Affecting Factors on Gloss Value for Galvanized Cold Rolled Sheets

Özgür KARAKAŞ[a*] , Erdogan KANCA[b], İbrahim GÖÇER[a], Alper AKÜN[a], Erkan PÜGE[a], Güzin Müge LÜLE[a], Ali DOĞAN[a], Ahmet ÖZDEMİR[a]

[a]*MMK Metalurji San. Tic. ve Liman İştl. A.Ş. Dörtyol, Hatay, Turkey, okarakas@mmkturkey.com.tr*

[b]*Mechanical Engineering Department, Iskenderun Technical University, Hatay, Turkey,kancaerdogan@gmail.com*

***Abstract*— Flat steel products are coated with zinc to ensure decorative requirements and prevent the steel from corrosion. Galvanized cold rolled (GCR) sheets has three main characteristics for decorative requirements, these are metallic effect, spangle and gloss. High gloss value is one of effective parameter on the customer demand.**

In order to define influencing factors on gloss value, GCR sheet samples, with different dimensions and produced with different parameters, had been taken. Influencing factors such as zinc coating mass, sheet thickness, chemical composition of zinc coating, line speed were investigated under constant zinc pot metallurgy conditions.

This study finds out increase in strip thickness and Al% content of zinc coating leads to increase in gloss value, increase in coating mass leads to decrease in gloss value and gloss-line speed data gives a Gaussian curve where the gloss value reaches a maximum magnitude at about 100 m/min.

***Keywords:* Galvanized Cold Rolled, Gloss, Zinc, GCR, Zinc Pot, Coating Mass.**

I. INTRODUCTION

Galvanization is the process of applying zinc coating on steel to prevent corrosion. In addition to corrosion inhibition effect, zinc coating gives aesthetic metallic surface to steel. This metallic surface is also used to meet decorative requirements and has become a customer request over the years for applications like roofing, culvert pipes, panels, building sidewall panels, flashing doors etc. There are three different decorative expectations; metallic effect, spangle and shine. Metallic effect is come from zinc color in any case. As the Zn coating on a steel sheet solidifies, dendritic crystals grow around a core of solidified Zn, and in some cases, a flower-like pattern called "spangle" forms on the surface of the galvanized sheet. [1]. Shine is the ability of light reflection through galvanized surface [2]. The appearance of the coating (matte grey, shiny, spangled) does nothing to change the corrosion protection of the zinc coating [3].

There are two different production types according to application of zinc to steel surface. One is hot dip galvanizing which structural steel pieces are dipped into a molten zinc bath, held there until the temperature of the steel equilibrates with that of the bath and cooled down. The second is continuous hot dip galvanizing which is applicable to strip and where strip passes through a zinc bath as continuous.

Continuously galvanised steel sheets are defined in EN 10346-Continuously hot-dip coated steel flat products – Technical delivery conditions, but shine or gloss is not a specified characteristic of the product in this standard [4]. Also there is no quantitative specification to evaluate the appearance of galvanized sheet. Only, International standard ISO 14713-2:2009 divides coating characteristics into two groups relating to steel chemical composition: 1) Coating has a shiny appearance with a finer texture. Coating structure includes outer zinc layer. 2) Coating has a darker appearance with a coarser texture [5]. Whereas shine is a requested property for galvanised sheet by consumers in the market.

For example, shinier galvanized sheets are preferable for the producer of panels according to MMK Metalurji customer request analyse [6]. Because, it is known that "Consumers focus increasingly on the visual appearance of product features and often evaluate the product quality and performance based on this [7].

For some constructions the visual homogeneity is important. However, the ones, which are composed of galvanized sheet with different thickness and coating mass, have shine difference between parts of the body. Fig. 1 shows a silo which has dull and shiny parts on the body.

Fig.1 A Silo with dull and shiny parts

In batch hot dip galvanizing, it is known how to make shine or dull appearance by the help of studies about this issue. In batch galvanizing, shiny surface is directly related to free zinc layer and this layer depends on steel chemistries (with a typical

levels of silicon, phosphorus, manganese & carbon), zinc bath chemistries, cooling time and withdrawal speed [8].

However, study, about shine property of continuous galvanized sheet, had not been found during literature research. On the other hand, parameters of production may change shine of surface relatively like Fig.3. This difference between two images on galvanized surfaces is a significant visual variation which is big enough to effect customer's aesthetic expectations.

Although the human eye is still the most capable instrument, automated gloss measurement is needed for quantitative and reliable quality control in industrial settings [9]. Under this article's test and assessment method title, determination of the best proximate evaluation method is discussed.

In this study, gloss change of continuously galvanized steel surface was examined according to parameters like line speed, strip thickness, coating thickness and Al% content of coating.

II. EXPERIMENTAL STUDIES

C. *Materials*

DX51D+Z grade steel sheets samples were used in the study produced by MMK Metalurji hot dip galvanizing line. Mechanical and chemical specifications of DX51D steel grade are given in Table 1 and Table 2 respectively.

TABLE 1
DX51D STEEL GRADE MECHANICAL SPECIFICATIONS

Tensile Strength (N/mm²)	Elongation (%) Min.
270 - 500	22

TABLE 2
DX51D STEEL GRADE CHEMICAL SPECIFICATIONS (MAX.)

C%	Si%	Mn%	P%	S%	Al%
0,18	0,50	1,20	0,12	0,045	0,030

D. *Devices and Equipment*

Sheet samples used in the study were prepared with hydraulic punch press which has 75 mm x 75 mm cut dimension. AND brand GR200 model precision scales (0,0001g precision) were used for weighing samples. Samples thickness had been measured with Horex brand IP54 model thickness gauge. Composition of the zinc coating was analysed with Varian brand ICP-OES 710-ES axial spectrometer. Gloss values were measured at 20 ° with BYK TRI-glossmaster device Fig. 2.

Fig. 2 Glossmaster™ Gloss Meter

E. *Chemicals*

Analytical Grade %36,5-38 HCl (Sigma-Aldrich brand) and %99 Hexamethylenetetramine (Merck brand) as an inhibitor were used in order to solubilise zinc coating from samples. Mutli-element Standard Solution IV (Merck brand) was used to create a method with ICP-OES 710-ES axial spectrometer.

F. *Test and Assessment Method*

Shine property measurement method and optical properties of different surfaces are widely studied especially by the glossmeter manufacturers from beginning of 20th century up to now.

Hunter R. S., in 1937 described six different kinds of gloss: (1) specular gloss, (2) sheen, (3) contrast gloss, (4) absence-of-bloom gloss, (5) distinctness-of-reflected-image gloss, (6) absence of-surface-texture gloss. He indicated that both metallic and nonmetallic surfaces exhibit specular reflectance [10].

Linke B., in 2016 investigated the gloss measuring systems of different surfaces and also metallic surfaces for determination of quality defects on metal surfaces by gloss measurements. For her purpose she used specular glossmeters with the angels 60° and 20° [11]

In the technical catalogue of glossmeter suppliers it is indicated that gloss measurement is available at 20° angle for the metallic surfaces which have mirror effects [12, 13]

Considering studies above, 20° and 60° gloss measurements are done and the most compatible angle with human eye is decided. The photo on the left gives 97 GU at 60° and 207 GU at 20° and the one on the right which is shinier gives 116 GU at 60° and 423 GU at 20°. 20° angle is decided to use because of its distinctiveness even for small shine differences for human eye Fig. 3.

Fig. 3 A photo of a dull and a shiny galvanize samples

The dimensions of related galvanized steel test specimens were 75 mm x 75 mm. Minimum 5 test specimens had been prepared for each parameter. Gloss values were calculated as an average of 3 different points' measurement values by glossmaster device on each test specimen in accordance with EN 13523-2. Zinc coating mass analyses were done in accordance with EN 10346.

Thicknesses of test specimens were measured with calliper gage. Zinc pot metallurgy and coating compositions were analysed by in ICP-OES (inductively coupled plasma optical emission spectrometry) device in accordance with TS EN ISO 3815-2 [14] .

Influencing factors such as zinc coating mass, sheet thickness, chemical composition of zinc coating, line speed were investigated under constant zinc pot metallurgy conditions Table 3.

TABLE 3
ZINC POT METALLURGY OF MMK METALURJI

%Al	%Cd	%Fe	%Pb	%Sb
0,22-0,25	0,003	0,0400	0,0200	0,0040

1) Effects of Zinc Coating Mass on Gloss Value: In this part, effect of zinc coating mass on gloss value was investigated with test specimens which have constant thickness 1.00 mm and variable zinc coating mass range between 80 – 300 gr/m^2 (Total Number of Samples: 25).

2) Effects of Sheet Thickness on Gloss Value: Effect of strip thickness on gloss value was studied under constant coating mass 100 g/m^2 (Total Number of Samples : 50)

3) Effects of Al% concentration of Zinc Coating on Gloss Value: Al% concentration of samples with different strip thickness and coating mass were analysed and gloss value of each sample is recorded. (Total Number of Samples: 29)

4) Effects of Line Speed on Gloss Value: In this part, effects of line Speed value was investigated on 36 test specimens which are randomly collected from HDG line products. The gloss values are measured and recorded.

III. RESULTS

1) Effects of Zinc Coating Mass on Gloss Value: Gloss value decreases by increasing coating mass as shown in table 4 and Fig. 4.

TABLE 4
GLOSS VALUES OF DIFFERENT COATING MASS

Coating Mass (g/m^2)	Average Gloss @20°	Sample Number
80	441	5
100	355	5
140	262	5
275	171	5
300	127	5

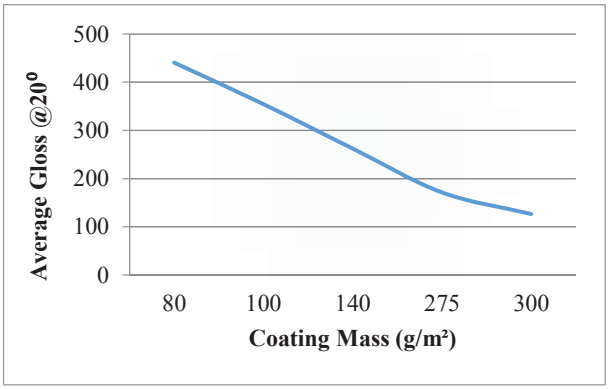

Fig. 4 Average Gloss – Coating Mass Graph

2) Effects of Sheet Thickness on Gloss Value: Increasing coil thickness results an increase at gloss value as shown in Table 5 and Fig 5.

TABLE 5
GLOSS VALUES OF DIFFERENT THICKNESSES

Thickness	Average Gloss @20°	Sample Number
0,43	249	5
0,50	222	5
0,60	288	5
0,80	332	5
1,00	261	5
1,20	447	5
1,35	467	5
1,40	384	5
1,90	530	5
2,00	467	5

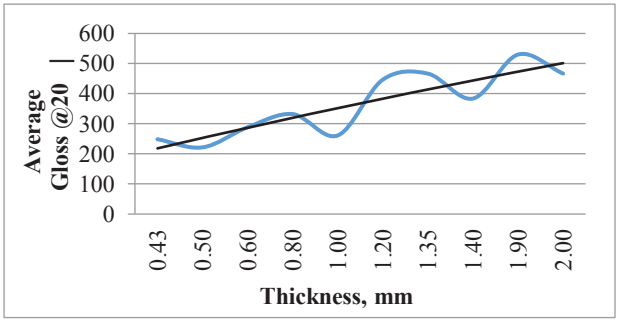

Fig. 5 Average Gloss – Sheet Thickness Graph

3) Effects of Al% concentration of Zinc Coating on Gloss Value: Increasing Al% content in the coating causes an increase on gloss value. The data regarding the effect is given in Table 6 and the graph in Fig. 6.

TABLE 6
GLOSS VALUES OF DIFFERENT AL % CONCENTRATION OF COATING

Al % Conc. of Coating Mass	Gloss @20°
0,28	139
0,31	267
0,32	257
0,33	197
0,34	253
0,35	262
0,35	161
0,36	256
0,36	178
0,41	236
0,46	206
0,48	259
0,48	224
0,50	272
0,51	266
0,52	211
0,53	257
0,53	171
0,55	229
0,56	459
0,59	265
0,61	513
0,62	493
0,64	537
0,67	469
0,69	669
0,71	527
0,73	739
0,81	596

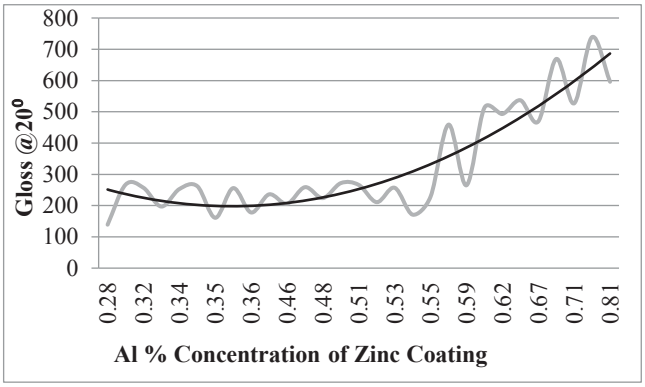

Fig. 6 Gloss – Al% Concentration of Zinc Coating Graph

4) Effects of Line Speed on Gloss Value: Line speed vs gloss values gives a Gaussian curve where gloss value increases up to a top magnitude at about 100 m/min and decreases then by increasing line speed, see, Table 7, Fig. 7.

TABLE 7
AVERAGE GLOSS VALUES OF GALVANISED SHEETS PRODUCED AT DIFFERENT LINE SPEEDS

Average Gloss @20°	**Line Speed (m/min)**
210	55
336	77
529	99
288	134
253	180

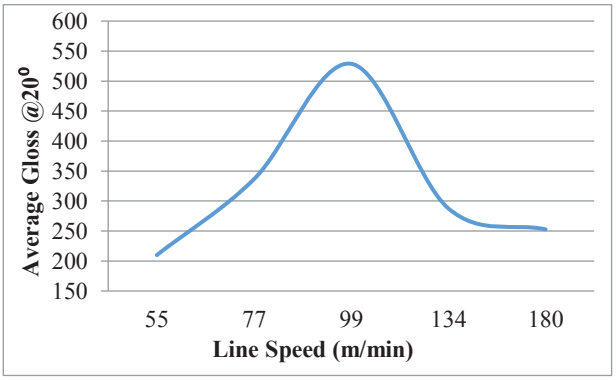

Fig.7 Average Gloss – Line Speed Graph

IV. CONCLUSIONS

This study finds out that gloss value increases by increasing sheet thickness, increasing Al% in the zinc coating and

decreasing coating mass. Also, line speed value is effective on gloss. The gloss of the galvanised sheet increases up to a certain line speed value like 100 m/min and tends to decrease on the line speeds bigger than 100 m/min.

Gloss is one of the leading decorative property on customer demand but unfortunately it depends on the customer order characteristics like sheet thickness, coating mass etc. which determines the line speed and Al% concentration of the coating during the galvanised sheet production.

According to the results of this study, in a conventional continuous hot dip galvanising line with the capacity 30 to 180 m/min line speed, 70 to 600 g/m^2 coating mass and 0,25 to 3 mm strip thickness, the most glossy (shiny) product can be obtained with the production parameters between 90 to 110 m/min line speed, 70 to 80 g/m^2 coating mass and 0,95 to 1,24 mm strip thickness.

ACKNOWLEDGEMENTS

This study was supported by MMK Metalurji San. Tic. ve Liman İşlt. A.Ş. The authors would like to thank MMK Metalurji CEO Mr Denis Kvasov for providing opportunity for this study.

REFERENCES

[1] Tobiyama Y., Abotani K., 2004, Hot-Dip Galvanized Steel Sheet with Excellent Surface Quality for Automotive Outer Panels, JFE TECHNICAL REPORT, No.4
[2] Koleske J. V., Paint and Coating Testing Manual, 2nd edition 2008, ASTM International
[3] STEEL INTERCHANGE, AISC's Steel Solutions, 2003
[4] EN 10346 Continuously hot-dip coated steel flat products – Technical delivery conditions
[5] S. Sepper, 2011 Methods for evaluating the appearance of hot dip galvanized coatings, Agronomy Research Biosystem Engineering Special Issue 1, 229-236
[6] MMK Metalurji Customer Request Analyse Report, 2016
[7] Du, P. and MacDonald, E. F., "Eye-Tracking Data Predicts Importance of Product Features and Saliency of Size Change," Proc. ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.
[8] The Basics of Hot Dip Galvanized Steel, Galvanizers Association of Australia, 2012
[9] Kigle-Boeckler, G., 1995, "Measurement of Gloss and Reflection Properties of Surfaces," Metal Finishing(May 1995), pp. 28 - 31.
[10] Hunter R. S., 1937, National Bureau of Standards, Research Paper Rp958, Part of Journal of Research of the :National Bureau of Standards, Volume 18, Washington, USA
[11] Linke B., Das J., 2016, Aesthetics and Gloss of Ground Surfaces: A Review on Measurement and Generation, Journal of Manufacturing Science and Engineering, 138(6)
[12] Gloss Measurement, Introduction, BYK-Gardner GmbH http://www.byk.com/fileadmin/byk/support/instruments/theory/appearance/en/Intro_Gloss.pdf
[13] Technical catalog of Sheen Instruments, Tri-GLOSSmaster (260), http://www.sheeninstruments.com/sites/sheeninstruments.com/files/SHE14a-Tri-Glossmaster.pdf
[14] TS EN ISO 3815-2 Zinc and zinc alloys - Part 2: Analysis by inductively coupled plasma optical emission spectrometry.