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Fineness Grade Effect on The Tribological Behavior of Low Carbon Steel Coated by Ni-P-Ptfe Electroless Plating

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ABSTRACT: The paniculate matter co-deposition within the rising film drove to a new obstetrics of electroless composite coating, many of which own stellar corrosion and wear resistance. Thus, it can be used not only for electrically conductive materials such as graphite but also rubber, fabrics, and insulators like plastics. The rate of low coating process can provide better reflectivity of many applications such as plated surface. The aims of this paper are studding the effect of adding the polytetraflouroethylene (PTFE) and the finesse of the low carbon steel samples, which are coated with electroless Ni-P, on the tribiological behavior of the sample's surfaces. Various concentrations of (PTFE) range, 1g/L, 3g/L and 5g/L in Ni-p composite were examined. The samples, with various surface fineness, were electroless coated by following the procedure of Ni-p plating. After a heat treatment for the plating samples, in 400 ℃ for one hour, was done, the tribological behaviors were tested. The micro hardness was increased by 258 % and the wear rate, which was valued by pin on disk technique, was decreased specific wear rate to 0.2×10^{-4} $mm^3/N.m$.

KEYWORDS: Electroless Ni-P-PTFE coating, Wear rate, Specific wear rate, Surface roughness, Microhardness.

INTRODUCTION

The improvement of the tribiological behavior of the equipment's parts is one of the biggest challenges in the different industries, in order to avoid the losses due the mechanical wear. In recent times, electroless plating technique is used with different coating materials to improve the hardness and wear resistance of the mechanical parts [1, 2]. The advantages of electroless planting method is the uniform thickness layer of coating [3]. With carbon steel which is widely used in mechanical equipment's, electroless deposition of Ni-P, as one of the surface treatment technique, is greatly used [4]. The effects of coating procedure and the use of other additives with Ni-P on surface mechanical properties of steel were studied. When polyvinyl-pyrrolidone (PVP) was added, the micro hardness decreases and adhesion increase [5]. Silver and alumina (Ag, Al_2O_3) with Ni-P improved the wear resistance of the carbon steel at high working temperature [6]. Adding (PTFE) has a significant effect on the wear rate and the hardness of the medium carbon steel. With the gradually increasing of PTFE the wear rate is decreased and then with higher content increased [7].

The combine of PTFE and SiO_2 with Ni-P coating improved the tribological performance of the mild steel coating [8]. The bath type in the Ni-P coating process of carbon steel has a clear effect on the erosion resistance which is doesn't depend on the heat treatment [9]. The study of coating of Ni-P on steel by using multilayer technique, with different percentage of coating materials, showed a gradient change in coating hardness and structure [10]. In order to improve the tribiological properties of oil equipment's, Ni-P coating on carbon steel was widely used for equipment in state of high alloys steel[11]. The effect of ammonium acetate, as an additive for the Ni-P coating, on the rate of precipitation was studied. The precipitation is increased with the additive increase [12]. To improve the tribological behavior of the 4340 steel, electroless coating by Ni-B with different concentration of CNT were used with a plaster nitriding [13]. The aim of this paper is to study the effect of the fineness grade and the concentrate of PTFE on the tribiological behaver of the low carbon steel when it is electroless coated by Ni-P in added to various weight of PTFE.

EXPERIMENTAL

The substrate samples were used in this work made of low carbon steel. The specimens, with 25 mm diameter and 10 mm height, were prepared by grinding the surfaces before plating. Emery paper, within the range from 400 to 3000, was used in several steps for this purpose. Distilled water and ethanol were used to clean the gridded samples. After the drying by electrical dryer, then the samples were drowned thirty minutes in acetone and washed. Before painting, in order to get rid of oils and dust, electrical cleaning was used by immersing the samples in a solution containing the substances (60g NaOH, 30g NaCo3, and 30g NaPbo4 with one liter of water) for two minutes at 70 to 75 ℃ and 3 volts. The last step in the preparation of specimens, before the coating process, is washing them with distilled water and drying them by electrical dryer.

Electroless Plating Procedure

After the preparing the samples' faces, the solution for the coating had prepared from different material. The concentrations of the chemical compounds are mentioned in table (1). Before the coating process, the samples were submerged in sulphuric acid for 5 seconds, then washed by distilled water and dried with electric dryer. The electroless plating with Ni-P-PTFT was done with different concentrations for PTFE (0, 1, 3 and 5 g), and with three grades of the samples surface fineness, at 85-90℃. Magnetic stir was used to ensure a uniform distribution of heat and plating. After one hour of plating process, the specimens were removed from solution, washed, dried and stored in a container with silica gel.

Table 1. The electroless bath conditions

	Bath Composition	g/L
1	Nickel sulphate	15
2	Sodium hypophosphite	30
3	Citric acid	20
4	Lactic acid	20
5	polytetrafluoroethylene (PTFE)	1,3,5
6	Temperature	85-90℃
7	Time	1 hour

Heat Treatment

In this paper, the specimens were annealed after the plating process by argon atmosphere furnace at (400℃) for 1 hour. The cooling period to the room temperature is in the furnace.

Characterization

To measure the hardness of the specimens coating layer, Vickers hardness tester (type TH-717) was used. For each sample with a different surface fineness grade and PTFE percentage added in the coating solution, the micro hardness was recorded. The applied load was 0.245 N for 15 second. The hardness number (HV) for all samples are listed in Table 2. Another indicator of the plating effect on the tribological behavior of the specimens is the wear resistance. The wear tester with 10 N load, 250 RPM as dice rotation speed and the wear prop at raids of 5 mm from the center was used. The sliding distance for the wear test was 235.5.5 meter for 1800 second (the test time). The weight losses of the specimens during the wear test were computed by comparing the weight of them before and after the test.

According to the formula [ASTM G99], the physical coefficient which is called specific wear rate (w_s) was calculated for the coated samples.

$$w_s = \frac{\Delta w}{\rho D_s N} \tag{1}$$

Where:

w_s is the specific wear rate.
Δw is the losses in weight.
ρ is the density.

D_s is the sliding distance.
N is the load.

The values of volume loss and specific wear rate according to the ratio the Teflon in the coating compound and the finesses grade are listed in Table 3. The roughness of the coated samples' surfaces, which one of the major effected parameters on the wear rate, was measured [14-46].

RESULT AND DISCUSSIONS

Light optical microscopy examination

All samples were examined with a microscope and in the wear test the area as shown in Fig.(1). A1,2,3 for the samples were coated by Ni-P without PTEF and the surface grinding range (1000, 2000, 3000). The images B1,2,3, C1,2,3 , and D1,2,3 for samples coated by Ni-P with various concentration of PTEF (1g, 3g, and 5g for each liter of the coating solution).

Surface roughness

In table (2) surface roughness are presented. It is clear that the surface roughness of the coated was decreased as the fineness of the base samples increased. For the samples which were coated by Ni-P without PTEF the roughness reduced from (0.865 to 0.0793) micron. From the roughness results it can be saw the effect of percentage of the PTFE added on the roughness, as the increase in the percentage, the roughness was decreases.
From the Fig (2), it can be observed the effect of the PTEF was added on the surfaces roughness for the 1000 fineness sample. It is decremented as the percentage of PTEF in coating solution increase. For the higher fineness it behave in inverting way, it was decreased before the 1g/L of PTEF then increased with flagging slope.

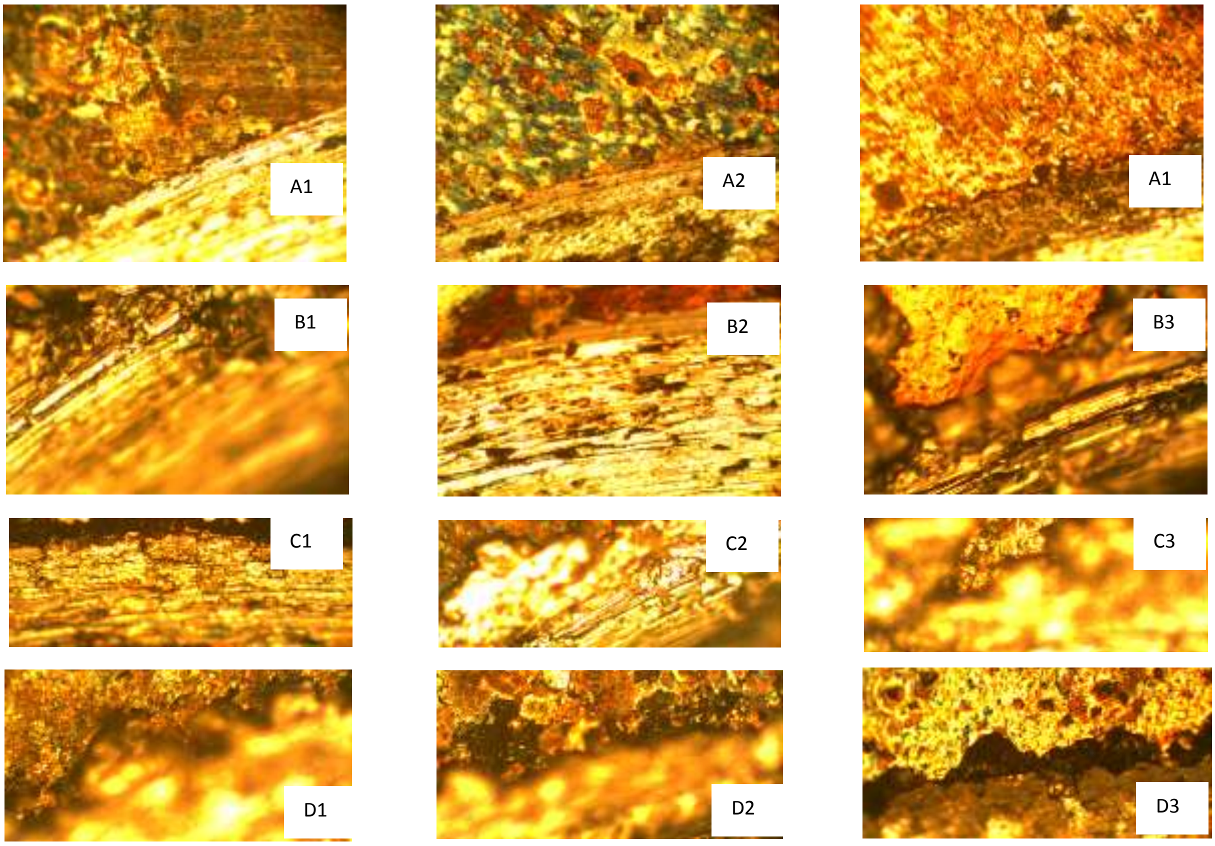

Figure 1. The microscope images for the coated samples, A1,2,3 for the samples coated without PTFE, B1,2,3 with 1gram PTFE, C1,2,3 with 3grams, and D1,2,3 with 5 grams.

Table 2. The samples' surface roughness in micron (μ).

Fineness Grade / PTEF %	1000	2000	3000
Nill	0.865	0.445	0.0793
1g /L	0.65	0.093	0.061
3g /L	0.502	0.419	0.333
5g /L	0.265	0.50	0.447

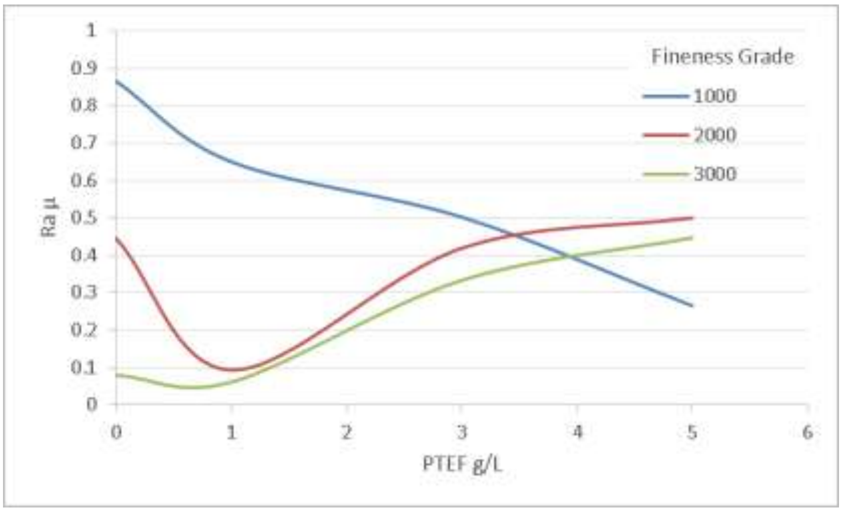

Figure 2. The samples' surface roughness for the three fineness grade versus PTEF%

Micro hardness

In this paper, two effective parameters on the surface performance were studied. The micro hardness of the coated surfaces of the samples and the effect of the fineness grade of the base surfaces and the percentage of the PTEF in the coated solution are shown in table (3). From the table it can be observed that the base samples without coating, the hardness decrease as the surface fineness increase. Significant rise in hardness after the process of coating which was reached to 258 %

Table 3. Micro hardness (HV) of the sample's surfaces

Fineness Grade / PTEF %	1000	2000	3000
Base samples	150	141.42	130.81
Nill	388	251.4	224.9
1g /L	355	243.9	160.75
3g /L	353.03	281.5	324.5
5g /L	424.25	312.8	306.8

The behavior of the samples' surface hardness with increasing of the added PTFE is evident in Figure 3.

Wear behavior

The wear rate of the coated samples depends on a several factors, and in this case due to the presence of several variables that would change the nature of the surfaces, it depends on the hardness and the level of surface roughness. The weight losses for the samples are mentioned in table (4), the specific wear rate was computed according to equation (1) and listed in table (5). From the Fig.(4), it is clear that the wear rate increase as the percentage of PTEF increase in the coating path, because PTEF is classified as a low friction material but at the same time a high wear rate material [47, 48]. The wear rate for grades (1000, 3000) decrease due to the compound effect of the hardness and roughness while the grade (2000) continues to increase.

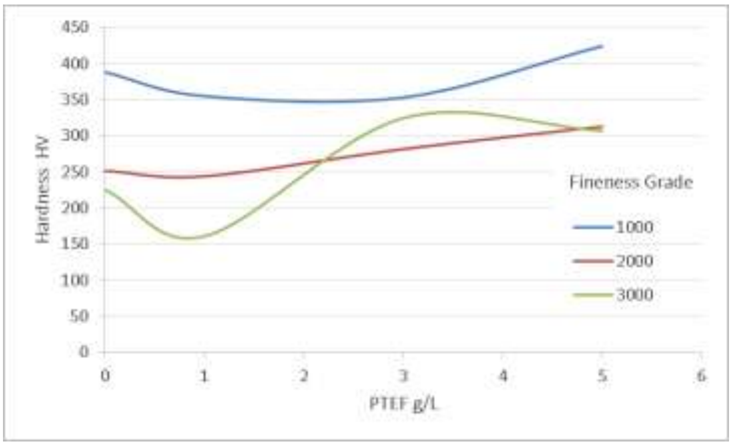

Figure 3: The samples' surface hardness for the three-fineness grade versus PTEF%.

Table 4. Samples' surfaces weight losses in gram

Fineness Grade / PTEF %	1000	2000	300 0
Nill	0.0043	0.0004	0.0019
1g /L	0.011	0.0006	0.012
3g /L	0.0037	0.0082	0.013
5g	0.0062	0.02	0.0014

Table 5. Specific Wear Rate $(mm^3/N.m)\times10^{-4}$ Samples' surfaces

Fineness Grade / PTEF %	1000	2000	3000
Nill	2.155×10^{-4}	0.2×10^{-4}	0.9×10^{-4}
1g /L	5.52×10^{-4}	0.3×10^{-4}	6.01×10^{-4}
3g /L	1.854×10^{-4}	4.11×10^{-4}	6.516×10^{-4}
5g /L	3.107×10^{-4}	10.02×10^{-4}	0.701×10^{-4}

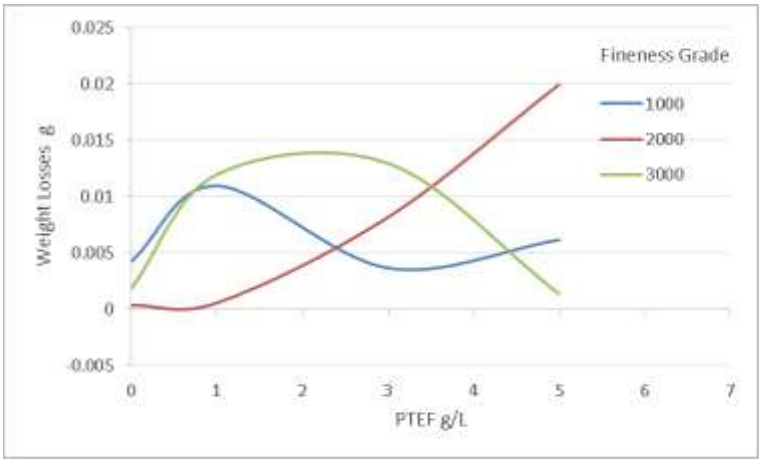

Figure 4. The samples' weight losses for the three-fineness grade versus PTEF%

CONCLUSIONS

A significant improvement in the tribiological behavior of the low carbon steel samples were observed when they were electroless coated with Ni-P. The following notes has been installed:

1. The increment of the base samples' surfaces finesses decrease the micro hardness and in the same time decrease the surface roughness as a result, wear rate is reduced. The best base finesses is grade 2000.
2. The added of PTEF to the coating path improved the wear rate and the preferable amount is (from 2.7 to 4.2 g/L of PTFE) with grade 1000 of the base samples' surface.
3. The micro hardness of the coated samples can be increment to 258 % of the base metal.

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