Investigation of a nickel coating deposition processes from solid nickel electrolyte

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Abstract. Nickel is the basis of most of the heat-resistant materials used in the aerospace industry for power plant parts. Recently, the method of electrolytic coating with nickel is used to create protective coatings on aluminum, magnesium, zinc and cast irons. It is known to use the method of nickel plating of aluminum and magnesium alloys, in particular to protect the duralumin blades of screw aircraft. The lifetime of nickel-plated cast-iron drums for drying in paper production is significantly higher than in conventional cast iron, and paper quality is also improving. The aim of the work is to influence the concentration of hypophosphite on the kinetics of the cathode process and on the properties of the resulting nickel coating.

To increase the wear resistance of rubbing surfaces of parts and to restore their dimensions, hard nickel plating is often used. Nickel coatings have less hardness than chromium plating and have the following advantages: they are relatively easy to process, have a high viscosity with a layer thickness of up to 2 mm; the coefficient of nickel linear expansion is close to the coefficient of steel linear expansion, while in chromium it is several times higher. For solid nickel plating, the power of direct current sources is 3 to 4 times lower than for chromium plating, and the energy consumption is about 20 times less. In the paper, the task is to find a technique for obtaining a nickel coating on properties not inferior to chromium plating.

The following composition was chosen as the electrolyte of solid nickel plating (g/l): $NiSO_4 \cdot 7H_2O$ - 250; $NiCl_2 \cdot 6H_2O$ -50; H_3BO_3 -40; $NaH_2PO_2 \cdot 2H_2O - 25$. This composition is usually used to apply the top layer of a bi-nickel coating. It is interesting to determine the influence of hypophosphite concentration on the kinetics of the cathodic process and on the properties of the coating.
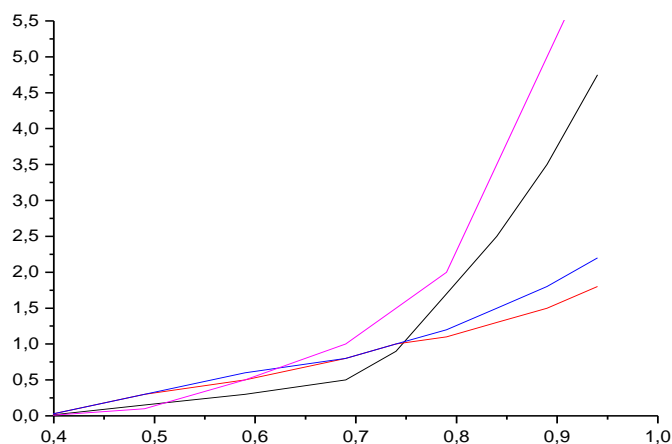
Figure 1. Cathodic polarized curves (CPC) in the electrolyte of solid nickel plating (g/l): $NiSO_4 \cdot 7H_2O$ -250; $NiCl_2 \cdot 6H_2O$ 50; H_3BO_3 -40; at concentration NaH_2PO_2 (g/l): 1-7; II -15; III-25 at a temperature 25 ^{O}C and pH=1,8.

Figure 1 shows the total cathodic polarized curves in the potentiodynamic regime at various concentrations of sodium hypophosphite. As can be seen from the CPC, the introduction of sodium hypophosphite into the electrolyte leads to a decrease in the polarization of the electrode. And the speed of the cathode process in the potential range 0.4-0.85 V varies sympathetically the concentration of hypophosphite. Depolarization of the cathodic process in the presence of sodium hypophosphite in the electrolyte can be explained, according to the literature data, by the flow on the cathode of two independent electrochemical reactions: discharge of nickel ions $Ni^{2+}+2\bar{e} \rightarrow Ni$ and restoration of phosphorus donors $H_3PO_2^-+H^++\bar{e} \rightarrow P+2H_2O$ or an anion of hypophosphite $H_3PO_2^-+2H^++\bar{e} \rightarrow P+2H_2O$. This mechanism of the process is confirmed by the data presented in Figure 2.
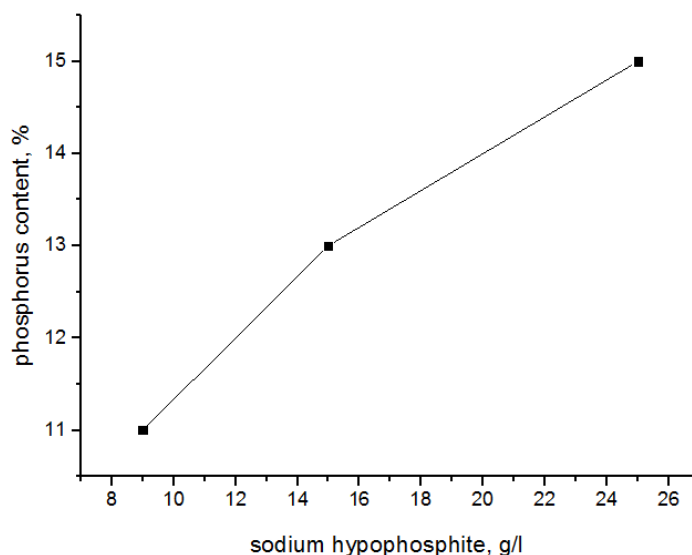

Figure 2. Dependence of the phosphorus content in the cathode deposit on the concentration of NaH_2PO_2 in the electrolyte of solid nickel plating.

It follows from Fig. 2. that an increase in the concentration of sodium hypophosphite leads to an increase in the phosphorus content in the nickel-phosphorus alloy. With a current density of more than 2.5 A / dm2 on the CPC (Figure 1), a limit current area appears, associated with a decrease in the concentration of hypophosphite in the near cathode space (NCS). The temperature of the

electrolyte is one of the most important factors affecting the electrodeposition of nickel from the nickel-hypophosphite electrolyte.
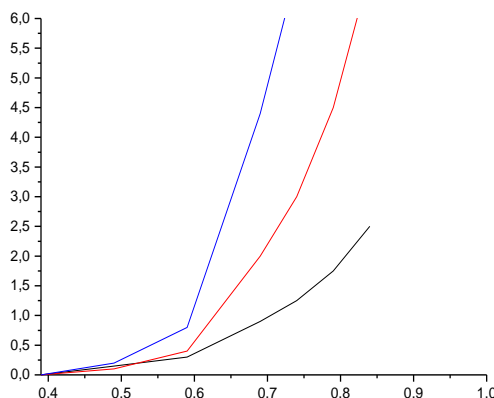

Figure 3. Cathode polarized curves in electrolyte of solid nickel at temperatures (^{O}C): I-25; 2-45; 3-65.

From the CPC shown in Figure 3, we see a decrease in the polarization of the cathodic process as the temperature of the electrolyte increases. This may depend on the reduction of the concentration limitations of electrode processes due to the enhancement of the discharging ions diffusion. Установлено, что качественные никель-фосфатные осадки получаются при температуре электролита 50° и более. It is established that qualitative nickel-phosphate precipitates are obtained at an electrolyte temperature of 50 ° and more. The current yield of nickel under these conditions is 85-88%, however, it is impossible to exclude the imposition of non-current processes on the main electrochemical reactions according to the equations: $H_2PO_2^- + H_2O = H_3PO_2^- + H_2$ and $2H_2PO_2^- = H_2PO_3 + P + OH^- + H$. The influence of electrolyte mixing on the coating quality was also studied. When moving, ion diffusion accelerates to the electrode, the solution and acid composition in the NCS are equalized, and galvanic precipitation is uniform in thickness and appearance.

The   working capacity or amount of passed electricity (Q) is a criterion for the life of the electrolyte. The electrolyte of solid nickel plating is determined by the concentration of ions Ni^{2+} $H_2PO_2^-$. As the Q increases, the acidity of the solution decreases, diffusion difficulties occur, and impoverishment by the phosphor of the galvanic coating may occur.

The change in NaH_2PO_2 concentration as a function of transmitted electricity amount is shown in Figure 4.

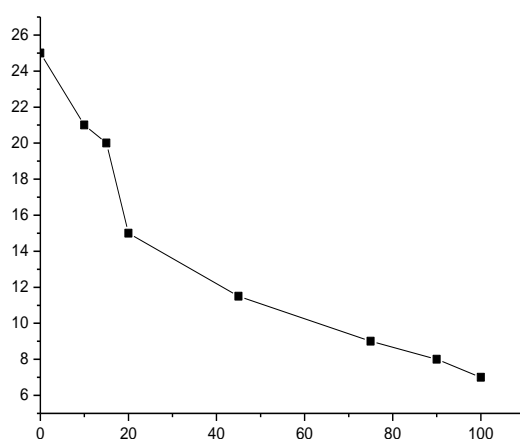Figure 4. Change in the sodium hypophosphite concentration from the amount of transmitted electricity

When Q 100 A * h/l is passed, the NaH_2 PO_2 content is reduced to 7 g/l. This has no significant effect on the phosphorus content in the plating and the quality of the coating. It is shown that the current yield of a metal depends little on Q and the content of sodium hyposite (Fig. 5) and when the

concentration is adjusted, the electrolyte's performance is not limited by other and components of the solution.
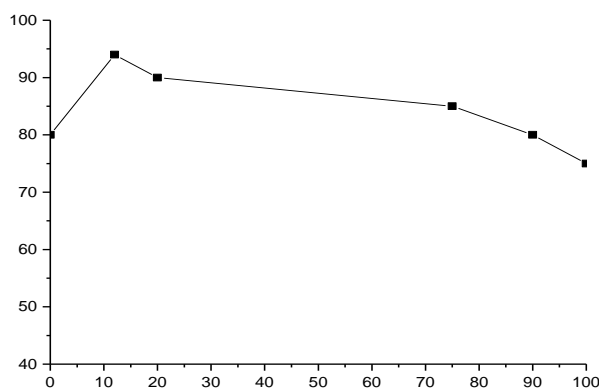

Figure 5. Dependence of the yield of metal on the amount of transmitted electricity

Table 1 Dependence of the yield of metal on sodium hypophosphite content

Content NaH_2PO_2 , g/l	25	20,3	15	8,2	7,9	7,4
the yield of metal, %	80	95	91	86	82	72

The study showed that a multiple adjustment of the sodium hyposphite concentration to the initial value (25 g / l) makes it possible to obtain non-porous and wear-resistant nickel-phosphoric coatings. When controlling the components of the electrolyte and the correct electrolysis regime, the electrolyte of solid nickel plating is not different from the usual sulfate nickel electrolytes.

The combined electrocrystallization of nickel and phosphorus causes the galvanic coating to be more hard than ordinary nickel precipitates From the literature data it is known that freshly deposited coatings are a supersaturated solid solution of phosphorus in $\mathcal{L}$-nickel. Microhardness of the coating depends on the content of phosphorus in the sediment.

Figure 6 shows that when the content of phosphorus in the coating varies from 11 to 14% of the weight, the microhardness of the nickel-phosphorus precipitate fluctuates between 550-669 kg / mm^2, and in some cases reaches 700 kg / mm^2.
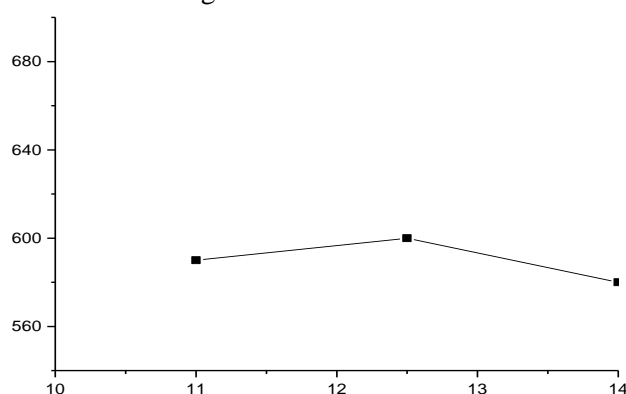

Figure 6. Dependence of the nickel-phosphorus coating microhardness on the content of phosphorus

The inclusion of phosphorus in the galvanic sediment changes not only the microhardness of the coating, but also imparts antifriction properties and high corrosion resistance to the coating.

References

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