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OPTIMIZING HOT DIP GALVANIZING OPERATIONS OF STEEL SHEETS FOR BETTER QUALITY

O.R. ADETUNJI

Mechanical Engineering Department, University of Agriculture, Abeokuta, Nigeria.
E-mail: adetunjiolayide@yahoo.co.uk; adetunjior@unaab.edu.ng

ABSTRACT

Hot dip galvanizing operations were conducted in the laboratory for steel sheets of 0.20 mm, 0.60 mm and 1.0 mm thicknesses. The operations were carried out using 99.8% zinc with small amounts of aluminium addition at 450°C for 1.0 min immersion duration at withdrawal speeds of 3 m/min, 4 m/min and 5 m/min. Steel plates were withdrawn into a clean area in an open space where they were rapidly cooled. The quality of the galvanized coatings produced was evaluated by their appearance, lustre and uniformity. The results obtained showed varying quality parameters for different thicknesses. Gauges 18, 22 and 28 steel sheets had best quality in terms of coating lustre and uniformity at respective withdrawal speeds of 3m/min, 4 m/min and 5 m/min. The differences in the heat capacities of different gauges led to their different responses in cooling time which accounted for the results obtained.

Keywords; Temperature, withdrawal speed, coating, uniformity, quality.

INTRODUCTION

Protection of steel from rust through hot dip galvanizing is an age long activity. Many methods of protecting steel from corrosion are possible. Such methods are painting, electroplating, alloying addition (for example, nickel or chromium), cathodic protection (using sacrificial anodes or impressed currents) or by coating with a thin layer of corrosion resistant metal. Many current corrosion control measures use coatings, conversion layers, material selection, design, cathodic protection, inhibition and environment alterations among other control measures (Lawal *et al.,* 2006, Lee and Charackhs, 1993 and Abiola and Oforkar, 2002). A galvanized steel sheet includes a galvanized coating layer. The zinc phosphate or chromate coating layer contains from about 0.5 to 10.0% by weight of magnesium, from about 0.1 to 2.0% by weight of nickel, and from about 0.5 to 8.0% by weight of manganese (US Patent 6322906, 2001). The performance of galvanized coating is known to depend to a large extent upon the nature of the environment to which it is exposed. However, for any specific exposure condition the thickness of galvanized coating is the most important factor determining its life of corrosion protection (Wall, 1989). Galvanized coating comprises an outer 'pure' zinc layer and several inner alloy layers of iron and zinc inter-metallic phases, the layers becoming successively richer in iron with depth. The role each of these layers plays in the overall corrosion performance of the galvanized coating is not yet agreed upon (Burns and Bradley, 1967).

The thickness of the alloy layers increases with increase in galvanising temperature and immersion time and is affected by certain bath additives (Adetunji *et al.,* 1992). Aluminium diminishes the relative thickness of the iron-zinc alloy layer in the coating by reducing the solubility of iron in zinc, thereby increasing the ductility of the coating since the iron-zinc layer is brittle. It is also known to increase coating adhesion. The thickness of the outer layer is determined by the bath temperature and the speed of withdrawal from the bath. Small amounts of some metals when present in the zinc bath may influence both the rate of alloying with iron and the character of the zinc coating so produced. Notably among such metals are aluminium and/or antimony which are usually added to the galvanizing bath to achieve an improvement in appearance and adherence of the coating (Hanna and Nassif, 1983).

This research aims at determining the effect of withdrawal speed on the overall quality of hot dip galvanized steel sheets with regards to sheet metal thickness.

MATERIALS AND METHODS

Materials

Steel sheets of compositions and thicknesses shown in Table 1 were cut into 3 cm x 3 cm sheets. A 2 mm hole was drilled at 2 mm to the edge of each sheet on the vertical central line to facilitate easy withdrawal from the bath using steel and copper wires, with steel wire attached to the sheets while the copper wire was attached to the motor's pulley. The two wires were joined together.

Laboratory Galvanizing Equipment

The equipment for galvanizing consisted of the following materials: A carbolite vertical furnace (0-1000^{o}C) was used to melt the zinc ingots. A cylindrical steel crucible was used to hold the zinc and lead inside the furnace. An electric (d.c.) motor was used to automate the withdrawal of sample during galvanizing. A d.c. power source provided electric power to the electric motor. Steel and copper wires facilitated easy withdrawal of samples. A rheostat used to vary speed of electric motor. Nitrogen gas cylinder was used to provide nitrogen gas to wipe the surface of molten zinc from oxidation. Valve was used to switch on and switch off the electric circuit while glass and rubber tubes conveyed gas and water.

Pre treatment Operations

The steel sheets were degreased by dipping them in 99.7% ethanol solution for thirty minutes to remove all traces of grease and oil. The degreased sheets were pickled in 15% hydrochloric acid solution for thirty minutes to remove scale and oxidation products from the samples. The acid concentration was kept constant at 15% by periodic additions of concentrated acid. A pH of 2.0 was maintained.

The samples were rinsed under running tap water for ten minutes to remove all traces of iron salts formed by pickling. The samples were then dipped in aqueous zinc ammonium chloride solutions (prepared by mixing 3 moles of ammonium chloride with 1 mol of zinc chloride). The fluxed steel sheets were dried on the magnetic hot plate at 100^{o}C for one minute.

Galvanizing Procedure

Zinc ingot (99.8% Zn) was charged into the steel crucible with one percent by weight of pure lead which was put in the bottom of the cylindrical crucible. The crucible was put in the carbolite vertical furnace and covered with a refractory material. The furnace was then switched on till the set galvanizing operations were completed. The three gauges of the samples galvanized at 450°C, for 1 min and withdrawn at speeds of 3 m/min, 4 m/min, and 5 m/min.

Low pressure and high volume of nitrogen gas was injected to the bath surface as a cover during immersion, in addition to the protection against oxidation by the flux. The oxidation of the molten zinc was found to reduce tremendously.

The galvanized samples were withdrawn into a clean area in an open space where they were normalised. They were later dipped into a dilute solution of potassium dichromate for passivation except one set of sheets galvanized at 450°C for 1 min and withdrawn at 3 m/min. the thickness of the coatings were measured by micrometer screw gauge. They were stored in a dessicator for preservation before testing.

RESULTS AND DISCUSSIONS

Coating Quality

The quality of the coatings produced was evaluated by their appearances, lustre and uniformity. The uniformity of the coatings was determined by finding the difference between the thickest part of the coating and the thinnest on the same side. If the difference is within 2 μm, the coating's uniformity is regarded as being very good whereas if it is within 5μm, it is termed good. Within 10 μm difference in thickness on the same side, the coating is described as fair while poor uniformity is ascribed to the difference exceeding 10 μm. Lustre which is the degree of shineness of the samples was evaluated by physical appearance. The carbon and silicon contents of the steel galvanized had no negative effect on the results obtained as values were within mild steel classification. The results obtained are summarized in Tables 2 to 4.

Uniformity against withdrawal speeds and Lustre against withdrawal speeds are given in Figures 1 and 2 while the overall quality plot (lustre + uniformity) against withdrawal speeds is given in Figure 3.

Table 1: Composition and thicknesses of steel sheets

Gauge No	Thickness (mm)	% (Carbon)	% (Silicon)
18	1.0	0.15	0.09
22	0.6	0.15	0.33
28	0.2	0.15	0.55

Table 2: Quality of gauge 28,22 & 18 samples galvanized at 450 ^oC, 1 min duration and 3m/min withdrawal speed

Sample code	Temp. (C)	Immersion time (sec)	Withdrawal speed (m/min)	Coating thickness (μm)	Coating intensity (g/m2)	Lustre	Degree of Uniformity
A1	450	60	3	75	538	2	1
B1	450	60	3	70	509	2	1
C1	450	60	3	101	722	2	3

Note: Poor- 1, Fair- 2, Good- 3, V. Good- 4.(degree of uniformity and lustre)
A-28 Gauge,B-22 Gauge and C-18 Gauge, Withdrawal speed of 3m/min is indicated by 1

Withdrawal Speed

The quality improves with increase in withdrawal speed. The best quality was obtained at 5 m/min for gauge 28, 4 m/min for gauge 22 and 3 m/min for gauge 18. The variation of withdrawal speeds with the quality of the coating for gauge 28 showed thinnest sheets (0.2 mm) require higher speed with shorter drainage period owing to its lower heat capacity.

Table 3:Quality of gauge 22 samples galvanized at 450 ^oC at 1 min duration and various withdrawal speeds

Sample code	Temp. (C)	Immersion time (sec)	Withdrawal speed (m/min)	Coating Thickness (μm)	Coating intensity (g/m2)	Lustre	Degree of Uniformity
B1	450	60	3	70	509	2	1
B2	450	60	4	81	610	3	3
B3	450	60	5	85	640	2	3

Note: Poor- 1, Fair- 2, Good- 3, V. Good- 4(degree of uniformity and lustre), Withdrawal speed of 4 m/min is indicated by 2 while that of 5 m/min is indicated by 3.

Table 4: Quality of gauge 28 & 18 samples galvanized at 450 °C for 1 min duration at various withdrawal speeds.

Sample code	Temp. (C)	Speed m/min	Thickness (μm)	Coating intensity (g/m2)	Lustre	Degree of Uniformity
A1	450	3	75	538	1	1
A2	450	4	80	630	2	3
A3	450	5	85	650	2	4
C1	450	3	101	722	2	3
C2	450	4	103	726	2	2
C3	450	5	105	730	1	2

Note: Poor- 1, Fair- 2, Good- 3, V. Good- 4.(degree of uniformity and lustre),Afor 28G and C for 18G.

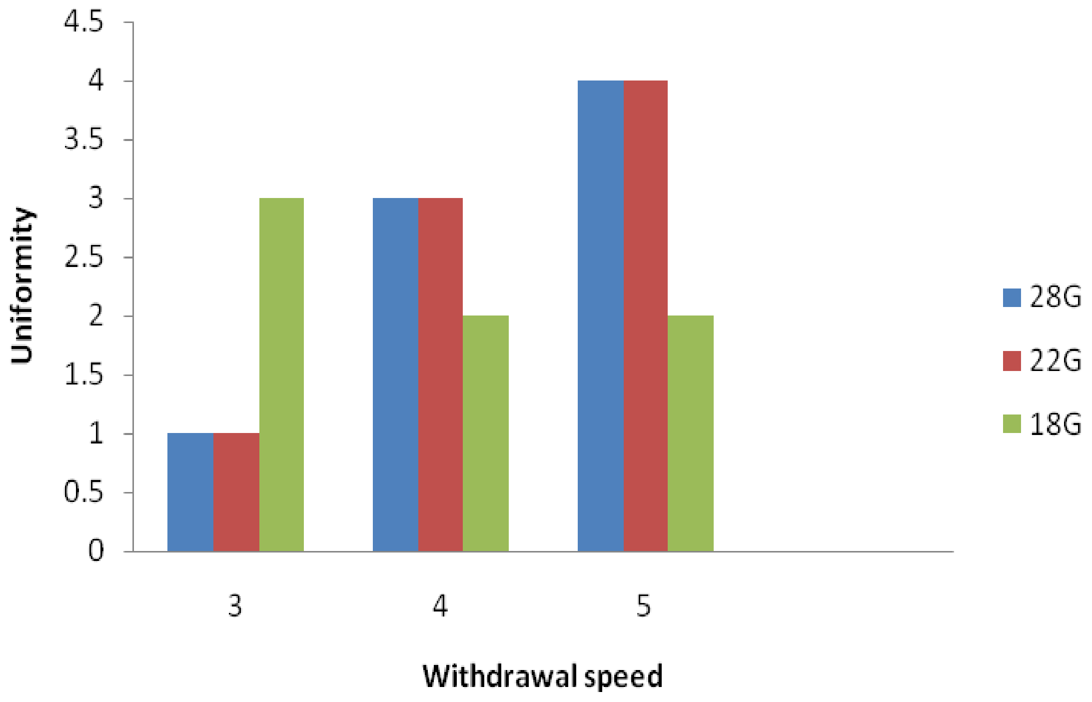

Figure 1: Plot of degree of uniformity against withdrawal speeds at 1min immersion

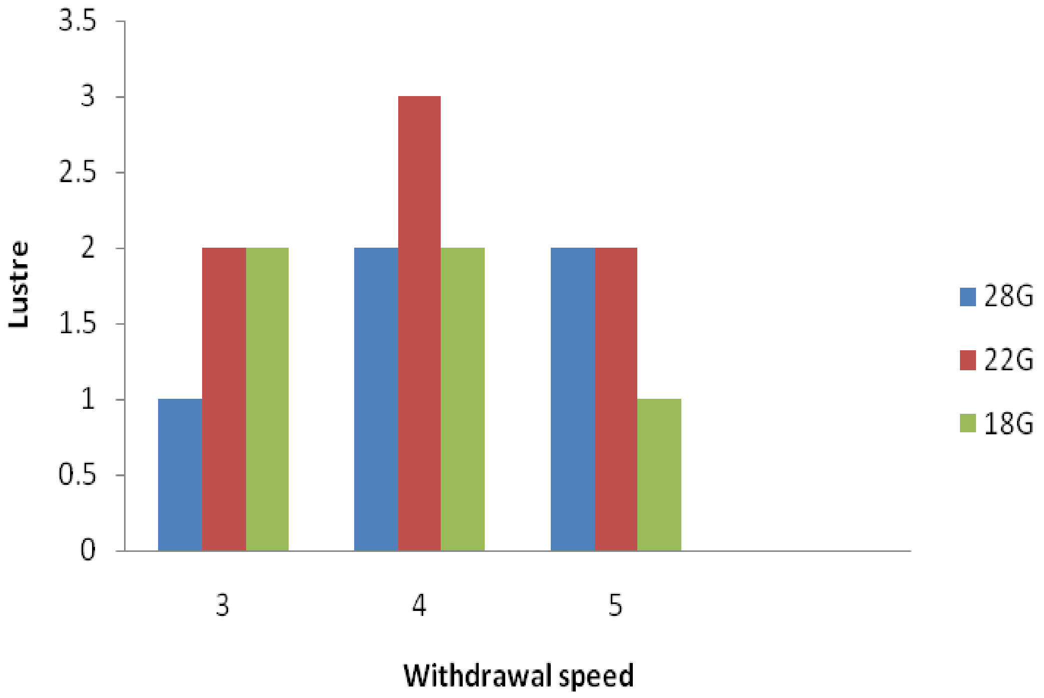

Fig. 2: Plot of lustre against withdrawal speeds at 1 min immersion

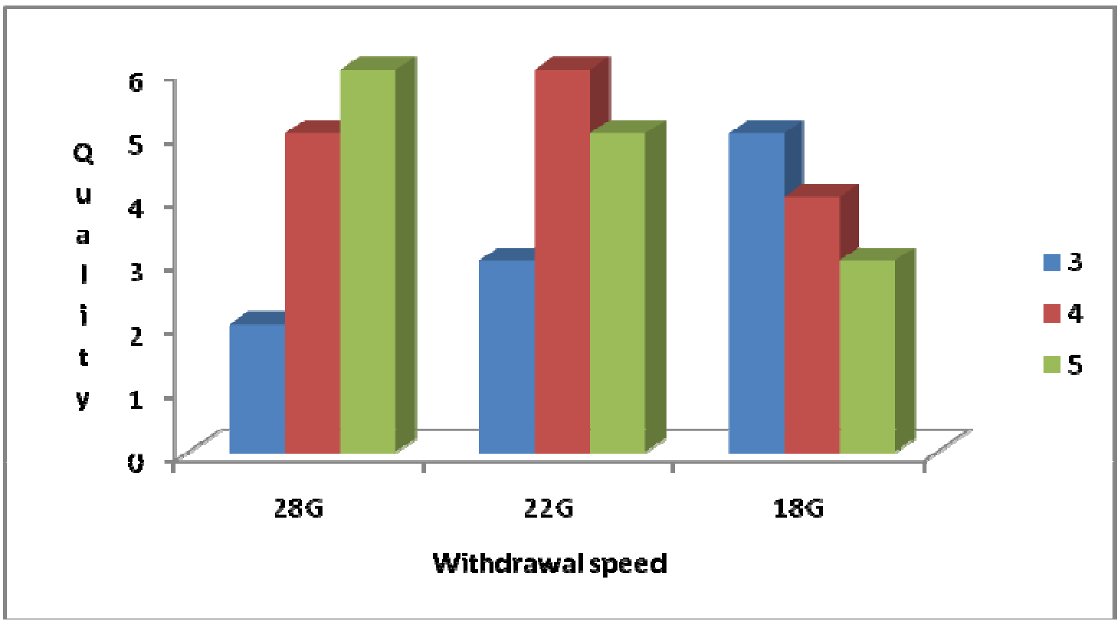

Figure 3: Plot of quality (lustre + uniformity) against speeds at 1 min immersion

CONCLUSION

The hot dip galvanized coatings in terms of lustre and uniformity determine their quality irrespective of their thicknesses. Correlating withdrawal speed with steel sheet thickness is found to improve quality of galvanized steel sheet products. Thus, the overall quality of steel sheets galvanised at 450 ^{o}C for 1 minute immersion time was best at withdrawal speeds of 3 m/min,4 m/min and 5 m/min for gauges 18,22 and 28 sheets respectively.

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