L4, L5, L6, L7 and L8 with respect to time.
Corrosion Resistance = 7.8 + 0.225 L1 + 0.125 L2 + 0.025 L3 + 0.650 L4 + 0.619 L5 + 0.375 L6 + 0.113 L7 - 1.67 L8.

Table no. 4 Corrosion Resistance with density of solution

Trail No.	Actual Factor								Corrosion Resistance
	1	2	3	4	5	6	7	8	
1	10	6	10	10	19	24	24	19	21.61
2	10	6	5	10	19	19	19	24	17.93
3	10	6	5	20	22	24	24	19	24.61
4	10	6	5	20	22	24	24	24	21.28
5	10	10	10	10	19	24	24	19	21.02
6	10	10	10	10	19	24	24	24	18.18
7	10	10	10	20	22	19	19	19	24.27
8	10	10	10	20	22	19	19	24	20.41
9	13	6	10	10	22	19	24	19	23.96
10	13	6	10	10	22	19	24	24	20.63
11	13	6	10	20	19	24	19	19	22.59
12	13	6	10	20	19	24	19	24	19.53
13	13	10	5	10	22	24	19	19	24.97
14	13	10	5	10	22	24	19	24	21.41
15	13	10	5	20	19	19	24	19	22.15
16	13	10	5	20	19	19	24	24	19.91

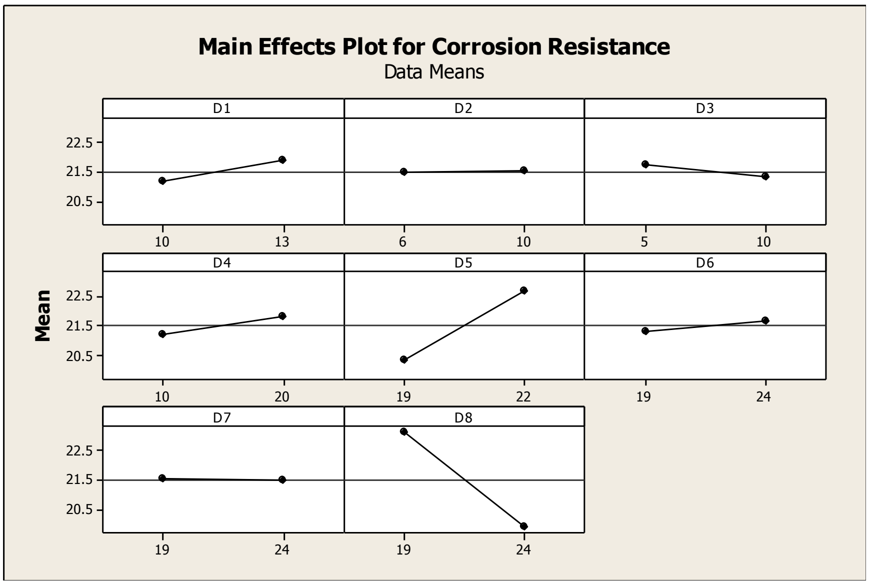

Figure no. 4 Main effect plot for density variation

Corrosion Resistance versus D1, D2, D3, D4, D5, D6, D7, D8 With respect to density of solution.
Corrosion Resistance = 14.6 + 0.236 D1 + 0.0124 D2 - 0.0708 D3 + 0.0609 D4 + 0.785 D5 + 0.0792 D6 - 0.0029 D7 - 0.651 D8

From the main effect plots it was found that the corrosion resistance of electroplating process is more affected by chrome and semi bright for time variation. The degreasing is basic cleaning process. Semi bright and chrome are actual plating processes that are affected with the time of individual process. Also the corrosion resistance is more affected with density of solution and it is found that similar to time there is effect of semi bright and chrome on corrosion resistance. Better corrosion resistance was observed for lower level of density for chrome and higher level of density for semi bright.

3.2. Optimization

Using the developed regression mathematical model, optimization of the process is done using genetic algorithm (GA). The developed mathematical model was converted into a MATLAB (R2009a) function.

In the objective function f (1) is for corrosion resistance with time, function f = singleobjT (x)

```
function f = singleobjT(x)
f(1)=(7.8+(0.225*x(1))+(0.125*x(2))+(0.025*x(3))+(0.650*x(4))+(0.619*x(5))+(0.375
*x(6))+(0.113*x(7))-(1.67*x(8)));
```

In the objective function f (1) is for corrosion resistance with density, function f = singleobjD (x)

```
function f = singleobjD(x)
f(1)=(14.6+(0.236*x(1))+(0.0124*x(2))+(0.0708*x(3))+(0.0609*x(4))+(0.785*x(5))+(0
.0792*x(6))-(0.0029*x(7))-(0.651*x(8)));
```

This function was input to the GA Toolbox of MATLAB 2009a as the objective function. 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 maximization of corrosion resistance. Here, an initial population size of 60 is taken and optimization is carried out by setting 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. The details of GA for time and density variation is as shown in table no. 4

Table No. 4 Details of GA for time and density 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: 61	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: 75

According to the algorithm, ranking and sorting of solutions are done and reported in table no. 5 From the result shown in table optimum value of corrosion resistance with effect of time is 25.776 hr. and for density variation is 25.23 hr. so the effect of time is more dominating for the corrosion resistance.

Table No. 5 Details of Optimize Values

	Factors	Iteration	Degreasing	Anodic	HCL	H_2SO_4	Semibright	Triplex	Bright	Chrome
1	Time	61	5.01	3.003	2.465	2.044	20	3.029	14.068	4.996
2	Density	75	10.131	6.29	9.958	10.02	19.018	19.225	22.814	23.958

IV. CONCLUSION

The effect of parameter on nickel-chromium electroplating process of cold draw electric resistance butt welded steel tubes (CEW) is investigated. Based on observation following conclusions are drawn:

- Electroplating of nickel chrome has wide range of application providing the cheapest surface improvement solution.
- Optimum corrosion resistance is affected more by time than density of solution.
- Considering time factor, the semi bright process contributes more with increase in process time and chrome contributes more for less time, so setting should be accordingly for better corrosion resistance.
- Considering density factor, anodic shows better results for higher density of solution and lower value for chrome for better corrosion resistance.
- Most influencing processes during the electroplating are semi bright, anodic and chrome.

ACKNOWLEDGEMENT

I am very much thankful to Zumtara Press Chrome Pvt. Ltd. for their guidance and support.

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