Abstract

Galvanic plating in engineering. Development of technology for triple-layer nickel coatings on steel parts.

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The project has developed a technology for applying protective and decorative triple-layer nickel coating for the protection of steel parts from corrosion.As a part of the machine was considered a steel handle with a diameter of 40 mm and a length of 1000 mm. Operating conditions of the parts are moderate. In order to protect parts from corrosion in moderate conditions, the coating was selected with thickness of 15 µm.

The preliminary treatment of the surface of the metal plays one of the main roles when we precipitate the electroplating on any part of machine.

For qualitative coating it is necessary to ensure a good adhesion of the based metal with nickel coating, for this purpose, the based metal is cleaned from living contaminants.In that cause carry out an degreasing operation. For more effective removal of fatty contaminants the process is carried out electrochemically.

The rate of degreasing of parts on the cathode is greater than at the anode. This is due to the fact that the volume of released hydrogen is greater than the volume of oxygen, and hydrogen bubbles are smaller than bubbles of oxygen, and better delayed on the surface of oil droplets, and therefore the removal of oil is more effective.

The degreasing is followed by a reaction:

$$K: 4H_2O + 4e^- = 2H_2 + 4OH^-$$

$$A: 4OH^- = O_2 + 2H_2O + 4e^-$$

$$2H_2O = 2H_2 + O_2$$

We degrease in a solution of the following composition, g/l:

$NaOH$	10 – 20
Na_3PO_4	30 – 50
Na_2CO_3	10 – 20

Conditionsofelectrolysis:

time of cathode period - 3 minutes

time of the anode period - 1 minutes

current density is 5-10 A / dm^2

temperature - 60-70^{0}C

To remove rust and oxides from the surface of the metal, carry out an etching operation. This is a chemical dissolution of metal oxidation products in solutions of acids or alkalis. For etching of steel parts a solution of composition g/l is used:

HCl	200-250
Urotropin	3-5

temperature: t = 18-25 ˚C.

processingtime: 5-20 minutes.

Immediately before coating the products are activated in solution, g/l:

H_2SO_4	50-100

temperature: t = 18-25 ˚C

processingtime: 0,5-1 minutes.

Wash operations. Purpose of the wash is a qualitative removal from the surface of the details of solutions and products of previous operations.Rinse water can be cold, warm (49-59^{0}C) and hot (60-90^{0}C). Warm water is used after the degreasing operation. Hot water is used only before drying.

To reduce the removal of the electrolyte, rinsing in the catching bath is carried out. The water from the catching bath is used to fill the main production bath. Rinses are made in stationary baths with cold running water. It is used tap water from the city network.

Electrolytes of nickel are divided into complex and simple. Complex electrolytes are more often used for the production of alloys. And simple ones are used in obtaining one-, two- and three-layer coating.

Simple electrolytes of nickel are divided into: sulfate, sulfamate, chloride, silicon-fluoride, hydrofluoric.

The most common are electrolytes based on nickel sulfate $NiSO_4.7H_2O$ because this salt is well soluble in water up to 400 g/l. To reduce the passivation of the anodes in such electrolytes are added alkali metal salts - sodium chlorides, calcium rarer. In many cases nickel chloride $NiCl_2.6H_2O$ is used as an anode activator in nickel sulfate electrolyte. These electrolytes are called Watson electrolytes.

Quite often in electrolytes of nickel as a buffer additive boric acid H_3BO_3 is used. In electrolytes with low pH, more effective buffers are added - NaF and other compounds..

To increase the electrical conductivity in solutions, sodium sulfate, or magnesium sulfate, may be injected, especially in solutions with a low concentration of nickel sulfate (150 - 200 g/l). In the presence of magnesium, more plastic precipitates are formed and the electrolyte dissipating ability is greater. The cathode current of nickel in sulfate electrolytes is within 90 ... 100%.

For stable bath work it is necessary to maintain a constant composition of the electrolyte, accordingly it is necessary to add nickel sulfate, boric acid and chlorides in the bath. The maintenance of a stable pH of the electrolyte occurs by introducing a 3% solution of NaOH or H_2SO_4.

From ordinary electrolytes, matt precipitates are obtained. To give them a decorative look, they are polished. The polishing process is very laborious and expensive. Also, when polishing, about 20% of nickel is lost, which goes to cover. To polish it is necessary to use expensive and scarce equipment: felt and cotton wheels, chrome mastic.

For the formation of shiny precipitates directly in the process of electrolysis in the electrolyte are introduced special additives-shiny agents.

When we talk about multilayer protective and decorative coatings, electrochemically precipitated nickel is used as the main layer, which combines both protective and decorative qualities. In relation to iron, nickel has a less electronegative potential and therefore protects iron only mechanically if coating has a considerable thickness of the layer and is continuous.

Nickel is well stable in the air due to its ability to passivation, and it is also not active in relation to alkalis and acids. If we talk about shiny nickel his corrosion resistance is inferior to matte nickel due to less chemical resistance in atmospheric conditions, since shiny nickel coatings contain in their composition the inclusion of sulfur S, which is always included in the precipitate by introduction into the electrolytes of shiny additives. Sulfur inclusions shifts the nickel potential toward a more negative value.

To increase the corrosion resistance of shiny nickel coatings, systems of corrosion-resistant, shiny combined coatings have been developed, which include coatings: bi-nickel, tri-nickel, sil-nickel.

The coating of bi-nickel is characterized by a double nickel layer in which the first layer, semi-shiny, does not contain sulfur. The second layer, shiny, more fragile, contains sulfur in its composition and has a striped structure.

Since nickel is a cathodic coating in relation to steel and can protect steel from corrosion only under conditions that pores are absenced , in comparison with single-layer nickel coating, the three-layer nickel coating is more effective. When applied three-layer nickel coating there is an overlap of pores and accordingly, increases the level of protection of the metal base from the corrosive effects of the medium. The difference in such coating is that the nickel is applied galvanically from three different composition of the electrolytes, with introduced various additives.

The first – matte layer of nickel was formed in an electrolyte of the following composition, g/l:

$NiSO_4 \cdot 7H_2O$	250-300
H_3BO_3	30-40
$NiCl_2 \cdot 6H_2O$	40-60
NitecNetzmittel	3ml/l

The second layer of nickel, which has an increased content of sulfur, was formed in an electrolyte of the following composition, g/l:

$NiSO_4 \cdot 7H_2O$	280-300
H_3BO_3	35-45
para-aminobenzenesulphamide	0,1–0,15
$NiCl_2 \cdot 6H_2O$	40-60
saccharin	0,5 – 0,6

The third glossy layer of nickel was applied from an electrolyte of the following composition, g/l:

$NiSO_4 \cdot 7H_2O$	250-300
H_3BO_3	30-40
1,4 butyndiol	0,12-0,2
$NiCl_2 \cdot 6H_2O$	40-60
saccharin	1,5 – 2,5

Conditionsofelectrolysis:

temperature50-60 ^oC;

densitycathode current2-6 A/dm^2;

pH4,5-5,5;

Cathodic efficiencyis 96%.

After finishing the coating and washing operations, the technologist conducts coating control. The quality of the resulting coating must meet the requirements of GOST 9.301-86. The control of the appearance of the resulting coating is made visually in 100% of the parts or under a microscope. The coating should have good adhesion to the metal base, there should be no peeling, splinters, swollen or dendrites, roughness, pitting and cracking.

The method of determining the porosity is based on the interaction of certain reagents through the pores with the metal base, resulting in well-marked reaction products are formed in a certain color, which differs from the color of the coating.

The thickness control of the coating is carried out by X-ray spectroscopy.

Control of thickness and porosity is carried out for 0,1-1% of products, but not less than 7.

For the execution of an annual program of 10 600 m^2, a steel bath with a lining size of 1250x710x1600 mm is selected. The bath is equipped with on-board ventilation, electric heater, drain valve. The amperage in the bath is 776,826 A, the voltage is 3,29 V. To maintain the thermal regime, there are 6 heaters of 10 kW each.

Since in this production waste water is acid-alkaline and metal-containing for sewage treatment, choose a reagent method. It is based on oxidation, regeneration, neutralization, coagulation and precipitation of various components of effluents. The reagent method of sewage treatment makes it possible to reduce the concentration of harmful substances in the drains to the level of their MPC. As a result of wastewater treatment toxic substances are destroyed with the formation of new low-toxic compounds, which are removed together with the sediment.

The reagent method has several advantages: the possibility of processing wastewater with a complex composition of impurities; low sensitivity to organic compounds, mechanical contamination, ease of operation of equipment.

At the first stage there is a mutual chemical neutralization of acid and alkaline effluents:

$$H^{+} + OH^{-} = H_2O$$

Neutralization of free mineral acids is achieved by the addition of alkaline soluble in water. When discharging sewage into a city sewage system, mixtures with acidity of 6.5 - 7.5 are considered neutral.

Cleaning from heavy metal ions occurs in the same way as neutralizing acid and alkaline effluents, with heavy metal ions converted into difficult soluble hydroxides that fall into the sediment:

$$Me^{2+} + 2OH^{-} = Me(OH)_2 \downarrow$$

$$Me^{3+} + 3OH^{-} = Me(OH)_3 \downarrow$$

Reagent clearing of waste water from heavy metal ions consists of two stages:

1. Formation of difficult soluble metal compounds;

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Coagulants (most commonly aluminum or iron compounds) and flocculants (high molecular weight organic substances, such as polyacrylamides) are added to the purified water to accelerate the processes of coagulation and sedimentation of dispersed particles. After defending the precipitate (sludge) is separated from the solutions, dehydrated and sent for recycling.

The advantage of the reagent method is the ease of operation and the ability to automate the continuous treatment of wastewater from harmful substances to their level of MAC.

Technological process of sewage treatment

1) Sewage water after washing baths containing nickel Ni^{2+} ions is treated with a solution of NaOH in the reactor (pH = 10), resulting in the transfer of nickel to the slightly soluble hydroxide, which is separated on the filter press.

2) After the press-release, the waste water enters the reactor, which feeds the shredded lime to convert the boric acid into calcium tetraborate which is separated on the filter press together with calcium sulfates and phosphates.

3) The formed liquid enters the capacitance neutralizer, where the alkaline and sour drains after the van dehydration and etching come in, to set the pH that provides the formation of hydroxides. The pH value should be within the range of 7-8. If necessary, acidification of the solution in it add 10% solution of H_2SO_4. The acid is stored in a bottle with a plastic casing.

4) Now the drains are passed through several filters (a press filter that captures colloidal particles, formed hydroxides, and a carbon filter that adsorbs organic matter - saccharin and other additives).

5) Final stage is desalting installation of reverse osmosis, after which purified water is again in electrochemical production.

To optimize the process of applying triple-layer nickel coatings, reduce manual labor costs, and strictly adhere to the rules of the technological process, the bath is equipped with an automatic control and regulation system.

The main parameters associated with the debugging of the automatic line are:

- temperature;
- acidity of the electrolyte;
- the level of electrolyte in the bath;
- amperage and voltage in the bath.

Scheme of automation involves measurement, automatic control and registration of these parameters.

In the economic-organizational calculations the department was calculated as an object of the economy: the optimal type of movement of labor objects, the number of employees and their schedule, the technical and economic indicators of production were calculated:

annual output 10 812 m^2/year;

value of fixed assets	1 552 000 UAH
the cost of working capital	2 464 437,69 UAH
investment	4 016 437,69 UAH
price	640UAH/ m^2
profitability	30,61%
period of return of investments	3,31years

According to the results of calculating the economic parameters, an enterprise was created for the application of protective and decorative coating of triple-layer nickel coating on steel parts (handrails). During the calculations, it was found that the company is profitable and economical. Period of return of investments is 3,31 years that indicates the demand in the market of goods and their competitiveness.

Keywords: galvanic coating, triple-layer nickel, Watson's electrolyte, shiny nickel plating, technological card, galvanic bath, current source, current density, automation scheme, wastewater cleansing, corrosion.