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EVALUATION AND OPTIMIZATION OF COATING THICKNESS IN NI-CR ELECTROPLATING ON MILD STEEL

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ABSTRACT

The aim of this investigation is to check t the process parameters that affect Ni-Cr electroplating on Mild steel. To evaluate the process three of process factors were selected: the amount of voltage, the time that the voltage is applied, temperature of the process are the factors that were tested. The hypothesis for each factor was developed as: The relation between the time and the thickness of metal coated should be proportional up to 4.1 volts and later on decreases. For a certain time interval, when the thickness of Ni-Cr plating developed on the Mild steel is constant after 19 seconds of time. The thickness of metal deposited also depends almost linearly with respect to process temperature. After a series of experiment following were concluded: Time is proportional to surface thickness and surface thickness also increases with temperature.

KEYWORDS: Electrolyte, Surface Thickness, Time, Temperature, Voltage

1. INTRODUCTION

1.1 The Principle of Electro - Plating

Electroplating is the depositing of positively charged metal particles (ions) moving through a solution by electricity, attracting them onto an object that has been given a negative charge. Using the immersion plating technique, the object to be plated (the cathode) is connected to the negative (-) side of the battery, giving it the negative charge, and a metal plate usually made of the plating metal (the anode) is connected to the positive (+) side of the battery, giving it a positive charge. Positive ions flow from the anode toward the object being plated, through the plating solution (the electrolyte), and are deposited onto the surface of the object. The longer the system is left on, the thicker the resulting plate will be. The Nickel Plate is the hard protective layer, and is really the ultimate performance of a chrome plate. It is this nickel you usually see peeling from an old bumper. As this is a hard metal, it is more difficult to polish or burnish, and so it is essential that all blemishes and repairs are done before this stage. Nickel, given time and the elements, will dull down, giving a flat almost leaden look. It can often easily be brought back to life with a little chrome polish, but it is for this reason that chrome is applied.

Decorative Chrome plate is a very thin layer of plate. It can be applied directly to many metals, but it is extremely porous and will allow the part to rust through in next to no time. Only by providing adequate under layers of copper and or nickel, will this be avoided.

2. LITERATURE REVIEW

[1] Hassan Karami, Hamid Babaei, work shows a full study of the pulse electroplating of cobalt hard gold on a

nickel substrate. The study influences the electro deposition variables on the surface morphology, particles sizes, film composition, mechanical characteristics and electrochemical behaviors of the deposited layer. The obtained results indicate that under the optimized conditions for pulse electroplating. Effective factors such as morphology, hardness and corrosion behavior can be evaluated. [2] M. Yavorska, J. Sieniawski, study the oxidation resistance of platinum modified aluminide coating deposited by CVD method on nickel super alloys under atmosphere was evaluated. The increase of platinum thickness to get a greater surface roughness parameter of aluminide coatings. On the ground of the obtained results, it was found that platinum modification of aluminide coatings provides to increase of oxidation resistance Ni-based substrates and are widely used for turbine blades.[3] Oluwole O., Garus-Alaka W. Ajide, O.O**.** investigate the corrosion resistance characteristics of electroplated Medium Carbon Steel (MCS). The plated and unplated MCS were exposed to sodium carbonate environment for 360 hours. The weight loss was taken every 24 hours in order to estimate corrosion penetration rate (CPR). The results obtained showed that plated MCS generally showed a better corrosion resistance than the unplated one Nickel and Gold plated medium carbon steels are found to be both reliable materials for decorative objects applications in sodium carbonate environment.[4] SiamakAkhlaghi and Douglas G. Ivey, investigates the electroplating solution stability along with the effect of agitation and temperature on the electroplating process was studied.[5] S. Rekha, P.A.Jeeva, D. Kumaran, S.Karthikeyan, K. N. Srinivasan, Electrolysis copper deposition: An Experimental and Theoretical approach, In this investigation, theorem and few of its derivatives were used as stabilizers. The role of action of these compounds on the rate of electro less copper plating has been studied by weight gain.The results of weight gain studies for the electroless copper plating in the presence and absence of thiourea derivatives.[6] T. J. Tuaweri, E.M. Adigio and P. P. Jombo, A Study of Process Parameters for Zinc Electro deposition from a Sulphate Bath. Cathode current efficiency and deposit thickness were determined by weight measurement method. Influence of current density on the deposition process was also investigated. **Summary on Literature review**: The literature survey of the above papers are provides the electroplating and various evaluation tests performed on mild steel specimens. In this study it is noticed that the variation of the parameters such as voltage, time and temperature which effects the coating thickness in Ni-Cr electroplating.

3. EXPERIMENTATION

3.1 Process Steps in Electroplating

The performance of electroplating process depends on the accuracy of the process activities. The following are the process activities involved in electroplating process.

3.1.1 HCL Dip

About 60-70% concentrated HCL, as shown in Figure 3.1 is used for removal of Mill scale (hot-rolled scale) developed during hot forming of metal, Scale developed during welding, Scale developed during heat treating. Superficial oxide which interferes with painting, porcelain enameling, Rust and corrosion products, Proteinase deposits, Hard water scale, Products of reaction of hard water with soil, especially protein and work piece and is now washed with water after the HCL dip.

Figure 3.1: HCL Dip

Figure 3.2: Degreasing Water

Figure 3.3: Wire Brush Cleaning

3.1.2 Degreasing Water Clean

Degreasing is another primary cleaning operation. But for any further surface finishing to be done properly, removal of the film left by degreasing is required. At the same time, you should recognize that, while degreasing is an excellent in-process step and while you may get proper surface preparation in the alkaline cleaner station, as shown in Figure 2.

3.1.3 Wire Brush Cleaning

After HCL dip, now work piece is subjected to low grade wire brush as shown in Figure 3.3 it is used to remove the traces of residues and particles.

3.1.4 Buffing

Buffing is finishing processes for smoothing a work piece's surface using an abrasive and a work wheel or a leather strop. Buffing uses a loose abrasive applied to the work wheel. Buffing is less harsh, which leads to a smoother, brighter finish. Most mirror bright finishes are actually buffed. Buffing there are two types of buffing motions: the *cut motion* and the *color motion*. The cut motion is designed to give a uniform, smooth, semi-bright surface finish. This is achieved by moving the work piece against the rotation of the buffing wheel, while using medium to hard pressure. The color motion gives a clean, bright, shiny surface finish. This is achieved by moving the work piece with the rotation of the buffing wheel, while using medium to light pressure.

Buffing wheels, also known as mops, are either made from cotton or wool cloth and bleached or unbleached. Specific types include: sisal, spiral sewn, loose cotton, canton flannel, domet flannel, denim, treated spiral sewn, cushion, treated vented, untreated vented, string buff, finger buff, sisal rope, mushroom, facer, tampered, scrubbing mushroom, hourglass buffet etc.,

3.1.5 Carbon Powder Cleaning

In this the carbon ash is used to clean the work piece for the removal of oil traces present on it. The work piece after buffing is subjected to carbon powder wash to remove oil traces if any, Equally the carbon ash is spread over the work piece with a cloth and it is then cleaned. otherwise it effects the electrolyte solution.

3.1.6 HCL and Distilled Water Bath

Now before placing the work piece in electroplating bath, the work piece is cleaned with HCL bath and then with distilled water.

3.1.7 Electro Plating

Now after performing all the above steps, the work piece is knotted with a copper wire and is connected to the cathode rod, which is dipped in the solution for plating.

The work piece is subjected to following plating process:

- Nickel plating
- Chromium plating

3.1.8 Smoothing (Polishing)

Smoothing is a finer buffing for a smooth surface finish. Smoothing is done by changing the buffing wheels with a fine smooth layer. Used for light cutting and for coloring. A superior grade of fine cotton sheeting held together with two or more circles of lockstitch sewing. Gives a resilient, cushioned effect when in use. Smoothing can also be as a final surface finishing.

3.2 Preparation

3.2.1 Preparation of Specimen

Initially mild steel of size 100x60 x 50 mm is cut from the mild steel flat by using cutting machine. It is then grind for neat surface edges in order to connect the mild steel work piece to the cathode rod we have make a hole so the work piece is subjected to drilling process. After HCL dip the initial thickness of the work piece is measured by using digital vernier callipers

3.2.2 Preparation of Nickel Electrolyte

Electrolyte solutions are a mixture of the following and its preparation and constituents are as shown in Figure 3.4.

- **Ni Salt:** Nickel salt which is in the powder form is used as the primary constituent in the preparation of electrolyte solution. 3 kg of Ni salt is used ideally on commercial scale.
- **Ni Additive:** Nickel additive is brightener which is added for a bright surface finish of the work piece.
- **Ni Spectra:** Nickel Spectra is a performance enhancer. It speeds up the brightness of the specimen.
- **Water:** To form a solution, water is basic constituent. 15 lts of water is added on commercial scale.

3.2.3 Nickel Plating

After conducting all the tests on the work piece like (HCL dip, buffing, carbon powder cleaning). Now the work piece is subjected to nickel plating. The work piece is connected to a copper wire and is placed in the tank which consists of nickel chloride solution as electrolyte with anode and cathode in it. Anode is the nickel and work piece is tied to the cathode rod. The D.C current is passed into it. The equipment used in plating are single phase rectifier, heater, filter, air agitator. Filter and air agitator are used for finishing.

Due to electrolysis respective reactions take place:

At Anode: Ni(s) ->$Ni^{2+} + 2e^{-}$

At Cathode: $Ni^{2+} + 2e^{-}$ --> Ni(S)

By considering various parameters like voltage, time, temperature we have to evaluate plating thickness. Therefore by conducting experiment at different values the surface thickness is high at which values can be found out. The experiment has been proceeded for various values.

Initially the voltage is set at 3.5V and the series of experiments are conducted for varying voltages of 3.8V, 4.1V, 4.4V, 4.7V. The process is carried out as follows:

- The work piece is with distilled water and then it is tied to the copper wire.
- Now the specimen which is tied to the copper wire is dipped in the nickel electrolyte, which acts as cathode.
- After dipping the specimen in the electrolyte, now the filter is kept on. The main use of electrolyte is to filter the electrolyte i.e. which removes the dust particles from the electrolyte.
- The heater is kept in on position to heat the electrolyte to the required temperature.
- In the next step air agitation is kept on which gives shiny look to specimen.
- Now the voltage is adjusted to the required voltage by the voltage regulator.
- After the plating is completed the specimen is taken out from the electrolyte and washed with normal water and

dried in the sun.

Figure 3.4: Nickel Plating Set Up

The same procedure is carried out for different temperatures (i.e. 31°C, 33°C, 35°C, 37°C and 39°C) and at varying time intervals (i.e. 15 min, 17 min, 19 min, 21 min and 23 min).

After nickel plating the piece is placed in distilled water and then cleaned with normal water. Now to get desired visual appearance it is subjected to chromium plating.

3.2.4 Chromium Plating

In chromium plating the electrolyte used is chromic salt which speed up the process. The cathode used is Ni plated piece and the anode used is chromium. Hence, the cathode is placed in the tank and the anode is moved around the work piece for 10 seconds while the current is supplied. The respective reactions take place as follows:

Anode mass decreases: $Cr_{(s)} \rightarrow Cr^{3+}_{(aq)} + 3e^-$

Cathode mass increases: $Cr^{3+}_{(aq)} + 3e^- \rightarrow Cr_{(s)}$

Generally the chromium plating is a short process. It is carried out as following: as shown in Figure 3.7.

- The work piece taken after Nickel electroplating is washed with water.
- Now it is attached to the cathode by means of a copper wire as shown in Figure 3.5.
- The work piece is dipped into the electrolyte when the current is supplied for a time span of 5-8 seconds.
- Now the work piece is removed and cleaned with water and now it appears with a bluish tint, which is visually pleasing, as shown in Figure 3.6.

Figure 3.5: Chromium Plating

Figure 3.6: Specimen after Ni-Cr Plating

3.3 MEASUREMENT

After conducting experiment at different values, the amount of metal deposition rate and surface thickness is high at which values can be found out. The experiment has been preceded for various values.

The amount of coating thickness is measured using:

- Digital Vernier callipers

3.3.1 Digital Vernier Callipers

Digital callipers (sometimes also called Digital Vernier Callipers) are a precision tool. It measures internal and external distances accurately. The examples shows below distance measurement are read from LCD display. Earlier versions of this type of measuring instrument had to be read by looking at the analogue dial. Digital callipers are provided with digital dial, which gives accurate measurement.Ordinary 6-in/150-mm digital calipers are made of stainless steel, have a rated accuracy of 0.02mm and resolution of 0.01 mm. The same technology is used to make longer 8-in and 12-in calipers; the accuracy for bigger measurements declines to 0.03 mm for 100–200 mm and0.04 mm for 200–300 mm.

Figure 3.7: Measuring with Digital Vernier Calipers

The thickness is measured at the center of each piece as shown in as shown in Fig.3.7 and readings are tabulated. The difference in the final and initial values gives the surface thickness increased. From these values the respective graphs are drawn.

4. RESULT & DISCUSSIONS

4.1 Detail of Experiments Conducted for Investigation

The series of experiment are conducted as mentioned in the Table 1.The measurements of output parameters are also tabulated in the same table and the graphs are developed with the respective output values. For Ni-Cr plating metal deposition rate and plating thickness are developed by considering voltage, temperature and time are the input parameters.

Table 4.1: Detail of Experiments Conducted for Investigation

Specimen No.	Temperate (°C)	Voltage (V)	Time (min)	Thickness without Plating (mm)	Thickness with Plating (mm)	Plating Thickness (mm)
1	35	3.5	19	5.51	5.59	0.08
2	35	3.8	19	5.61	5.70	0.09
3	35	4.1	19	5.48	5.57	0.09
4	35	4.4	19	5.47	5.54	0.07
5	35	4.7	19	5.58	5.66	0.08
6	35	4.1	15	5.59	5.67	0.08
7	35	4.1	17	5.55	5.61	0.06
8	35	4.1	21	5.57	5.64	0.07
9	35	4.1	23	5.63	5.71	0.08
10	31	4.1	19	5.55	5.62	0.07
11	33	4.1	19	5.55	5.61	0.06
12	37	4.1	19	5.56	5.66	0.10
13	39	4.1	19	5.48	5.57	0.09

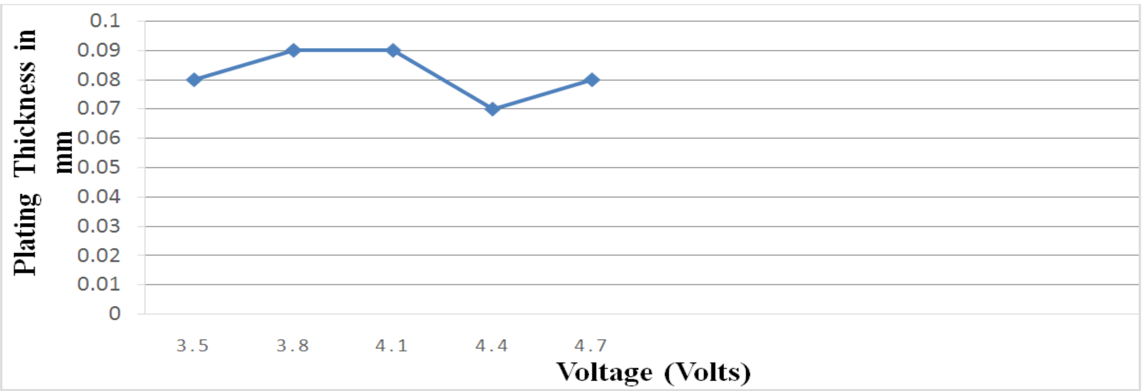
4.2 Effect of Voltage on the Plating Thickness

The series of experiments were conducted to investigate the influence of voltage in Ni-Cr plating. To evaluate the time and temperatures are kept constant and the voltage is varying from 3.5 to 4.7 volts. The change in output values are tabulated and detailed in Table 2.

Table 4.2: Influence of Voltage on Process Characterization

Specimen No.	Voltage (V)	Time (Min)	Temperature (°C)	Plating Thickness (mm)
1	3.5	19	35	0.08
2	3.8	19	35	0.09
3	4.1	19	35	0.09
4	4.4	19	35	0.07
5	4.7	19	35	0.08

The Table 4.2 readings are used to plot a graph between thickness and voltage of the Ni-Cr plating process. Thickness is plotted on y- axis and voltage is marked in x-axis and values are plotted gives in the Graph 4.1.



Graph 4.1 Plating Thickness VS Voltage

From the graph, it is concluded that the thickness is maximum at 4.1 volts and it starts gradually decreasing thereafter.

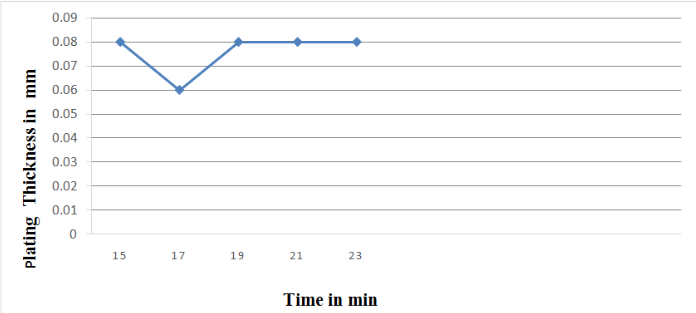
4.3 Effect of Process time on the Plating Thickness

The series of experiments were conducted to investigate the influence of time in Ni-Cr plating. To evaluate the voltage and temperatures are kept constant and the time is varying from 15 to 21 minutes. The change in output values are tabulated and detailed in Table 4.3.

Table 4.3: Influence of Time on Process Characterization

Specimen No.	Voltage (v)	Time (min)	Temperature (°c)	Plating Thickness (mm)
6	4.1	15	35	0.08
7	4.1	17	35	0.06
3	4.1	19	35	0.09
8	4.1	21	35	0.07
9	4.1	23	35	0.08

The Table 4.3 readings are used to plot a graph between Plating thickness and time of the Ni-Cr plating process. Plating thickness is plotted on y- axis and time is marked in x-axis and values are plotted gives in the Graph 4.2



Graph 4.2: Plating Thickness VS Time

From the above graph, it is observed that plating thickness varies upto some extent and it remains constant for a certain time interval.

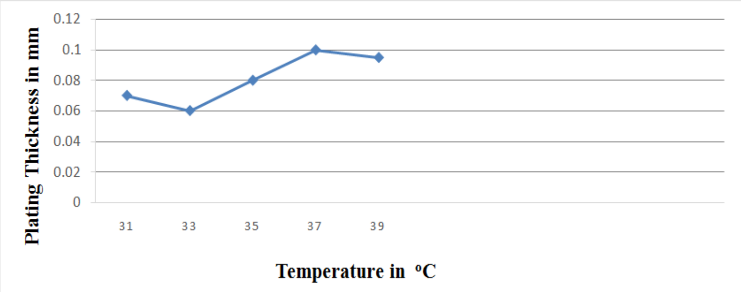
4.4 Effect of Temperature on the Plating Thickness

The series of experiments were conducted to investigate the influence of temperature in Ni-Cr plating. To evaluate the voltage and time are kept constant and the temperature is varying from 31 to 39°C. The change in output values are tabulated and detailed in Table 4.

Table 4.4: Influence of Temperature on Process Characterization

Specimen No.	Voltage (V)	Time (Min)	Temperature (°C)	Plating Thickness (mm)
10	4.1	19	31	0.07
11	4.1	19	33	0.06
3	4.1	19	35	0.09
12	4.1	19	37	0.10
13	4.1	19	39	0.09

The Table 4.4 readings are used to plot a graph between Plating thickness and temperature of the Ni-Cr plating process. Plating thickness is plotted on y- axis and temperature is marked in x-axis and values are plotted gives in the Graph 4.3.



Graph 4.3: Plating Thickness VS Temperature

From the graph, it is concluded that if the temperature applied to the electrolytic cell is increased then the plating thickness of Ni-Cr metal is increases.

5. CONCLUSIONS & FUTURE SCOPE OF WORK

5.1 Conclusions

Mild steel flat of size 100 x 60 x 50 mm are successfully plated with Ni and Cr electroplating. On Experimentation the following conclusions are obtained from the process with respect to plating thickness. The surface thickness is maximum at 4.1 volts and from there after the thickness starts decreasing gradually. The surface thickness varies up to some extent with respect to time and from 19 minutes the thickness remains constant. The surface thickness almost increases with increase in temperature.

5.2 Future Scope of Work

Surface roughness analysis can also performed on these is specimen to observe the variations in the surface finish on specimens with the change in process parameters.

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