

Research Article

Effects of Hard Surface Grinding and Activation on Electroless-Nickel Plating on Cast Aluminium Alloy Substrates

Olawale Olarewaju Ajibola,^{1,2} Daniel T. Oloruntoba,¹ and Benjamin O. Adewuyi¹

¹ *Metallurgical and Materials Engineering Department, Federal University of Technology, Akure, Akure 340252, Nigeria*

² *Materials and Metallurgical Engineering Department, Federal University Oye Ekiti, Oye Ekiti 371104, Nigeria*

Correspondence should be addressed to Olawale Olarewaju Ajibola; olawale.ajibola@fuoye.edu.ng

Received 30 May 2014; Revised 19 August 2014; Accepted 4 September 2014; Published 21 September 2014

Academic Editor: Mariana Braic

Copyright © 2014 Olawale Olarewaju Ajibola et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

This work examined effects of hard surface polishing grits and activation on electroless-nickel (EN) plating on cast aluminium alloy substrates in sodium hypophosphite baths. As-received aluminium alloy sample sourced from automobile hydraulic brake master cylinder piston was melted in electric furnace and sand cast into rod. The cast samples were polished using different grits (60 μm –1200 μm) before plating. The effects on adhesion, appearance, and quantity of EN deposits on substrates were studied. Observation shows that the quantity of EN deposit is partly dependent on the alloy type and roughness of the surface of the substrates, whereas the adhesion and brightness are not solely controlled by the degree of surface polishing. The best yield in terms of adhesion and appearance was obtained from the activation in zincate and palladium chloride solutions. Higher plating rates ($\text{g}/\text{mm}^2/\text{min}$) of $3.01E - 05$, $2.41E - 05$, and $2.90E - 05$ were obtained from chromate, zincate, and chloride than $8.49E - 06$, $8.86E - 06$, and $1.69E - 05$ as obtained from HCl etched, NaOH, and H_2O activated surfaces, respectively.

1. Introduction

Al alloys are widely used in engineering structures and components where light weight or corrosion resistance is required [1] such as automotive engines. Aluminium-magnesium alloys are found useful in automotive engine cylinder, master brake, and clutch cylinder and so on, but they are subject to wear and corrosion. Ajibola and Jimoh [2] and Ajibola et al. [3] had studied the quality, while Ajibola et al. [4] studied the wear behaviour of Al alloys used in making brake master cylinder pistons used hydraulic brake fluid. The studies were performed to assess the metallurgical properties and wear rates of pistons with the view to improving on the wear resistance and corrosion resistance of the Al alloy substrates in brake fluid. The studies [4, 5] also suggested the application of surface treatment and overlay of durable metallic film as remedy to alleviating wear and corrosion of this useful machine part in brake oil.

There are various methods of metal coating. These include processes like hot dipping, anodising, electroplating [6–8], electroless-plating [9–13], autocatalytic plating [13], cladding,

Parkerizing, and galvanising. Plating has been done for hundreds of years, but it is also critical for modern technology. Plating is used for decoration, corrosion inhibition, to improve solderability, to increase hardness, to improve wear resistance, to reduce friction, to improve paint adhesion, and to alter conductivity, for radiation shielding, and for other purposes.

Electroless-nickel (EN) plating is a chemical reduction process which depends upon the autocatalytic reduction process of nickel ions in an aqueous solution (containing a chemical reducing agent) and the subsequent deposition of nickel metal without the use of electrical energy [13]. With correct surface pretreatment sequence and accurate process control, good adhesion, and excellent service performance, very uniform thickness is produced all over the part, even for irregular shapes, holes, recesses, internal surfaces, and valves.

There are numerous methods of cleaning and pretreating the surface of the metal substrates prior to the deposition of suitable protective film. Such methods may include chemical cleaning (alkaline, acid), electrical and electrolytic process (anodic), mechanical blasting, and many other methods.

Different hard and abrasive materials could also be used in achieving good and quality soil free surface. Good adhesion of EN deposits on Al alloy results from excellent cleaning and minimum etching. There is now a better understanding of the factors influencing adhesion. Good adhesion is dependent on having a clean surface free from soils, oxides, particulate matter, and embedded materials. For instance, mild etch alkaline cleaners work well for many soils.

Surfactants are wetting agents used that lower the surface tension of a liquid, allowing easier spreading, and lower the interfacial tension between two liquids or a liquid and solid surface. In an EN bath, presence of the surfactant promotes deposition reaction between the plating solution and immersed substrate surface [14]. The deposition of EN on cast Al was investigated through experimental methods and reported in this paper for the purpose of its application to resist wear and corrosion.

2. Materials

The commercial Al alloy sample was sourced from the floating piston of the automotive hydraulic brake master cylinder. The floating piston (designated as “As-received Al alloy” or “AR”) was procured from automobile spare part shop from which Cast sample (designated as “Cast Al alloy” or “AC”) was produced. Pretreatment chemicals including deionised water, emulsifier, sodium hydroxide, hydrochloric acid, sodium phosphate, zinc oxide, potassium sodium tartrate, sodium nitrate and ferric chloride; and EN plating chemicals such as palladium chloride, nickel chloride, sodium hypophosphite, sodium citrate, ammonium chloride; and antitarnish chemical (potassium-di-chromate solution) were procured from chemical stores. The chemical compositions of Al alloy substrates were determined using Atomic Absorption Spectrometer (AAS) Thermo series 2000 Model.

3. Method

3.1. Preparation of Al Alloy Substrates. 2000 g of as-received commercial Al alloy was weighed into a melting pot in electric furnace under a controlled atmosphere, melted, and cast at pouring temperature range of 700–800°C. The molten metal was sand cast to rods of 300 mm long by 30 mm diameter from which the set of test specimens were cut and machined out. The cast sample was turned on the lathe machine to obtain smoother surface of the substrate which was sliced to coins of 15 mm thickness by 25 mm diameter size (Figure 1) used for plating tests. The surfaces of the Al alloy substrates were grinded and polished with different grit of emery papers (60, 120, 220, 320, 400, 600, 800, and 1200 μm) on the grinding and polishing machines.

3.2. Chemical Pretreatment of Al Alloy Substrate. The samples were cleaned in series of chemicals consisting of bases and acids (Table 1), to prepare the surface for good adhesion. Each of the chemical pretreatment stage was followed by water rinsing. Degreasing removes soil and oil, while acid cleaning removes scaling. The surface activation is done in six



FIGURE 1: Sliced specimens used for EN plating tests.

different types of solutions: sodium-di-chromate, palladium chloride solution, zincate, water, HCl, and NaOH solution. After the coating process, coated material is finished with an antitarnish chemical to prevent unwanted stains. The cleaned samples are activated in palladium chloride at 85°C and before finally being immersed in the EN bath for deposition (Figure 2).

3.3. EN Deposition on Al Alloy Substrates. The polished samples were immersed into the EN bath operated at varying temperatures of 80°C, 85°C, 90°C, and room temperature (26°C). EN deposition is carried out using nickel chloride as the source of nickel, sodium hypophosphite as the reducing agent, and sodium citrate as the stabilizer according to WinowlinJappes [15]. The pH of the bath was fixed by adding ammonium solution [15] or sodium hydroxide solution [8]. The EN coated samples were washed in distilled water after the EN deposition and dried in the oven after which the microstructures are examined.

The amount of EN deposit is determined by subtracting the initial weight (W_i) of substrate before immersion into plating bath from the final weight (W_f) after plating using electronic digital weight meter. The difference is expressed as

$$\Delta W = W_f - W_i, \quad (1)$$

where W_i is the weight (g) of the sample before EN-plating, W_f is the weight (g) of the sample after EN-plating, and ΔW is the EN film weight deposited (g). The EN plating rate R_p in $\text{g}/\text{mm}^2/\text{min}$ and amount of EN deposited per unit area R_A in g/mm^2 were calculated from the amount deposited:

$$R_A = \frac{\Delta W}{(A_T)}, \quad (2)$$

$$R_p = \frac{\Delta W}{(A_T \cdot t)},$$

where ΔW is the weight of EN deposition, A_T is the total surface area of substrate, and t is the plating time.

The result obtained is presented in Figures 9 to 15.

4. Results and Discussion

4.1. Chemical Composition and Hardness of Al Alloy Substrates. The chemical compositions and hardness of as-received Al

TABLE 1: Plating chemicals and the mixing ratio.

Bath	Media	Concentration	Temperature range (°C)	Time (min)
Rinsing	Water	—	25–30	1
Emulsifying	Emulsifier	—	60–65	1
Alkaline cleaning	Sodium hydroxide	0.4 g/L	60–70	1
Acid cleaning	Hydrochloric acid	5 mL/L	60–70	1
Surfactant		0.0~0.12 g/L	85–95	0.5
Plating	Nickel chloride	30 g/L*	85–95	10
	Sodium hypophosphite	40 g/L*		
	Sodium citrate	25 g/L*		
	Ammonium chloride	50 g/L*		
	PdCl ₂	0.02 g/L		
After plating	Potassium chromate	15 g/L	50–65	3

* According to Winowlinjappes 2004 [15].



FIGURE 2: Pictorial views (a), (b) of complete assembly of EN plating line showing EN solution replenishing tank, EN plating bath, PdCl₂ surfactant bath, pumps, and filters.

alloy (AR) and Cast Al alloy (AC) substrate used in this experiment are presented in Table 2. Different micrographs obtained from the EN plating on as-received and cast Al alloy substrates are shown in Figures 3 to 8. Deposition weight, deposition per unit area, and plating rates of EN on as-received Al alloy (AR) and cast Al alloy (AC) substrates at various polishing grits, temperatures, and surface activation are illustrated in Figures 9 to 15.

4.2. Characteristics of the Al Alloy Substrates. The Al alloy substrates, that is, as-received and cast samples, were characterised by atomic absorption spectrometry to ascertain the chemical composition of the substrate. The microstructural examination is carried out to reveal the microstructure of the alloy and to compare the similarities and differences. The hardness values are compared as means of predicting their behaviour under friction with respect to their composition and microstructure. With these, some reasons for their corrosion and wear behaviours of the Al alloy substrates could be understood.

Table 2 shows the chemical compositions and hardness of as-received Al alloy (control sample) and cast Al alloy used in the experiment. The analyses show that 98.87% Al, 0.38% Si, 0.40% Mg, and 0.23% Fe were present in the as-received Al alloy and that 98.44% Al, 0.32% Si, 0.29% Mg, and 0.16% Fe were present in the cast Al alloy while equal amounts of 0.001% Mn, 0.01% Cu, 0.001% Zn, 0.001% Cr, and 0.001% Ti were present in both as-received and cast Al alloys.

4.3. Effect of Plating Time on EN Deposition on the Al Alloy Substrates. Figure 3 shows the micrograph of the effect of the variation of plating time on EN deposition on the Al alloy immersed in EN solution for a range of 2 to 10 minutes. It was observed that the amount of EN deposition was dependent on the duration of immersion in the EN plating bath, while some other properties such as the adhesion and appearance were not time dependent.

4.4. Effect of Plating Temperatures on EN Deposition on the Al Alloy Substrates. Figure 4 shows the micrograph of EN deposition on 1200 μm polished cast Al alloy substrates at (a) 80°C, (b) 85°C, and (c) 90°C bath temperatures. From the different results obtained from the study, it was observed that the amount, adhesion, and appearance (colour, brightness, and lustre) of EN deposition were dependent on the bath operating temperature. No useful result was obtained from EN deposition at room temperature (26°C) while the least quality (appearance) of EN film deposition was obtained at 85°C.

4.5. Effect of SPG on EN Deposition on the Al Alloy Substrates. The effect of using different hard face polishing grits [(a) 60 μm , (b) 320 μm , (c) 600 μm , (d) 800 μm , (e) 1200 μm] on EN deposition on aluminium alloy substrates is shown in Figure 5. It was observed that the quantity of EN deposition was partly dependent on the degree of roughness or smoothness of Al surface unlike the adhesion and appearance. It

TABLE 2: Chemical composition and hardness of Al alloy substrates.

Sample	Al	Si	Mg	Fe	Mn	Cu	Zn	Cr	Ti	BHN
AR	98.87	0.38	0.40	0.23	0.001	0.01	0.001	0.001	0.001	43.6
AC	98.44	0.32	0.29	0.16	0.001	0.01	0.001	0.001	0.001	63.8

AR: as-received Al alloy, AC: cast Al alloy, and BHN: Brinell hardness number.



FIGURE 3: Micrographs showing EN deposition on as-received Al alloy substrate after (a) 2 minutes and (b) 10 minutes.

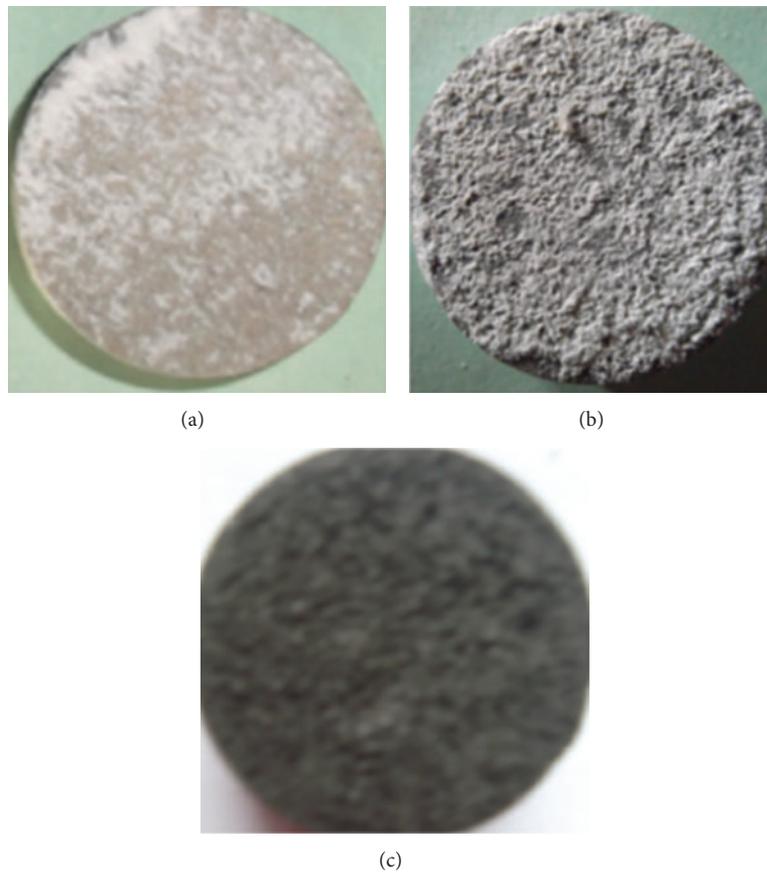


FIGURE 4: Micrographs showing EN deposition on 1200 μm polished cast Al alloy substrate at (a) 80°C, (b) 85°C, and (c) 90°C plating temperatures.

was obtained from the result that good looking and uniform metallic EN film could be deposited on 60 μm polished zincated Al alloy substrate (f).

4.6. Effect of Temperatures on EN Deposition on Cast Al Alloy Substrate with and without Activator. In Figure 6, the micrographs (a)–(f) of the effect of changes in plating temperatures for 80, 85, and 90°C with and without activating

the surface of Al alloy substrates in PdCl_2 solution prior to immersion in the EN solution are shown. The 60 μm polished surface in (a) was not plated. Using 80°C, 85°C, and at 90°C operating temperatures, surfaces in b, c, and d were not activated in PdCl_2 solution which resulted in different nature of EN deposition: nonmetallic and dull EN deposition at 80°C, dull EN deposition at 85°C, and bright EN deposition at 90°C, respectively. Metallic EN chips and dull EN flakes

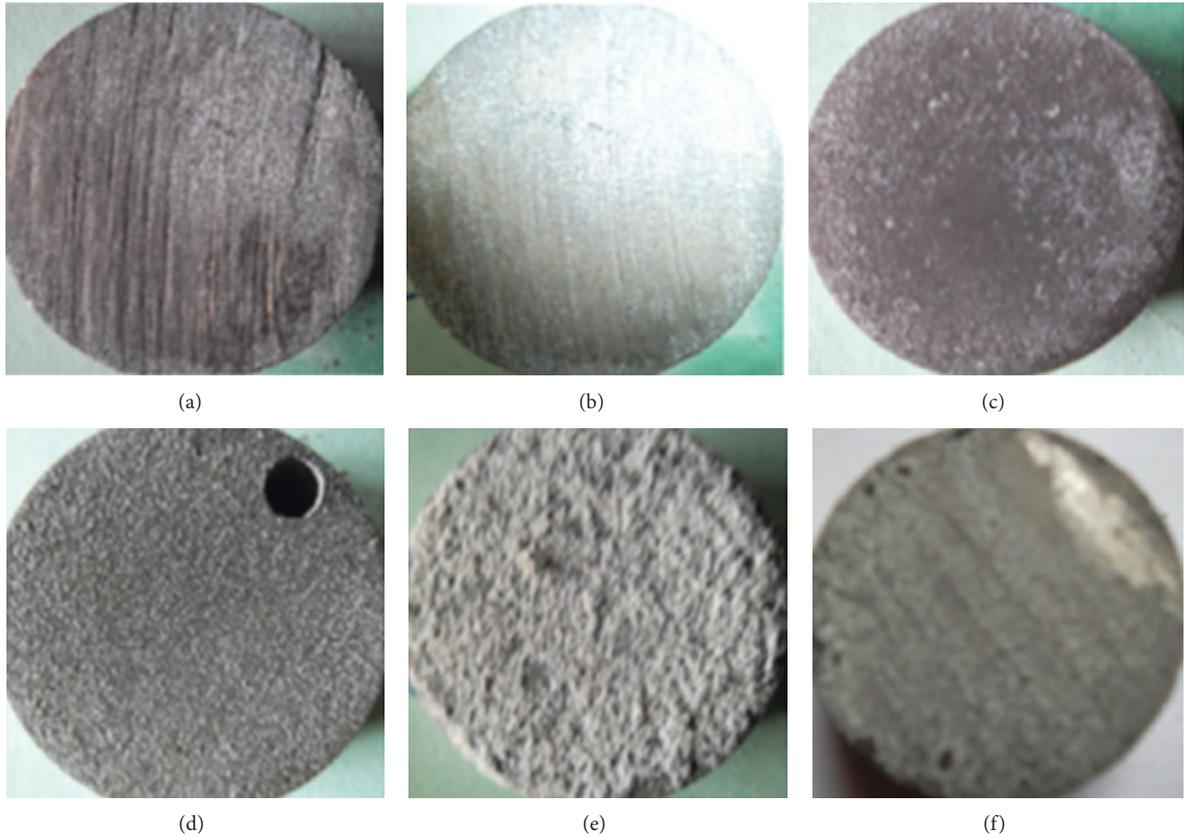


FIGURE 5: Micrographs showing EN deposition on (a) 60 μm polished, (b) 320 μm polished, (c) 600 μm polished, (d) 800 μm , (e) 1200 μm polished Al alloy substrates, and (f) 60 μm polished zincated substrate.

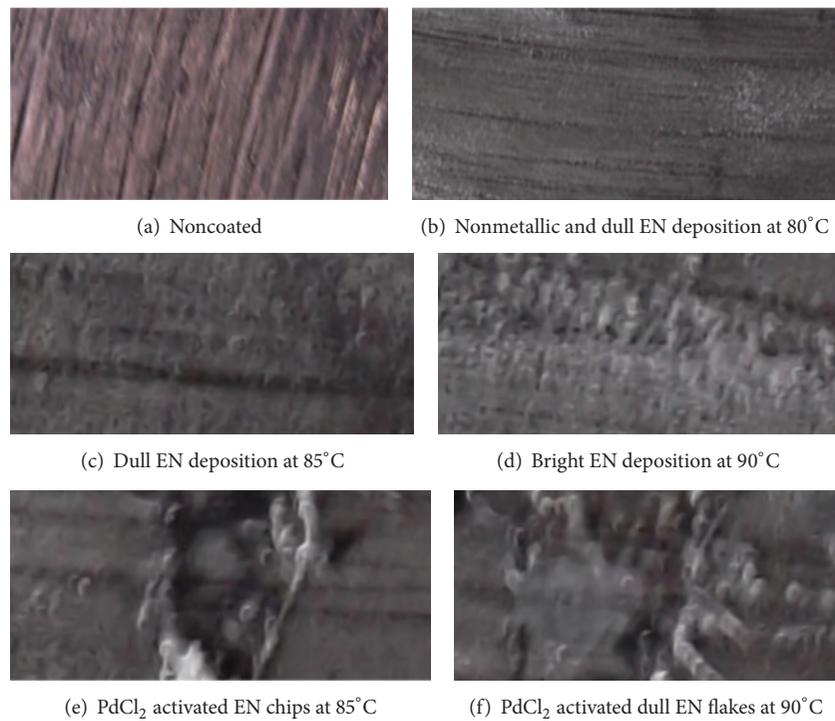


FIGURE 6: Micrographs showing EN deposition on (a)–(f) 60 μm cast Al alloy substrates.

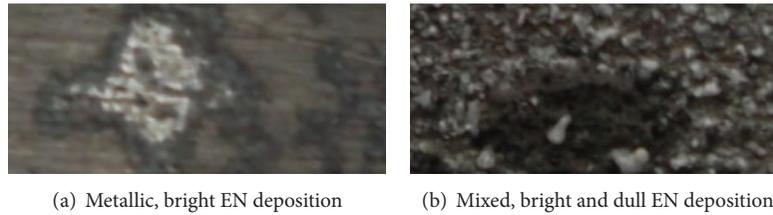


FIGURE 7: Micrographs showing EN deposition on (a) NaOH etched as-cast Al alloy surface and (b) HCl etched 1200 μm polished cast Al substrates at 10 minutes plating time.

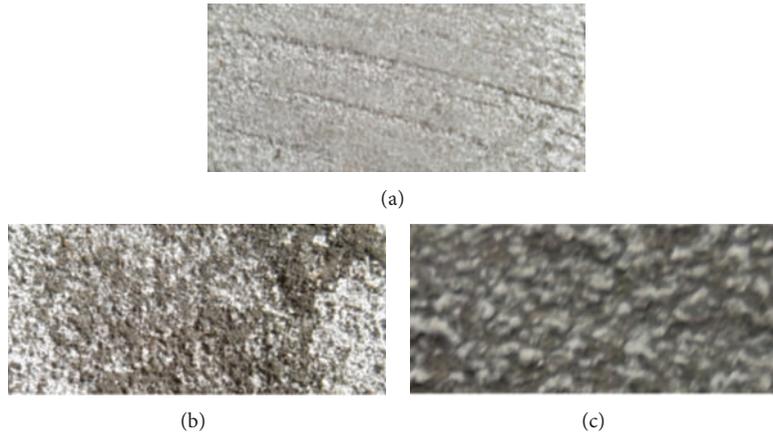


FIGURE 8: Micrograph of EN plating on (a) 120 μm nonactivated Al alloy surface, (b) 120 μm polished PdCl_2 -activated cast substrate and, (c) 120 μm zincated cast substrate.

were observed as defects on substrates in (e) and (f) that were activated in PdCl_2 solution at 85°C and at 90°C, respectively. Surfaces pretreated in PdCl_2 solution produced poorer EN adhesion than those treated with zincate solution.

4.7. Comparative Effects of NaOH and HCl Etched Cast Al Substrates on EN Deposition. Figure 7 shows the micrograph of EN plating on (a) NaOH etched as-cast surface and (b) HCl etched 1200 μm polished cast Al substrates at 10 minutes plating time. Enhancing good adhesion of EN film is a serious challenge in both of the alkaline and acid reduced hypophosphite baths. The surfaces of the Al alloy substrates [(a) as-cast and (b) polished] was cleaned in either (a) NaOH or (b) HCl solution thus removing the oxide film layer on the substrate prior to the activation in PdCl_2 . The best of the results showed that the EN film adhesion profile tremendously improved on the NaOH etched as-cast Al alloy substrate. The film is metallic, bright, tenacious and continuous. Also with 10 minutes plating time; metallic, tenacious, combination of bright and dull EN film deposits, but discontinuous EN film deposition were produced on HCl etched 1200 μm polished cast Al substrates.

4.8. Comparative Effects of PdCl_2 and Zincate Activated Cast Al Substrates on EN Deposition. In Figure 8, the appearances of the EN film deposition on (a) 120 μm nonactivated Al alloy substrate, (b) 120 μm polished PdCl_2 -activated cast substrate and (c) 120 μm polished, zincated cast substrates

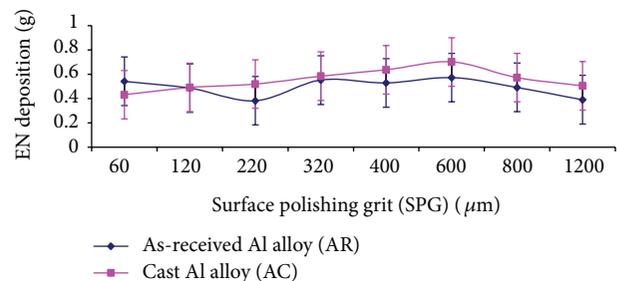


FIGURE 9: Amount of EN deposition (weight) on cast Al alloy and as-received Al alloy substrates using different surface polishing grits (SPG).

are compared as shown. The best of the results show that EN is sparingly coated on 120 μm nonactivated Al alloy surface (a). Mixture of bright and dull metallic EN deposit were obtained on 120 μm polished PdCl_2 -activated cast substrate at 85°C plating temperature (b), while lumps of dull EN film mixed with bright metallic EN film were deposited on 120 μm zincated cast substrate at 90°C.

4.9. Effect of Surface Polishing Grade Variation on Amount of EN Deposition. Figures 9 and 10 show the variation in the quantity of EN at varied surface polishing grits. Deposition of EN on as-received Al and cast Al alloy substrates at various polishing grit is carried out for 10 minutes at 85°C.

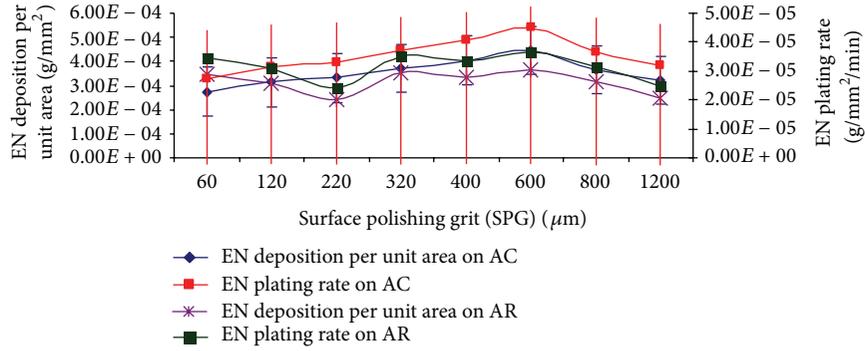


FIGURE 10: Effect of surface polishing grits (SPG) variation on EN deposition per unit area and EN plating rate on as-received Al alloy and cast Al alloy substrates at 85°C.

Figure 9 shows that, in using 60 μm and 120 μm grits, there is more of EN deposition on the as-received alloy than the cast Al substrate. There is steady increase in the quantity of EN deposition on cast Al substrate as the grade of surface polishing grits increased from 60 μm to 600 μm , above which there was reduction in the amount of EN deposition obtained on the cast Al substrate. There is subsequent greater amount of EN deposition on cast substrate than the as-received substrate with respect to the increase in the grade of surface polishing grits used.

It was observed that there is fall in the quantity of EN deposition on as-received alloy as grade of surface polishing grits increased from 60 μm to 220 μm , above which there was increase in the amount of EN deposition obtained on the as-received Al substrate. 600 μm surface polishing grits produced the highest quantity of EN deposition on both the cast and as-received Al substrates.

The polynomial trend of the amount of EN deposited with respect to increasing polishing grit as obtained from using MS excel application is presented in (3). The trend-line models equations from the plots are given as

$$M_{n1} = -0.0000006x^2 - 0.0008x + 0.3990, \quad (3)$$

$$M_{n2} = -0.0000003x^2 - 0.0003x + 0.4629,$$

where $60 \leq x \leq 1200 \mu\text{m}$, x is the grade of surface polishing grits (μm), and M_{n1} and M_{n2} are the amount of EN deposited with respect to surface polishing grits on cast and as-received Al alloy respectively in acidic sodium hypophosphite reduced bath.

Both EN deposition rate and EN deposition per unit area increased with increasing SFG from 60 μm to 600 μm after which there is reduction in the amount of EN deposition per unit area on cast Al alloy substrate. The case is different on the as-received Al alloy; there is reduction in the EN deposition per unit area on 60 μm to 220 μm ; there is increase in EN deposition per unit area on 220 μm to 600 μm after which there is reduction in EN deposition per unit area obtained. 0.000446 g/mm^2 and 0.000364 g/mm^2 were obtained on the 600 μm as the maximum EN deposition per unit area on the cast and as-received Al substrate, respectively.

All the plots in Figures 9 and 10 show the values of amount of EN deposition, EN deposition per unit area (g/mm^2), and EN plating rate ($\text{g}/\text{mm}^2/\text{min}$) on Cast Al alloy and As-Received Al alloy substrates measured from 8 different SPG. The error bars for each plot mean maximum and minimum amount of EN deposition of each SPG. For the cast and as-received substrate samples, error bars are within the EN deposition of the SPG points.

4.10. Effect of SPG and Temperature Variations on Amount of EN Deposition. Figures 11, 12, and 13 show the variation in the quantity of EN deposit, EN deposit per unit area, and EN plating rates on cast and as-received Al alloy substrates in acidic sodium hypophosphite reduced bath at varying plating bath temperatures and surface polishing grits (SPG). The temperature is varied as 80, 85, and 90°C while the surface polishing grits varied from 60 to 1200 μm .

In Figure 11, 60 μm polishing on cast Al produced the highest EN deposition at 80°C followed by 85°C and 90°C while, on other polished surfaces grits from 120 μm to 1200 μm , the highest values of EN deposition are obtained at 90°C. The result obtained at 85°C shows that there is decline in quantity of EN deposit on 60 μm to 220 μm polished Al substrate. The 60 μm polishing on as-received Al produced least quantity of EN deposition at 80°C followed by 85°C and 90°C. The 90°C plating temperature produced the highest values of EN deposition on 220, 320, 400, 600, and 1200 μm grit polished surfaces. Similar trends in quantity of EN deposition are obtained on 400 to 1200 μm polished surfaces for 85°C and 90°C plating temperature operated baths. The trend of EN deposition at all plating temperatures is observed to be controlled by the increasing plating temperature especially for 400 to 1200 μm polished surfaces grits.

Results in Figure 11 show that, at 80°C and 85°C plating temperatures, it was observed that EN depositions on as-received Al alloy (AR) and cast Al alloy (AC) samples are of similar trend and values in each of the plating temperatures. Hence, the deposition is controlled by polished surface grits rather than the Al alloy material type while further observation shows that, for 90°C plating temperature, the deposition is dependent on both polished surface grits and the Al alloy material types.

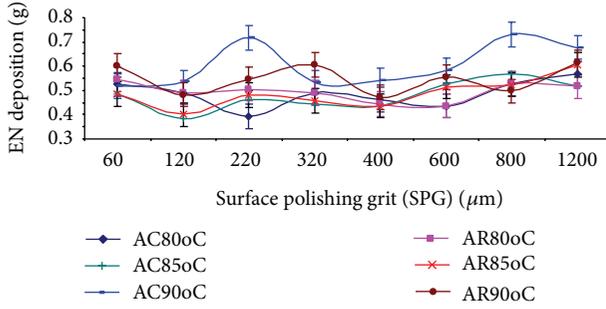


FIGURE 11: Effect of surface polishing grits (SPG) on EN deposition on as-received Al alloy (AR) and cast Al alloy (AC) substrates at varying temperatures.

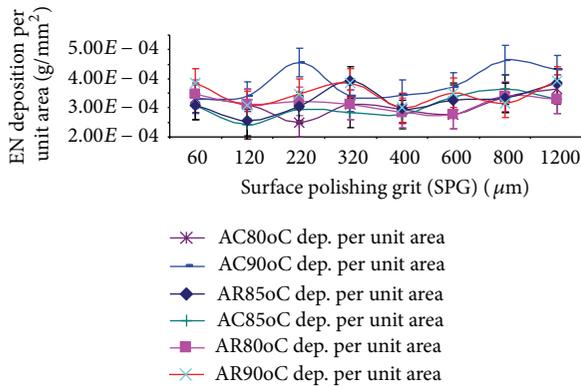


FIGURE 12: Effect of surface polishing grits (SPG) on EN deposition per unit area on as-received Al alloy (AR) and cast Al alloy (AC) substrates at varying temperatures.

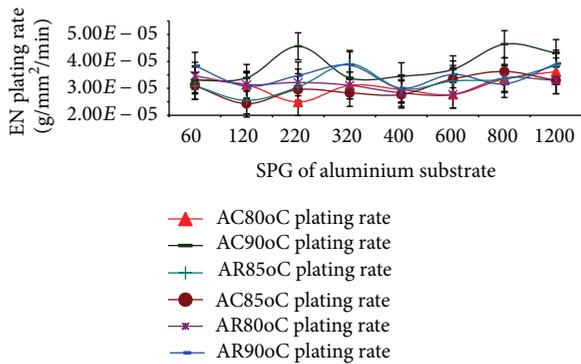


FIGURE 13: Effect of surface polishing grits (SPG) on EN plating rates on as-received Al alloy (AR) and cast Al alloy (AC) substrates at varying temperatures.

The trend of the amount of EN deposited with respect to increasing plating bath temperature and surface polishing grits was studied using the experimental data generated from the experiment. The polynomial fit trend equations obtained from the trend-lines of EN deposition using MS excel application with respect to plating bath temperature

(°C) and surface polishing grits operated at 80°C, 85°C, and 90°C are given in (4) and (5):

$$M_{n1} = 0.0086x^2 - 0.07x + 0.5834, \quad (4)$$

$$M_{n2} = 0.0037x^2 - 0.017x + 0.4614, \quad (5)$$

$$M_{n3} = 0.002x^2 + 0.0019x + 0.5437, \quad (6)$$

where $60 \geq x \geq 1200 \mu\text{m}$, x is the surface polishing grits, and M_{n1} , M_{n2} , and M_{n3} are the amount of EN deposited with respect to plating bath temperatures and surface polishing grits on cast Al alloy in acidic sodium hypophosphite reduced bath operated at 80°C, 85°C, and 90°C, respectively:

$$M_{n4} = 0.0066x^2 - 0.0415x + 0.5054,$$

$$M_{n5} = 0.0066x^2 - 0.0415x + 0.5054, \quad (7)$$

$$M_{n6} = 0.0049x^2 - 0.0432x + 0.6175,$$

where $60 \geq x \geq 1200 \mu\text{m}$, x is the surface polishing grits (μm), and M_{n4} , M_{n5} , and M_{n6} are the amount of EN deposited with respect to plating bath temperatures and surface polishing grits on as-received Al alloy in acidic sodium hypophosphite reduced bath operated at 80°C, 85°C, and 90°C, respectively. EN plating rate on as-received Al alloy and cast Al alloy is not controlled by the increase in level of the polishing grit. The least trend of plating rate is obtained at 85°C producing the best of the adhesion and appearance at SFG of 600 μm and above.

All the plots in Figures 11, 12, and 13 show the values of amount of EN deposition (g), EN deposition per unit area (g/mm^2), and EN plating rate ($\text{g}/\text{mm}^2/\text{min}$), respectively on cast Al alloy and as-received Al alloy substrates measured from different SPG points under varying temperature conditions. The error bars provided indicate the maximum and minimum values recorded from the 48 readings to highlight the extents of fluctuation in EN deposition per unit area and EN plating rate throughout each experiment. For the cast and as-received substrate samples, error bars are within the EN deposition of the SPG point while the standard deviation was not larger than 5%.

4.11. Effect of Surface Activation on Amount of EN Deposition.

Figures 14 and 15 show the variation in the quantity of EN deposit on cast Al alloy substrates in acidic sodium hypophosphite reduced bath using six different reagents as the surface activators. Surfactants are wetting agents that lower the surface tension of a liquid, allowing easier spreading, and lower the interfacial tension between two liquids or a liquid and solid surface. In an EN bath, presence of surfactant promotes the deposition reaction between the bath solution and immersed substrate surface according to Baudrand [11].

In this work, the surface activators used to wash the Al alloy specimen include HCl, NaOH, water, sodium-dichromate, zincate, and palladium chloride solution, before the cast substrates are immersed into the EN plating baths. Figure 3 shows that trend of increase in the quantity of

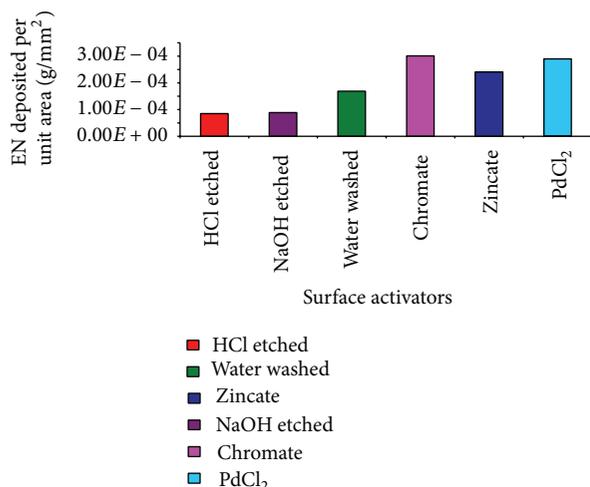


FIGURE 14: EN deposition per unit area on Cast Al alloy substrates using different surface activators.

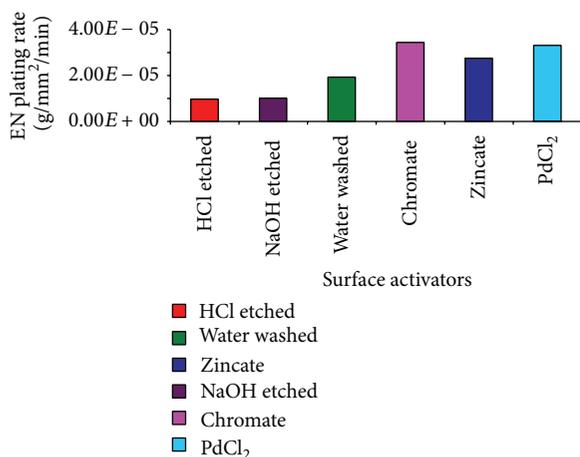


FIGURE 15: EN plating rates on cast Al alloy substrates using different surface activators.

EN deposit is in order of sodium-di-chromate, palladium chloride solution, zincate, water, HCl, and NaOH solution.

It was observed that HCl, NaOH, and water activated cast Al alloy substrates did not yield much substantive quantity and quality of EN deposit as compared with sodium-di-chromate, zincate, and palladium chloride activated cast Al alloy substrates in acidic sodium hypophosphite reduced EN bath. For a 60 μm polished cast Al alloy substrates, the best plating results were obtained in terms of the plating quality (lustre and reflectivity, tenacity, adhesion, and appearance) from the activation of cast Al alloy in the zincate and palladium chloride solutions (Figures 6(e) and 6(f)), though what were gotten in Figure 4 were of lower quality (lustre and reflectivity, tenacity, adhesion, and appearance) as compared with what was obtainable on zincate pretreated cast Al alloy (Figures 5(f) and 8(c)).

Adhesion problem is one of the major experienced challenges of EN plating especially when the substrate is Al alloy. The cast Al alloy has greater challenges of EN plating than the

wrought Al alloy materials. Cast surfaces are specially prepared by cleaning in diverse reagents and followed by surface activation.

Lower plating rates of $8.49E - 06$ g/mm²/min, $8.86E - 06$ g/mm²/min, and $1.69E - 05$ g/mm²/min were obtained from using HCl, NaOH, and water as cleaning reagents. Pure Al and Al alloys will form layer of oxide when exposed to air and water. This oxide reduces the adhesion of EN on the surface. The oxide is reactive to both acid and alkaline; hence they disallow the continuity of autocatalytic reaction at the immediate interface of the EN solution and the substrate. Higher plating rates of $3.01E - 05$ g/mm²/min, $2.41E - 05$ g/mm²/min, and $2.90E - 05$ g/mm²/min were obtained from cleaning with chromate, zincate, and chloride. The highest plating rate is obtained from chromate cleaned substrate but is of worst adhesion quality among the three. Zincate and chloride cleaned Al alloy substrates yielded better quality than chromate cleaned cast Al alloy substrate. Zincating on cast Al alloy substrate prior to EN-plating has been reported to be result oriented and encouraged for better adhesion [16–20].

5. Conclusion

EN has been deposited on the cast Al alloy substrates in sodium hypophosphite bath. With the variation in the surface finishing, it was observed that the quantity of EN deposition is partly dependent on the type and roughness of the surface of the aluminium alloy substrates, whereas the adhesion and brightness are not solely controlled by the surface polishing grits. There are instances where low polishing grit produced better and more tenacious coating than the higher polishing grit. The best yield in terms of the plating quality (adhesion and appearance) was obtained from the activation in zincate and palladium chloride solutions. Higher plating rates (g/mm²/min) of $3.01E - 05$, $2.41E - 05$, and $2.90E - 05$ were obtained from chromate, zincate, and chloride than $8.49E - 06$, $8.86E - 06$, and $1.69E - 05$ as obtained from HCl etched, NaOH, and H₂O activated surfaces, respectively. Zincating on cast Al alloy substrate prior to EN-plating as it has been reported to be result oriented and, hence, encouraged for better adhesion [18–20].

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

The authors would like to express their sincere gratitude to the staff of the following laboratories and establishments such as the Premier Wings Engineering Services, Ado Ekiti, and the Department of Metallurgical and Materials Engineering FUTA, Engineering Materials Development Institute (EMDI), Akure.

References

- [1] I. J. Polmear, *Light Alloys: Metallurgy of the Light Metals*, Arnold, 1995.
- [2] O. O. Ajibola and B. O. Jimoh, "Aluminium recycling industries in Nigeria: entrepreneurship challenges and opportunities," in *Proceedings of the 7th Engineering Forum*, F. I. Aluko, Ed., vol. 2, pp. 238–247, School of Engineering, Federal Polytechnic, Ado Ekiti, Nigeria, November 2011.
- [3] O. O. Ajibola, B. O. Adewuyi, and D. T. Oloruntoba, "Design and performance evaluation wear test jig for aluminium alloy substrate in hydraulic fluid," in *Proceedings of the 8th Engineering Forum, School of Engineering, Federal Polytechnic*, F. I. Aluko, Ed., Ado Ekiti, Nigeria, pp. 85–96, School of Engineering, Federal Polytechnic, 2012.
- [4] O. O. Ajibola, B. O. Adewuyi, and D. T. Oloruntoba, "Wear behaviour of sand cast eutectic Al-Si alloy in hydraulic brake fluid," *International Journal of Innovation and Applied Studies*, vol. 6, no. 3, pp. 420–430, 2014.
- [5] O. O. Ajibola, D. T. Oloruntoba, and B. O. Adewuyi, "Metallurgical study of cast aluminium alloy used in hydraulic brake calliper," *International Journal of Innovation and Scientific Research*, vol. 8, no. 2, pp. 324–333, 2014.
- [6] M. Paunovic and M. Schlesinger, *Fundamentals of Electrochemical Deposition*, Wiley, New York, NY, USA, 1998.
- [7] O. O. Ajibola and D. T. Oloruntoba, "Effects of polishing grades and Saccharin-550 additive on copper electroplating on NST60Mn and NST50⁻² steels," *International Journal of Innovation and Scientific Research*, vol. 8, no. 2, pp. 334–344, 2014.
- [8] D. T. Oloruntoba, *Investigation of electrodeposition of nickel on heat treated low carbon steel substrate. FUTA Thesis [Ph.D. thesis]*, 2009.
- [9] I. Apachitei, F. D. Tichelaar, J. Duszczek, and L. Katgerman, "The effect of heat treatment on the structure and abrasive wear resistance of autocatalytic NiP and NiPSiC coatings," *Surface Coating Technology*, vol. 149, no. 2-3, pp. 263–278, 2002.
- [10] J. Balaraju and S. K. NSeshadri, "Preparation and characterization of electroless Ni-P and Ni-P- SiC composite coatings, Transaction of IMF, 2008, 77, 84, in Pari et al.; study on the performance of electroless nickel coating on aluminium for cylinder liners," Patent F2008-SC-015, 2008, 1.
- [11] D. W. Baudrand, "Electroless nickel plating," in *Surface Engineering*, vol. 5, pp. 954–1010, 1994.
- [12] D. W. Baudrand, R. N. Duncan, and J. R. Zickgraf, *Nickel Electroless Plating, Research & Engineering*, ELNIC, 1986.
- [13] H. Pari, R. Raj, G. Pandiarajan, and E. Rasu, "Study on the performance of electroless nickel coating on aluminium for cylinder liners," Patent F2008-SC-015, 2008.
- [14] S. K. Das and P. Sahoo, "Tribological characteristics of electroless Ni-B coating and optimization of coating parameters using Taguchi based grey relational analysis," *Materials and Design*, vol. 32, no. 4, pp. 2228–2238, 2011.
- [15] T. J. WinowlinJappes, *Studies on electroless Ni-P and Ni-P/diamond composite coatings [Ph.D. thesis]*, IIT Madras, 2004, in Pari et al, Study on the performance of electroless nickel coating on aluminium for cylinder liners, Patent F2008-SC-015, 2008.
- [16] "ThomasNet.com—Electroless Nickel Plating Suppliers," <http://www.thomasnet.com/products/plating-electroless-nickel-61650107-1>.
- [17] M. H. Hafiz and B. S. Mahdi, "Surface preparation of aluminium for plating by Zincating," *Engineering & Technology*, vol. 25, no. 10, pp. 1184–1193, 2007.
- [18] Z. Abdel Hamid and M. T. Abou Elkhair, "Development of electroless nickel-phosphorous composite deposits for wear resistance of 6061 aluminum alloy," *Materials Letters*, vol. 57, no. 3, pp. 720–726, 2002.
- [19] M. Hino, K. Murakami, M. Hiramatsu, K. Chen, A. Saijo, and T. Kanadani, "Effect of zincate treatment on adhesion of electroless Ni-P plated film for 2017 aluminum alloy," *Materials Transactions*, vol. 46, no. 10, pp. 2169–2175, 2005.
- [20] M. Hino, K. Murakami, Y. Mitooka, K. Muraoka, R. Furukawa, and T. Kanadani, "Effect of zincate treatment on adhesion of electroless Ni-P coating onto various aluminum alloys," *Materials Transactions*, vol. 50, no. 9, pp. 2235–2241, 2009.



Hindawi

Submit your manuscripts at
<http://www.hindawi.com>

