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Research Article

Tribological Test and Mechanical Properties of Electrodeposited Nickel Coating on the Metal Surface of Carbon Steel 4140

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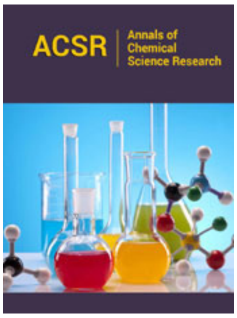

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Abstract

In this study, we used the electrodeposition technique of nickel on the metal surface of carbon steel 4140. To produce the coating, we worked with Watts and Sulfamate baths. The sliding wear properties were analyzed for tribological test, so as the roughness, hardness, and thingness layer, all these in accordance with the normative ASTM.

Keywords: Nickel coating; Electrodeposition; Adhesion; Hardness; Corrosion

Introduction

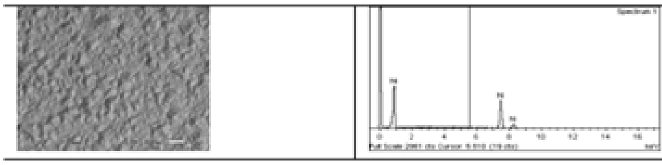
Wear and corrosion are the main problems in mechanical elements in mechanical contact and therefore there are economical losses. To enhance the tribological properties of the metallic materials, nickel coating has found a wide application in aerospace, automobile, chemical industries and other. In this research nickel coating on carbon steel substrate were developed using nickel sulfamate bath and Watts nickel bath to obtain homogeneous electrodeposits so as good adherence and nonporous material. Nickel is one of the most used metals in the nuclear industry as well as in conventional industry, so it is important to study its morphological composition and its mechanical properties. The crystal structure of nickel: It is distributed in two phases, gamma (γ) and gamma prime (γ'): -Gamma phase: solid solution centered on the faces that acts as a matrix. Gamma prime phase: dispersion of ordered inter-metallic precipitates, responsible for the great resistance of the super-alloys.

Experimental development

Electroless nickel coatings [1-3] based on the bath types have been progressively applied to a wider variety of applications in Industry. Several researches [4,5] have investigated the application of different electroless nickel coatings. They have observed that the nickel coating improved the tribological properties and protect the material surfaces in mechanical contact. In addition, the coating process can provide properties to reduce the stresses, to improve the adhesion and the corrosion resistance. In this study, we used the electrodepositions technique of nickel to produce a coating on the metallic surface of carbon steel with the objective to reduce the corrosion process. To obtain these coating we worked with two solutions, one of them is, Watts bath and the other one is sulphamate bath [6-10]. We used an electrolytic cell made of Pyrex glass. To produce the electrodeposition on the metallic surface of carbon steel used as cathode, in the upper head of the electrolytic cell was adapted a cap made of Teflon with 3 holes where it was connected whit two anodes in the extremes and one cathode middle of the cap, as anode was used nickel bars. A constant temperature circulator was adapted to the electrolytic cell through a hose. As power supply was used a galvanostat.

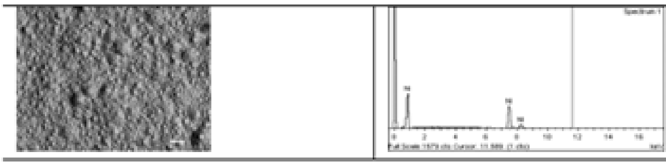
Preparation of electrolytes

Chemical compounds were chemically pure. These were mixed with 250ml of deionized water using an agitator (80rpm) in order to dissolve completely all the compounds. The electrolytes used to make the different nickel coatings are shown in Table 1. The coatings obtained were analyzed by scanning electronic microscope (SEM JSM6610-LV) obtaining the results shown in Figure 1 and 2. Rugness, Adhesion, hardness and Thickness of layer tests in accordance with the standards ASTM 4138 [11], ASTM D 4541-02 [12], ASTM E140-05 [13], ASTM D4138-94(1999) [14] respectively. The coatings were made with mirror-finished base material to obtain the surface characteristics shown in Table 2. The coatings obtained with the electrodeposition process under specific controlled conditions such as: temperature, current density, exposure time, pH, electrolyte concentration and agitation, produced and uniform layer of nickel over the entire surface.



Element	Weight %	Atomic %
Ni	100.00	100.00
Totals	100.00	

Figure 1: Percentage of nickel in the samples coated with Watts bath, SEM; 1000x.



Element	Weight %	Atomic %
Ni	100.00	100.00
Totals	100.00	

Figure 2: Percentage of nickel in the samples coated with nickel sulphamate bath, SEM; 1000x.

Table 1: Components of the Watts bath.

Components Bath of Watts	Amount (gl-1)	Components Bath of Sulfamate	Amount (gl-1)
Nickel Sulfate (NiSO4·6H2O)	330	Nickel sulfamate (Ni (SO3·NH3)2·2H20)	800
Nickel chloride (NiCl2·6H2O)	45	Nickel chloride (NiCl2·6H2O)	30
Boric acid (H3BO3)	37	Boric acid (H3BO3)	30

Table 2: Data obtained from mechanical tests.

Coating type	Rugness (μm)	Adherence (Kg/cm2)	Hardness (Hv)	Thickness of layer (μm)
Base material	Mirror finish	---	247.0	---
Watts bath	0.3	9-14	253.68	35.251-35.751
Sulfamate bath	0.5	10-12	745.52	25.149-26.881

Tribological tests

Table 3: Results of the sliding tests in accordance a normative ASTM G0099-04a [8].

Pin specimen	L [m]	Vw [mm3]	Q [mm3/m]	K [mm3/Nm]	Ff [N]	μ
Specimen uncoated	579.42	0.95	0.00160	3.2×10−4	4.79	0.96
Specimen coated (NSB)	579.42	0.20	0.00034	6.8×10−5	4.22	0.84
Specimen coated (WNB)	579.42	0.30	0.00051	1.0×10−4	4.39	0.87

The sliding wear properties have been analyzed for 4140 carbon steel pin specimens uncoated, 4140 carbon steel pin specimens coated with Watt nickel bath, and 4140 carbon steel pin specimens coated with nickel sulfamate bath, using a pin-on-disk tester at constant load of 5 N (≈ 0.2MPa), the test time was 600s, the velocity was 0.95m/s, the rotational speed was 200rpm, and the wear track radius was 0.047m. The tests were carried out at ambient temperature from 22 to 24 °C in dry condition. The material of the disk was stainless steel 304. Table 3 shows the results of sliding length (L), wear volume loss (Vw), wear rate (Q), wear factor (K), friction force, (Ff) and friction coefficient (μ). Figure 3-5 show the friction force as a function of the time. From Figure 3 it can been seen that there are large and irregular fluctuations of the friction force during the sliding test. In addition, it is observed that the friction coefficient of 0.96 is found under the values reported by the literature. The results shown in Figure 5 suggest that the coating with Watts nickel bath protected for a short time, approximately 20seconds, the 4140carbon steel pin specimen surfaces. While the coating nickel sulfamate bath presented more sliding wear resistance, which resists up to 250seconds. Therefore, the friction force and friction coefficient were smaller than the coated pin specimen with the Watts nickel bath and the pin specimen uncoated [9,10].

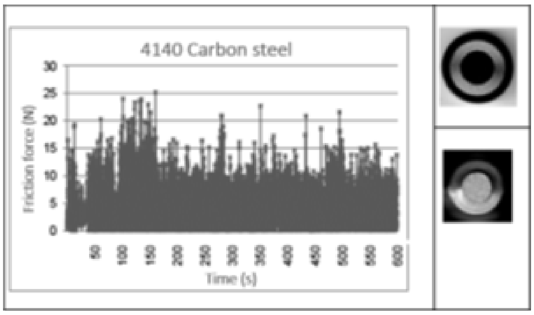


Figure 3: Friction force of the 4140-carbon steel pin specimen uncoated as function of the time.

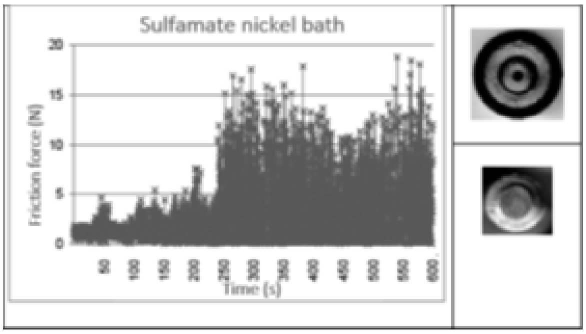


Figure 4: Friction force of the 4140carbon steel pin specimen coated with sulfamate nickel bath as function of the time.

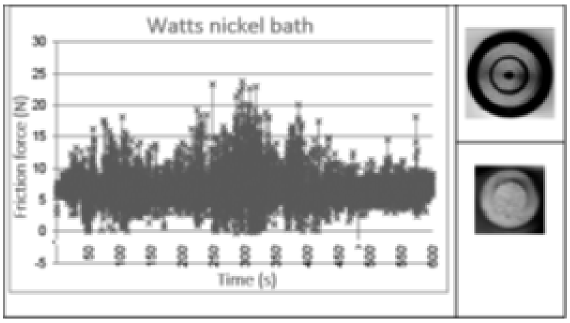


Figure 5: Friction force of the 4140carbon steel pin specimen coated with Watts nickel bath as function of the time.

The comparison of the results obtained from the corrosion test of the 4140carbon steel, the coated carbon steel with Watts nickel bath and coated carbon nickel sulfamate bath are shown in Table 1. From the results it can be observed a high polarization with coating nickel. The coated 4140 carbon steel with nickel sulfamate bath presented the highest resistance to the polarization and therefore the corrosion velocity was the lowest.

In the obtained coatings it can be seen that the mechanical properties are improved with respect to the base material since there is a hardness gain of up to 2.5 times the hardness of the base material, in layers of approximately 25µm. Tribological tests were also carried out to test the hardness of the electrodeposits, the results indicate that the nickel coating obtained by the sulphamate bath method is 2.5 times harder than the base metal [15].

Conclusion

The contribution of this work shows us that there are different treatments that can be applied in materials, whether surface or bulk, the selection of the type of treatment must be according to the type of work that the material must perform. Electrodeposited coatings change the surface properties of the base materials. In the case of a nickel coating on carbon steel, it produces a higher hardness as a surface characteristic. Due to its nickel properties when applied to a metallic material such as carbon steels that tend to oxidize very easily, the nickel coating would help to avoid this type of phenomenon. On the other hand, the layer of the nickel coating gives a good finish to the material, it should be borne in mind that the quality of the electrodeposition, will depend a lot on the surface finish that you have on the base part.

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