



Investigation on the Corrosion Performance of Nickel Electrodeposited Tempered Steel Substrate

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ABSTRACT

The investigation into the corrosion performance of nickel electroplating of low carbon steel substrate in Na_2CO_3 environment was studied. The substrate was heat treated at various tempering temperatures, plated with nickel for 30 minutes and subjected to corrosion in Na_2CO_3 solution. The microstructure and weight loss technique were adopted to evaluate the corrosion susceptibility of the substrate Na_2CO_3 medium. From the results, it was observed that the rate of corrosion of nickel plated tempered low carbon steel substrates is significantly low compared to the control (i.e unplated) sample, couple with the good mechanical properties of the steel confirmed it a good option for engineering applications.

Keywords: *Electro-deposition, Electroplating, Substrate, Tempered.*

1. INTRODUCTION

Steel is an effective, cheap and commercially available materials for structural applications, a large tonnage of commercial steels contains very little alloying elements with carbon composition at varied percentage and thus are classified as low carbon, medium carbon and high carbon steel [2]. Low carbon steel, for example, combines moderate strength with excellent ductility and are used extensively for their fabrication properties in the annealed or normalized condition for structural purposes. Improved low-carbon steels are produced by deoxidizing or killing the steel with Al or Si, or by adding Mn to refine the grain size, the addition of small amount of Nb to reduce the carbon content by forming NbC particles leading to strength improvement by precipitation hardening within the ferrite grains, but at the expense of its corrosion resistivity.

At elevated temperatures, nearly all metals and alloys react with their environment at an appreciable rate to form a thick non protective oxide layer. Molten phases may form on the scale layer, being particularly dangerous because they allow rapid two-way diffusion of reacting

species between the gas phase and the metallic substrate. Wet or aqueous corrosion, in which electrochemical attack proceed in the presence of water, can also destroy metallic surfaces and is responsible for a wide variety of difficult problems throughout all branches of industry.

In an attempt to prevent the steel from corroding, nickel has been one major elements used to plate. It has also been used to decorate, electroform in order to enhance the appearance by means of electro-deposition process. This work is therefore focus on investigation and evaluation of the corrosion performance of nickel electrodeposited on low carbon steel *substrate* in corrosive environment.

2. MATERIALS AND METHODS

Materials

The material used in this investigation is a low carbon steel substrate of chemical composition shown in Table 1. Hydrogen sulphide, sodium carbonate, nickel sulphate, nickel chloride, Boric acid, thinner, Formaldehyde, Distilled water, Saw dust, Copper wire and Binding wire.

Table 1: Chemical Composition of Low Carbon Steel Substrate

Alloy Elements	Composition, Wt%
Carbon	0.180
Silicon	0.100
Sulphur	0.031
Phosphorus	0.038
Copper	0.230
Chromium	0.100
Tin	0.008
Vanadium	0.006
Iron	99.31

Equipment

The equipment used for this investigation includes table lathe machine, table vice, bench grinder, polishing machine, digital weighing balance, multimeter, optical microscope, electroplating rectifier and bath, electrolyte degreasing tank.

Methods

After the substrates was prepared following ASTM G1 and G4 international standard for sample's configuration for corrosion experiment, the low carbon steel was heat treated in electric muffle furnace following a conventional procedures. After setting aside two (2) samples, all other samples were normalized at 900C, this is to annul the mechanical history and restore the structural homogeneity of the material. It was re-heated to the same temperature and quenched in water. It was subsequently tempered by heating it up to different temperatures of 400°C, 500°C and 600°C. At each stage, the samples were allowed to cool slowly in air. A minimum of two (2) samples each were treated at each tempering temperature for certainty. The tempered samples were pickled in 0.5M H₂SO₄ solution for 120 seconds and then rinsed in distilled water and degreased for 120 seconds before rinsing it with distilled water. The initial weight was observed using a digital weighing balance and recorded. The laboratory Nickel electroplating bath was stirred with the aid of a stirrer for 60 seconds. The samples were connected to the cathode

arm of the Nickel electroplating bath with the aid of a flexible copper wire and there after switching on the electroplating rectifier and control to a constant supply voltage of 2.0 Volts. The steel substrate was allowed to stay in the bath for 30 minutes, then dried in air and reweighed. The microstructures were captured using optical microscope of model number 702907 and analyzed before subjecting it to corrosion in a predetermined concentration of Na₂CO₃ and observed for 30 days at an interval of 5 days. The generated data were evaluated using a standard formular:

$$C.R = \frac{\text{Weight loss (mg)}}{\text{Exposed Total Surface Area (A)} * \text{Exposure Time (days)} / 360}$$

3. RESULTS AND DISCUSSION

Figure 1 shows the weight of the treated substrate before and after nickel-plated. From the result, it can be observed that the amount of nickel deposition on the material varies with the tempering treatments giving to the substrates. It was observed that the amount deposited on the sample tempered at 600°C (plated steel) has the highest weight gained of 1.79g. Implying that this sample has a larger amount of film deposited on the surface of the substrate which thus will retard the rate of corrosion attack on the sample.

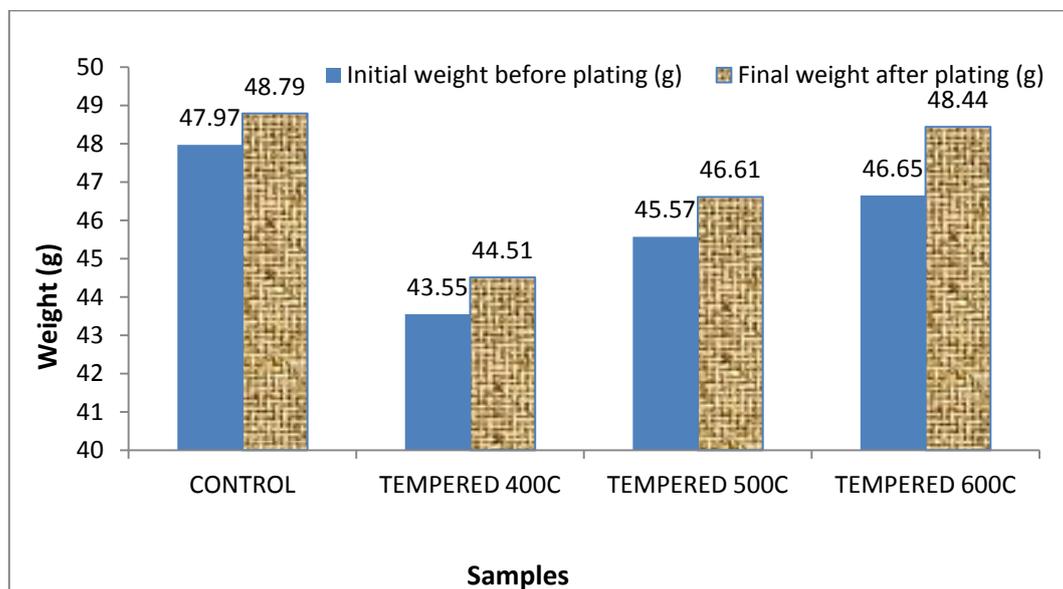


Fig. 1: variation of the weight of the substrate before and after plating

Plate 1 shows the micrograph of the control sample (untreated) of low carbon steel substrate. The structure is observed to exhibit a coarse. Because of the larger grain size of the substrate, the limitation or resistance of electrons to penetrate through the boundary will be low thus reducing its resistance to corrosive attack over a long period. This is in agreement to the findings from literature

review ^[1]. A tetragonal lattice structure –martensite– is formed (plate 2(a)) with interstitial carbon in solid solution and high dislocation density formed by shear^[3], this is as result of the rapid cooling the steel is subjected to thus leading a fine structures with more grain boundaries that allow for nickel penetration on the surface of the substrate (plate 2(b)) and protect the surface of the substrate from

the attack of the Na_2CO_3 solution. The microstructure result after tempering at 400°C is shown in plate 3(a and b). Here, cementite precipitates start to nucleate, and the dislocation density reduces, martensite loses its tetragonality, and low-C martensite becomes b.c.c. ferrite and above 400°C (Plates 4 and 5), carbide precipitates coarsen and spheroidise, ferrite starts to recrystallise^[4] and residual stresses decrease. The finer (compared to the quenched sample) structures formed after tempering results in more grain boundaries, accommodating more electron flows of the nickel electrodeposits thereby coating

the surface and preventing it from corrosion attack. From the selected range of tempering temperatures, the results show that the lower tempering temperature absorbed less deposits on its surface while the highest tempering temperature absorb more deposits, these is in proportion to the size of the grain and the volume of the grain boundaries formed. These imply that the selected substrate, when tempered, will resist corrosion for longer period of time in the presence of Na_2CO_3 . Therefore, it is a very good substrate for engineering applications^[1].

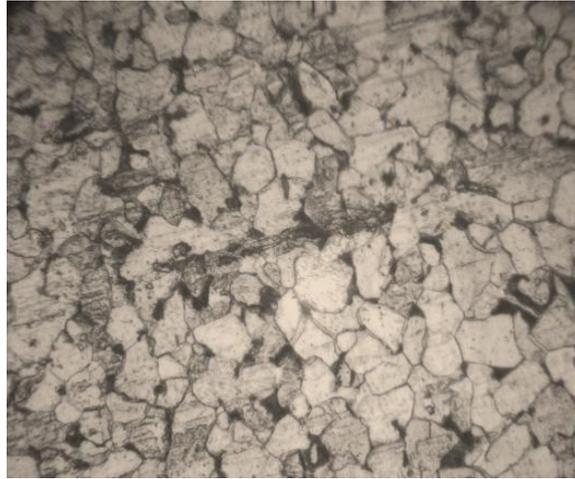


Plate 1: Microstructure of Normalised Low Carbon Steel Substrate (Control)



Plate 2(a): Microstructure of Quenched Low Carbon Steel Substrate before *plating*

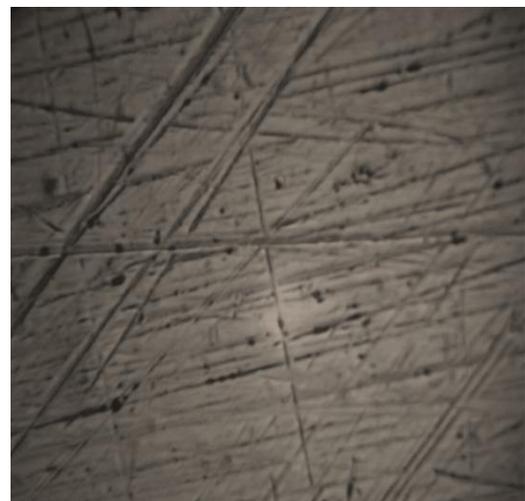


Plate 2(b): Microstructure of Quenched Low Carbon Steel Substrate after *plating*



Plate 3(a): Microstructure of Tempered (400⁰C) Low Carbon Steel Substrate before plating



Plate 3(b): Microstructure of Tempered (400⁰C) Low Carbon Steel Substrate after plating



Plate 4(a): Microstructure of Tempered (500⁰C) Low Carbon Steel Substrate before plating

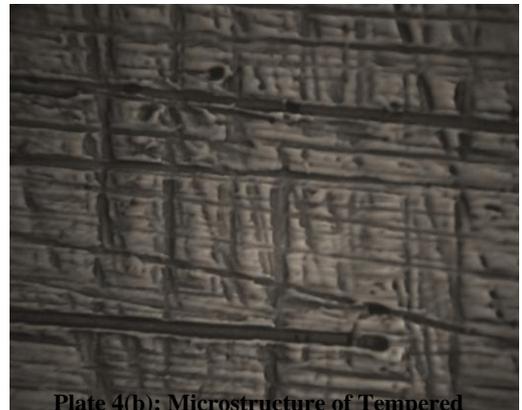


Plate 4(b): Microstructure of Tempered (500⁰C) Low Carbon Steel Substrate after plating



Plate 5(a): Microstructure of Tempered (600⁰C) Low Carbon Steel Substrate before plating.



Plate 5(b): Microstructure of Tempered (600⁰C) Low Carbon Steel Substrate after plating

Figure 2 – 4 shows the variation of electroplated steel sample in a solution of Na_2CO_3 . It was observed that tempering is a major factor in the accessing corrosion

susceptibility of steel substrate. For clarity, the plots were superimposed with the plot of the corrosion sample. The tempered samples were observed to have a significant

increase in its corrosion resistance to Na_2CO_3 attack. The electroplated samples still show a further resistance until day 20 when the whole samples converge at their minimal point and subsequently proceed at a constant rate.

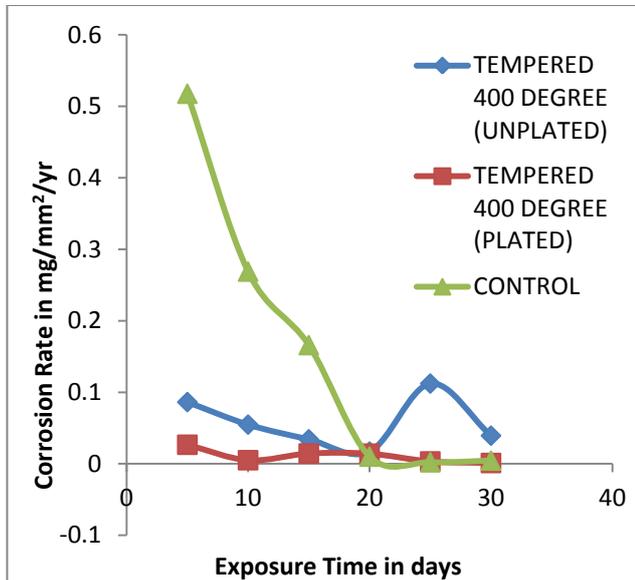


Fig. 2: Variation of corrosion rate for tempered (400°C) low carbon steel substrate in Na_2CO_3 solution.

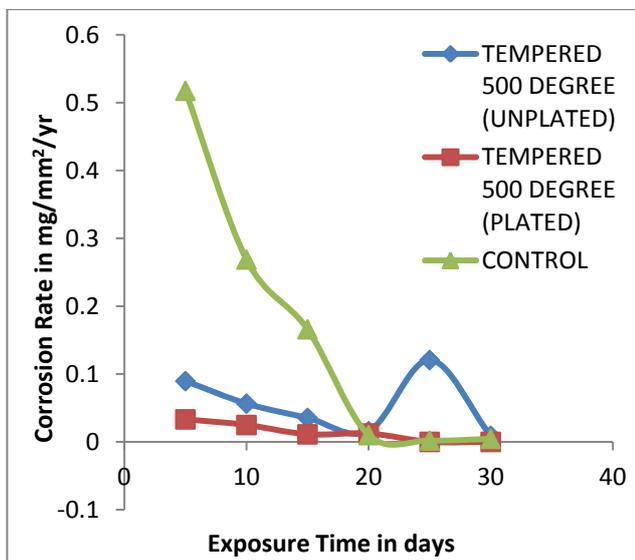


Fig. 3: Variation of corrosion rate for tempered (500°C) low carbon steel substrate in Na_2CO_3 solution.

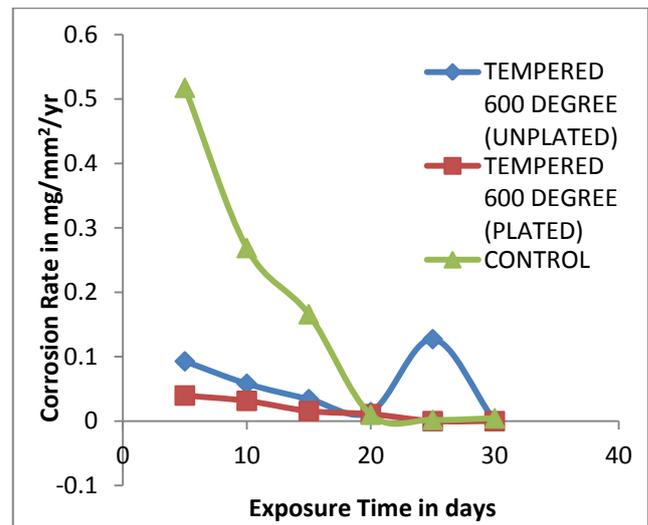


Fig. 4: Variation of corrosion rate for tempered (600°C) low carbon steel substrate in Na_2CO_3 solution.

4. CONCLUSION

The investigation into the corrosion performance of nickel electroplating of low carbon steel substrate in Na_2CO_3 environment was studied. The substrate was heat treated at various tempering temperatures, plated with nickel for 30 minutes and subjected to corrosion in Na_2CO_3 solution. Optical microscope was utilized to access the weight of nickel deposited on the surface of the substrate, while corrosion rate approach was used to evaluate the resistance of the plated substrate in the selected medium. From the results, it was observed that the rate of corrosion of nickel plated low carbon steel substrates is significantly low compared to the control (i.e unplated) sample, couple with the good mechanical properties of the steel confirmed it a good option for engineering applications.

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