Wear Mechanisms In Electroless Nickel Plating

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Abstract

In this study electroless nickel coating are deposited on high carbon low alloy steel type(13 A)substrate. After coatings some specimens were heat treated at different baking temperatures ranging from 300 to 800 C for one hour.

Wear testing by using a device of pin on rotary disc were carried on for the coated steel before and after baking treat.

It is concluded that electroless nickel coating and baking treatments both eventual effect on wear resistance of studied steel.

ألية البليان في طلاء النيكل اللاكهربائي

الخلاصة

في هذه الدراسة تم ترسيب غشاء من النيكل باستخدام الاسلوب اللاكهربائي وعلى سطح فولاذ عالي الكربون واطي السبائكية . بعد عملية الطلاء تم اجراء معاملات حرارية بين درجات حرارة ٣٠٠ الى٨٠٠ م لمدة ساعة واحدة.

تم اجراء فحوصات مقاومة البليان باستخدام تقنية المسار والقرص الدوار على الاجزاء المطلية قبلوبعد اجراء المعاملات الحرارية .

استنتج ان كلا من الطلاء اللاكهربائي بالنيكل والمعاملات الحرارية لها تاثير مهم على مقاومة البليانللفولاذ المذكور.

1-Introduction

Elecroles nickel coatings are produced by the controlled chemical reduction of nickel ions on to a catalytic surface. The deposit itself is catalytic to reduction, and the reaction continues as long as the surface remains in contact with the electroless nickel solution. Because the deposit is applied without an electric current, its thickness is uniform on all areas of an specimen in contact with fresh solution[1].

Electroless nickel is being used increasingly as wear-resistant coating on engineering components.It is known that heat treatment (baking) of the coating can almost double its hardness value and provide major improvements in wear resistance.

Maximum hardening is obtained 400C. Hardening of electroless nickel is due primarirly to the formation of nickel phosphide particles within the low alloy steel. At temperatures above 320 C the glass phase begins to crystallize and this causes it is hardness and wear resistance to increase rapidly [2].

2-Experimental procedure

To study the behavior of the a brasive wear rate, a pin on rotary disc test machine was used.

Material of the pin used in this test is this test is high carbon low alloy steel with chemical composition shown in table (1). This alloy is specified as (13A) according to DIN specification.

This pin is coated with nickel-

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Phosphorus alloy by electroless coating technology. The bath used for electroless plating contained (21g/L) sodium hypophite, (34g/L) lactic acid, (2.2) propionic acid and was operated at temperatures ranging between (70 and 90 C). Solution pH was 4.5 and the bath was agitated by using a mechanical thicknesses and Vickers micro hardness are shown in table(2). Vickers micro hardness was measured by (WOLPERT-AMSLER-D6700).

During wear test, the speed of the rotary disc was 540 r.p.m and a load was 1000 gm on the pin. The specimens were weighted before and after the test by a sensitive electronic scale type (OHAUS-GA200) which can read to decimal four number and with a degree of accuracy of 0.0001gm Weight losses were calculated on equal periods of 15 min. Wear products were removed by washing the specimens with acetone, dried by air and weighted. The volume of the removed material (V) per unit sliding distance (S)was found as follows[3]:-

$V/S=M/\boldsymbol{P}.V.T$

Where:-

M= mass of the removed material by the wearing processes(gm).

S= sliding speed (cm/sec).

T= period of sliding (sec).

V= the volume of the removed material (cm).

P= density of the removed material (gm/cm).

The purpose of this test is to show the damage produced during the test on the abrasive particle as well as the worn surface and to study the wear resistance of steel coated by nickel-phosphorus alloy.

Baking treatment was coducted at 300,400,600,700 and 800 C in electric furnace type (carbdite-max.temp .1200 C).

3-Result and discussion

The wear may be considered as the mechanical displacement of Material at surface due to the relative motion of a harder contacting solid. In practice, the wear generally involves the ploughing out of a surface by a harder material and is characterized by the presence of grooves parallel to the direction of motion of the abrading solid. Wear is proportional to the real contact area and hence is inversely proportional to hardness. However,some workers have shown that wear is not always inversely proportional to the hardness [4,5].

Fig. (1) and table (3) represent the results of the wear teats for the coated steel before baking treatment. The wear volume decreases with the increase of the hardness. This is because, crystallization cannot be completed before baking and the structure of the alloy is amorphous. And because the amorphous phase is tough, the wear volume decreases hardness increases.

A number of workers [4,6] have shown that electroless nickel in the as-deposited state without baking treatment is essentially amorphous since amorphous structures have no periodic lattice, the dislocation movement cannot occur and the high hardness of the as deposited implies that the stress required to trigger shear banding in the amorphous state is much higher than that normally needed to produce a dislocation movement in the crystalline nickel.

Fig.(2) shows, the high wear volumes at low hardness of as-deposit electroless nickel before baking treatment.

Baked electroless coatings gave lower wear volume than the as-deposited coatings. As shown in Fig. (3), the wear volume decreases with the increase of baking temperature in the rang of (300 to 600 C), while the wear volume increases with the increase of baking temperature beyond (600 up to 800 C), although the hardness increases with the increase of baking temperature within the range of (300 to 400 C) and decreases with the increase of temperature within the range of (400 to 800 C) as shown in table (4).

After crystallization the nickel particles agglomerate and become larger. When crack propagates into such a particle, enough lastic deformation can occur to slow down the growth of the crack and the wear volume can be decreased. Baking treatment of the electroless nickel at (400 C) results in great increase in hardness, which is associated with the initial rapid development of crystalline structure. Nickel forms the matrix in alloy with the result that the (Ni P) will tend to be the convex phase on (Ni-Nip) interfaces. This configuretion will increase the interfacial free energy of the (Ni P) so that in this phase the nickel will coarsen on baking treatment [4,5,6].

Fig. (4) shows that wing to the extreme brittleness of the crystallized (Ni-P) alloys at baking temperature of (400C), t is thought that some microspalting may occur, which increases during further wear, thus forming the large deep tracks. The baking electroless coating at temperatures above (400 C) results in hard (Ni P) particles embedded in a ductile crystalline nickel matrix as shown in Fig. (5).Crystalline nickel is a ductile phase of only moderate strength and so hardening on baking treatment is attributed to the increasing volume fraction of (Ni P) as crystallization proceeds.

At baking temperatures above (400 C) the softening is thus due to coarsening of the hard (Ni P) articles, which enable dislocation movement in the more ductile nickel matrix to take place at lower stress [7]. The applied stress will induce strain in the softer nickel and dislocation pile-ups will nucleate micro cracks where slip bands intersect the (Ni P) particles. Propagation of micro cracks within the the confines of a particle will produce a gravity, which draws out and ultimately leads to ductile rupture of the nickel. This comes in agreement with the ideas of any investigators Fig. (3) shows the minimum wear volume at baking treatment is at (650 C) and thus with (NiP) particle coarsening implies that the ductile rupture stage governs the failure of electroless nickel coating [4].

The hard (Ni P)particles are thus responsible for the high hardness but the ductile nickel matrix provides the toughness. The nickel isolates the particles from one another and prevents particle to particle crack propagation [1,4].

Baking treatment at (700&800 C) increases wear volume as baking temperature increases due to the further increase of size of the nickel particles,so the men free path or crack propagation becomes larger. This means that when a crack propagates into the matrix, the probability that it encounters a nickel particle is smaller, and so it follows that the wear volume increases [8].

5-Conclusions

By studying electroless nickel plating on high carbon low alloy steel at different conditions and the wear resistance of the coating films the following results can be concluded :-

1- The thickness and hardness of the as-deposit electroless nickel film were increased with increasing of non electrolytic bath temperature.
2-The baking treatment results in further increase in hardness of plating film and its wear resistance .

3-The wear resistance of the as-deposit electroless nickel increases with the increase of hardness before baking treatment.

4-Max wear resistance was obtained with baking at 650 C.

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Table (1): Chemical composition of studied steel

C	Si	S	P	Mn	Ni	Cr	Mo	V	Cu
0.568	0.253	0.004	0.004	0.482	0.220	0.79	0.031	0.200	0.144
W	**Sn**	**Co**	**Al**	**Fe**					
0.07	0.005	0.01	0.017	97.44					

Table (2) : changes of thickness and micro hardness before and after baking treatment at 400 C of electroless nickel plating for 1 hour in solution of 4.5 pH value and a ange of temperatures.

Bath Temperature (C)	Thickness (m)	Micro hardness Before baking treatment (HV)	Micro hardness after baking treatment (HV)
90	35	542	824
85	30	464	694
80	28	442	572
75	25	421	464
70	20	366	442

Table (3): Relation between micro hardness and volume of removed material per units sliding distance (V/S) and wear index (wt. loss in mg per 15 min) at a constant pH of 4.5 and variable bath temperatures of electoless nickel plating.

Bath Temperature C	Micro hardness HV	V/S cm/cm	Wear index (wt. loss in mg per 15 min)
90	514	6.26 x 10	45
85	464	7.98 x 10	52
80	442	8.73 x 10	55
75	421	9.04 x 10	58
70	322	10.54 x 10	60

* The wear volume of the base metal before coating is 178 mg or 28.43 x 10 cm/cm

Table (4): Relation between micro hardness and volume of removed Material per unites sliding distance (V/S) and wear index (wt. loss in mg Per 15 min) at different baking temperatures for one hour of electroless Nickel plating specimens .

Temperature of baking treatment C	Micro hardness H V	V/S cm /cm	Wear index (wt. loss in mg per 15 min)
300	542	4.96 x 10	33
400	802	3.80 x 10	22
500	733	3.42 x 10	21
600	701	3.36 x 10	15
650	642	2.11 x 10	14
700	572	4.64 x 10	31
800	386	5.08 x 10	34

*The hardness of all the specimens before heat treatment is 488 HV .

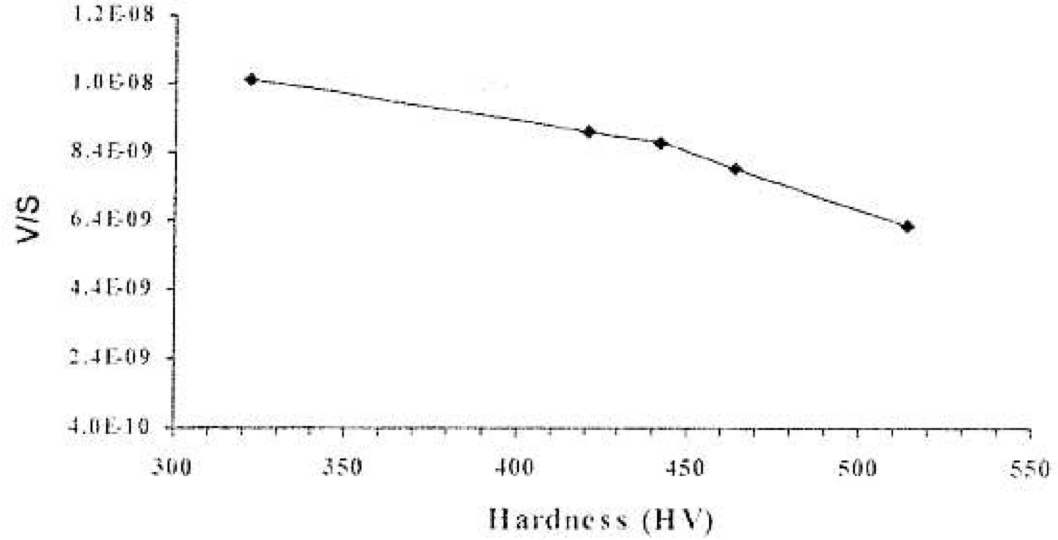

Fig. (1) Relation between the hardness and volume of removed material (V) per unit sliding distance (S) under constant pH=4.5 and variable bath temperatures of electroless nickel plating before baking treatment

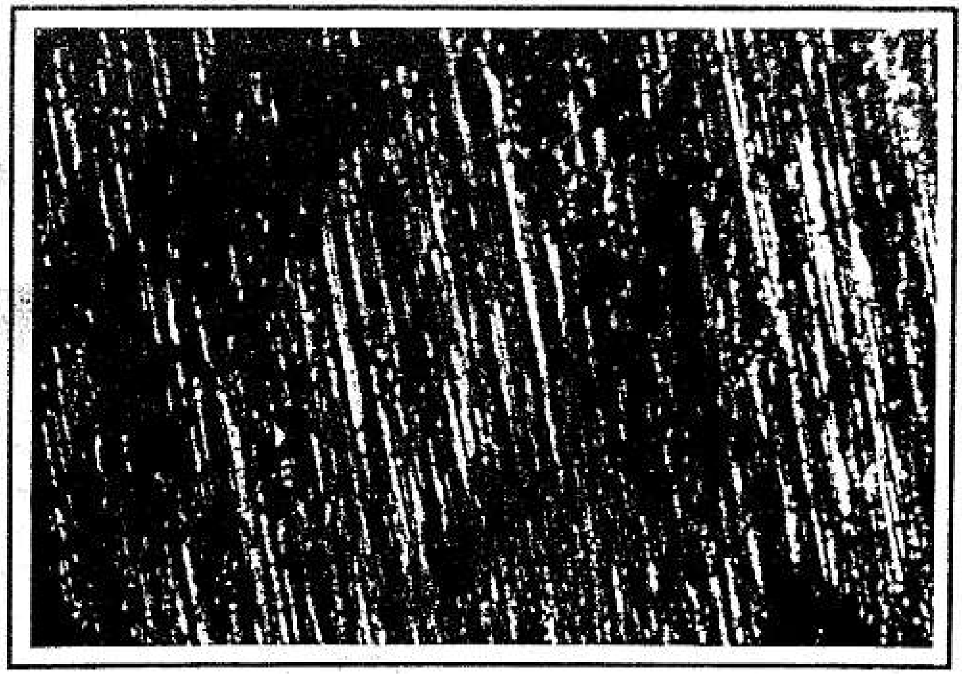

Fig. (2) Optical micrograph of electroless nickel deposit. Note a large deep tracks (White area) (400 X).

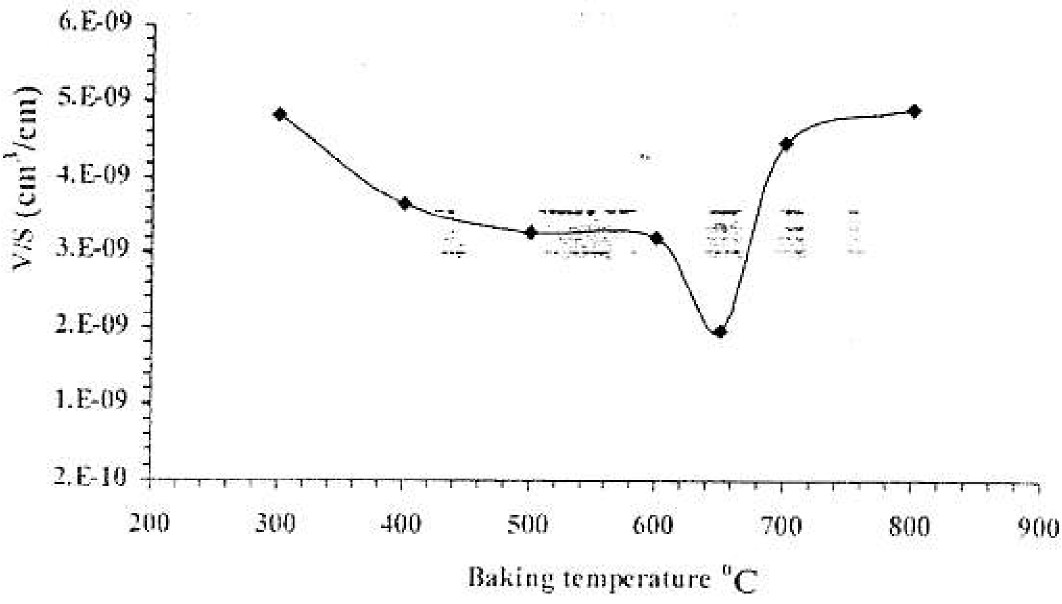

Fig. (3) Relation between the baking temperatures at one hour and wear volume of electroless nickel plated steel. The thickness of electroless coating is 20 μm per hour.

Fig. (4) Optical micrograph of electroless nickel deposit heat treated at 400°C. Note the deep tracks (White area) (400 X)

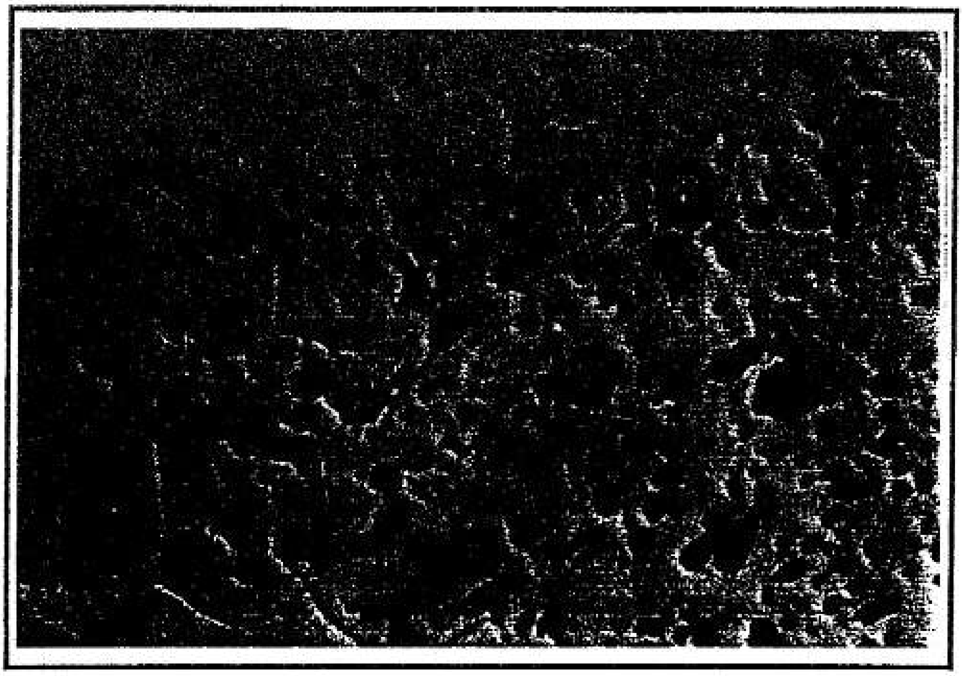

Fig. (5) Optical micrograph of electroless nickel deposit baked at 800°C. Note the cracking and granular nickel particles embedded in an Ni_3P matrix (400 X)