

# Enhancement of chromium plating by Nano ceramic particles

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**Abstract:** Cr- Al<sub>2</sub>O<sub>3</sub> Nano composite coatings with various contents of Al<sub>2</sub>O<sub>3</sub> nanoparticles were prepared by electrodeposition in optimized Cr plating bath containing different concentrations of Al<sub>2</sub>O<sub>3</sub> nanoparticles. Direct current electrocodeposition technique was used to deposit chromium layers with and without Al<sub>2</sub>O<sub>3</sub> nanoparticles on mild carbon steel. The effects of current density, stirring rate and concentration of nanoparticles in the plating bath were investigated. Energy dispersive analysis technique was used to verify the presence of Al<sub>2</sub>O<sub>3</sub> nanoparticles in the coated layers. The corrosion behaviors of coatings were investigated by potentiodynamic polarization and electrochemical impedance spectroscopy methods in 0.05 mol/L HCl, 1 mol/L NaOH and 3.5% NaCl (mass fraction), respectively. Microhardness measurements and pin-on-disc tribometer technique were used to investigate the wear behavior of the coatings.

**Key words-** Cr-Al<sub>2</sub>O<sub>3</sub> Nano-composite coatings; electrocodeposition; wear behavior.

## 1 INTRODUCTION

Chromium plating is resistant to corrosion in most atmospheres. There are two classes of chromium plating; the first one is decorative chromium plating. And the other one is hard chromium electroplating. In the decorative a thin layer used as a non-tarnishing and in hard chromium plating a heavy coatings are used to take advantage of the special properties of chromium, which include resistance to erosion, corrosion, wear, low coefficient of friction and anti-galling.

Hard chrome is used as a wear resistant coating on a wide variety of other metals. Hard chromium differs from decorative chromium because of the difference in deposit thickness. A typical hard chrome deposit thickness is more than 0.0125mm but not more than 1 mm.

Hard chromium deposits, impair a long service life of most parts [1].

These parts can be protected when newly manufactured, or they can be salvaged when they are worn and would otherwise be scrapped [2, 3].

Hard chrome plating is generally used in those applications where parts will be subjected to a very high degree of wear and thus a thicker layer of chrome is required. The added thickness induces cracks and greater porosity on the chrome surface. The cracks will increase with an increase in

chrome thickness. Further machining, such as grinding, polishing, is necessary to improve the hard chrome plated surface. A coarse surface finish will substantially decrease the wear resistance [3].

Protective coatings serve to prevent wear and corrosion and thus reduce the total loss from corrosion and wear. Hard chromium plating is one of the most widely used techniques for production of such coatings. However, hard chromium faces many problems [4].

Another more, many researches have been done to enhance the chromium deposits. M.P. Nascimento, held thermal treatment for the purpose of improving the resistance to fatigue of AISI 4340 base metal in order to enhance the properties of hard chromium deposit [5].

Marcelino P. Nascimento, studied the Effects of tungsten carbide thermal spray coating by HP/HVOF and hard chromium electroplating on AISI 4340 high strength steel [6]. It was also observed that the fatigue strength reduces in the hard chromium electroplating deposit [7].

L. Maria Rudaya Raj studied various Chromium coating defects that occur while electro plating of different mechanical

components and methodology adopted to prevent it [8]. Also, Castañeda F studied Multilayers coatings for corrosion resistance enhancement of chromium electrodeposits at two parameters, temperature and current density. The result was, the coatings are microcracked, have small grain size and show an unexpected very good corrosion resistance [9].

Addition of nanoparticles to deposited layers can mainly improve surface microhardness if they are distributed uniformly [10-13].

The aim of this work is introduce the nanoparticles of aluminum oxide in the hard chromium electroplating bath and study the influence of these particles on the shape, thickness, hardness, and wear resistance of chromium layer deposit on steel.

## 2 EXPERIMENTAL WORK

### 2.1 Sample preparation

The samples of St 37 wear prepared as follow:

- Cut the steel strip to samples of 1cm x 1cm x 2 cm.
- Prepare on side of sample for hanging by drilling and screwing.
- Grinding the sample from all sides by emerging paper of 220, 400, 600, 800, 1000 mesh using grinding machine.
- Numbering the samples by numbering tools.
- Calculate the weight of each sample before electroplating using four digits precision electronic balance.

### 2.2 Preparation of cleaning

#### solutions.

1. Alkaline solution is 10% NaOH, 90% water

2. Acidic solution is 17% HCl in water

The steel parts to be hard chrome plated are pre-cleaned in a suitable hot alkaline soak

cleaner and rinsed well to remove any grease or oil. Then, the samples were rinsed in acidic solution and rinsed in water.

### 2.3 Sequence of Operation

The following sequence of operation is usually followed for hard chrome process:

- a) degrease
- b) Soak clean
- c) Water swill
- d) Acidic cleaning
- e) Water swill

To obtain a good adhesion of the deposits, anodic etching in chromic -sulphuric acid bath for 15 sec. is carried out in a chromium-plating bath by change the polarity of power supply. After the etching, the parts are electro plated by return the polarity the origin case in chromium baths in tables 1, 2 and 3. The sample fixed by clamp with the cathode and the anode, which prepared in the arc shape from lead-7%tin. After plating the parts are immersed in drag out for rise followed, another cold water rinse and hot water rinse.

The parameters in the first experiment were as in table 1 bellow.

TABLE 1  
PARAMETERS OF EXPERIMENT 1

Cr O3	CrO3/ H2SO4	Sur face are a of sam ple	Cur rent den sity	tempe rature	Mag netic stirr er
350 gr/ l	70:1	10 cm 2	10 A/ dc m	45°C- 50°C	150 r/mi n.

Table 2 shows the parameters of experiment 2

TABLE 2  
PARAMETERS OF EXPERIMENT 2

CrO3	CrO3 /H2SO4	area	Cu current density	temperature	Magnetic stirrer	Aluminum oxide
350gr /l	1:70	10 cm <sup>2</sup>	10 A/dcm	45°C	150 r/min.	2gr.

Table 3 shows the parameters of experiment three. All parameters was the same as in experiment 2 except the mixing velocity changed to 380 r/min.

TABLE 3  
PARAMETERS OF EXPERIMENT 3

CrO3	CrO3 /H2SO4	Surface area of sample	Cu current density	temperature	Magnetic stirrer	Aluminum oxide
250gr /l	1:70	10 cm <sup>2</sup>	10 A/dcm	45°C	380 r/min.	2gr.

### 3 RESULTS & DISCUSSION

In this work the effect of time, temperature, current density, mixing velocity and the addition of Nano aluminum oxide on the thickness and properties of chromium electro plating layer on steel samples were studied.

#### 3.2 Thickness of deposit

Table 4 shows the thickness layers of hard chromium deposit of the first experiment at times 30, 60, and 90 minutes and 150r/min. mixing velocity.

TABLE 4  
THICKNESS OF CHROMIUM DEPOSITS OF EXPERIMENT 1

Sample No.	Plating Time	Chromium Deposit thickness
1	30 min	14 µm
2	60 min	18.5 µm
3	90 min	20 µm

Fig. 1 shows the relation between time and chromium layer of chromium electroplating. The chromium oxide, sulphate, current density and temperature are fixed but only time of plating was changed. It clearly evidence that, the chromium layer increased slowly. The rate of deposit decrease with time. This decreasing because of polarization of anodes. There was yellow layer covered the surface of anodes.

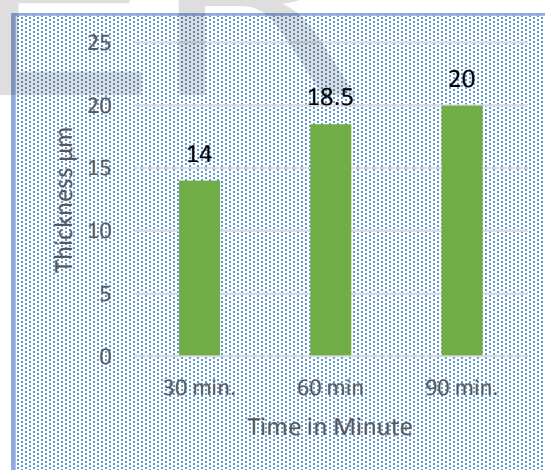


Fig.1. Relation between the time and thickness of chromium plating without using aluminium oxide ceramic Nanoparticles.

Table 5 shows the thickness of composite deposit of Nano ceramic of aluminum oxide and chromium of experiment 2.

**TABLE 5**  
THICKNESS OF CO-DEPOSIT CHROMIUM-NANO ALUMINIUM OXIDE COMPOSITE.

Sample No.	Plating Time	Chromium Deposit thickness
4	30 min	31.2 μm
5	60 min	32.3 μm
6	90 min	32.9 μm

Fig. 2 shows the relation between time and chromium-Nano particles deposit layer at fixing each of current density, temperature, magnetic stirrer and only two grams of aluminum oxide was added to the bath. Generally, there is increment in the chromium deposit layer in comparison with Fig. 1. The chromium layer increased from 14 μm to 31.2 μm at 30 min. time. In addition, the layer's thickness increased from 18.5 μm to 32.3 μm. at time 60 min., and the chromium layer thickness increased to 32.9 μm at 90 min. The reason for this increment returned to the precipitation of co-deposit of Nano aluminum oxide and chromium.

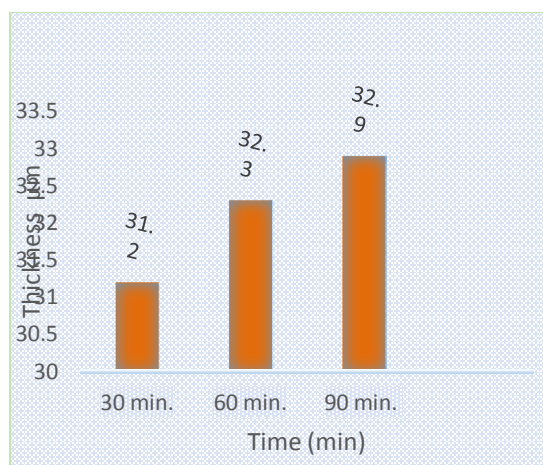


Figure 2. Thickness of plating deposit of the same parameters of experiment 1 except adding of 2 gr of aluminum oxide

Table 6 shows the thickness of co-deposit composite of aluminium oxide Nano particles and chromium.

**TABLE 6**  
EXPERIMENT3 RESULTS

Sample No.	Plating Time	Chromium Deposit thickness
7	30 min	45.8 μm
8	60 min	71.1 μm
9	90 min	110 μm

From Fig.2, it is clearly appear that, there are more increasing in the thickness of chromium layer. The thickness increased to 45.8 μm at 30 min. and 71.1 μm at 60 min. and at 90 min. the thickness of chromium layer reaches to 110 μm. The high rate of thickness belongs to the increasing in mixing velocity to 380 rpm. This increasing in velocity increases the dispersion of Nano particles and then increasing of aluminum oxide Nano particles to be in the way of chromium ions that move to cathode and precipitate on the steel surface.

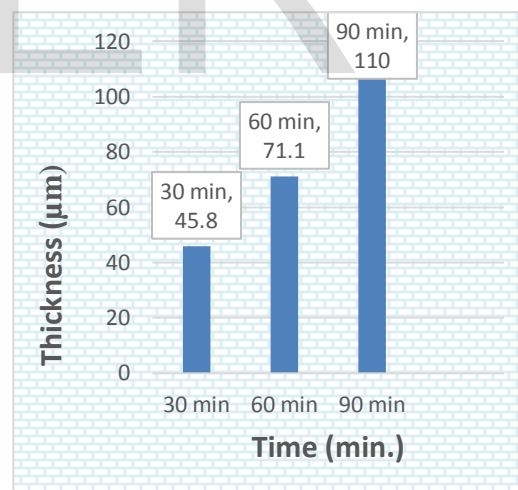


Fig.3. Thickness of plating deposit of the same parameters of experiment 2 except changing the mixing velocity to 380 rpm.

### 3.2 Dry sliding wear resistance

The dry sliding wear resistance was carried out on pin-on-disc wear resistance machine. Sample number 1 and sample number 4 were tested as in table 5 below:

Fig. 4 below shows the dry sliding wear resistance of two hard chromium plated

steel samples. The first one was sample 1; this sample was electroplated without adding Nano particles of aluminum oxide. The chromium deposit layer was 14µm. the second one was sample 4; this sample from the group, which electroplated by chromium and aluminum oxide Nano particles. It is clearly shown from Fig 4; that the wear rate was high in beginning of sliding but decreases very quickly. This behavior because of rough surface of the hard chromium plating but after sliding about 20 m the surface be smooth and the wear decreases. Also, reveals the difference between the wear rate of sample 1 and sample 4; the wear rate of sample 2 was higher than sample 4; the reason for that because the quickly precipitation of chromium and aluminum oxide on the surface of sample 4, but after the rough very thin layer was removed the wear stopped. This behavior give a good wear resistance for the chromium-aluminium oxide layer.

TABLE 7

DRY SLIDING WEAR RESISTANCE PARAMETERS, THE LOAD 5N, SPEED OF ROTATING DISC WAS 150 RPM AND DISC'S DIAMETER WAS 5 CM

Sample no.	Sliding time (min.)	Weight before wear (gram)	Weight after wear (gram)	Lost weight (gram)
1	0	24.8508	24.8508	0
	20		24.8506	0.0002
	40		24.8504	0.0004
	60		24.8504	0.0004
	80		24.8504	0.0004
	100		24.8504	0.0004
4	0	26.2270	26.2270	0
	20		26.2263	0.0007
	40		26.2260	0.001
	60		26.2260	0.001
	80		26.2260	0.001
	100		26.2260	0.001

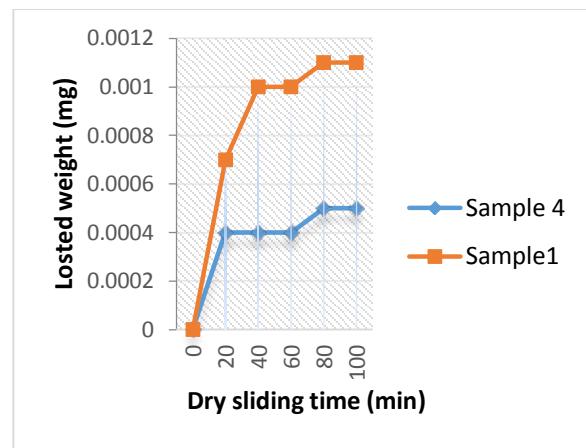


Fig. 4. Dry sliding wear resistance, sample 1 is wear resistance of chromium plating without addition of aluminum oxide Nano particles. Sample 4 is wear resistance of chromium plating with addition of aluminum oxide Nano particles.

### 3.3 X-ray diffraction test

Fig. 5 shows the x-ray diffraction test diagram, from this diagram it is possible differentiate the peaks of aluminum oxide in the chromium layer. There are two peaks, the first one in plain (110) and the other in plain (113). This result prove that the increment in the thickness of plating layer in experiment (2) and experiment (3) was belong to the precipitation of Nano aluminum oxide with chromium.

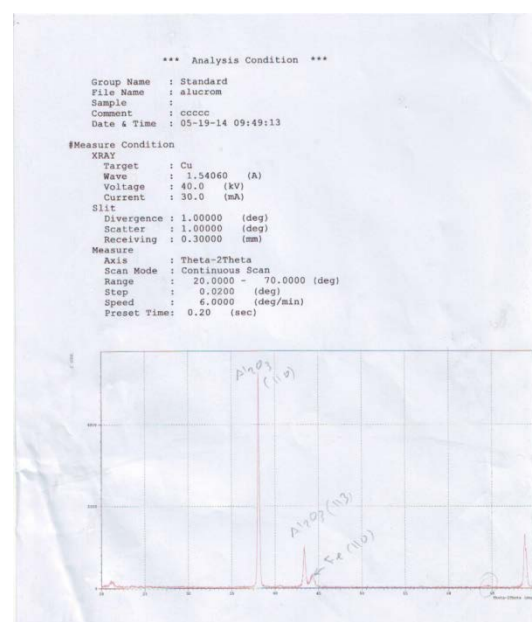


Fig.5. X- ray diffraction diagram

### 3.4 Hardness test

The hardness test was done for two sample; the first one was without addition of aluminum oxide and the other was with Nano aluminum oxide. The hardness test carried out by using micro hardness test because the thin layer of chromium electro plating. The load used in this test was 200g. The hardness of the first one was 814HV and the hardness of the second one was 1089 HV. These results indicate that, the hardness of the chromium - Aluminum oxide layer has higher hardness than only chromium layer. The reason for that is the higher thickness of chromium-aluminum oxide layer and homogeneity of precipitation. This homogeneity detected from the higher hardness. If there is no homogeneity the micro hardness may be lower.

### 4 CONCLUSIONS

It is concluded from the above results and discussion the following:

- It is useful using aluminum oxide as Nano particles to improve the hard chromium electroplating on carbon steel surface.
- This Nano particles precipitate uniformly with chromium deposit without roughness on the steel surface.
- The wear rate during dry sliding wear resistance test starts quickly and after a few second, the wear stopped or be very slowly.
- The hardness of chromium-aluminum oxide layer higher than the hardness of chromium layer only.
- Increasing the agitation of electroplating path by

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increasing mixing velocity increases the precipitation of chromium-Nano aluminum oxide layer and then increases the hard chromium layer.

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