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Experimental Investigation of the Galvanization Effects on the Properties of Low Carbon Alloy Steel

Ghazi S. Al-Marahleh

Department of Mechanical Engineering, Faculty of Engineering Technology
Al Balqa' Applied University
P.O. Box 15008, Amman – Jordan

Abstract

This paper aims to study the effect of galvanization on the properties of low alloy carbon steel, and changes that may occur after galvanization. Identify the properties of the alloy metals and determine the percent of each one, how they effect on the galvanization process. Also the microstructure of the galvanized samples is determined.

Keywords: galvanization, carbon steel, alloy, microstructure

1 INTRODUCTION

A process by which Zink is coated over corrosive metals is known as galvanizing. The galvanizing process is actually a method of coating corrosive metals, such as steel and iron, with a non-corrosive metal. Zinc is melted and applied, usually via what's known as a hot dip, to the metal, providing a coating of corrosion protection from one mil to just over four mils thick. When cured, the zinc, through reaction with the coated metal, becomes zinc carbonate. The galvanizing process not only prevents corrosion of various "soft" metals, but adds to the strength of the original, uncoated metal. Obviously, galvanized metal is thicker than uncoated metal, thus fittings and fastenings are generally measured with the additional galvanizing mil specs in mind. Various American Society for Testing and Materials (ASTM) specifications provide guidelines and continuity for the thickness of galvanized metals. Galvanization of nails and screws is the most common method of preventing the unsightly staining seen on many types of house siding. Non-galvanized steel nails and screws, when used outdoors, will “bleed” when they corrode, causing dark stains on the siding. This staining is only eliminated by re-painting the siding. Staining on a building façade due to corroded nails, screws or other types of fasteners, is not only ugly, but also indicates that, because they're not galvanized, the metal fasteners are deteriorating and must be replaced. **Steel** is a metal alloy whose major component is iron, with carbon content between 0.02% and 2.14% by mass. An **alloy** is a metallicsolid solution composed of two or more elements. Complete solid solution alloys give single solid phase microstructure, while partial solutions give two or more phases that may or may not be homogeneous in distribution, depending on thermal (heat treatment) history. Alloys usually have different properties from those of the component elements. Hardness has typically been defined as the resistance of a material to permanent penetration by another one that is harder. This can be achieved by using an intender with hardness similar to that of the diamond. In combination with the applied force on it and the velocity of the application and finally the total time of the penetration applied.

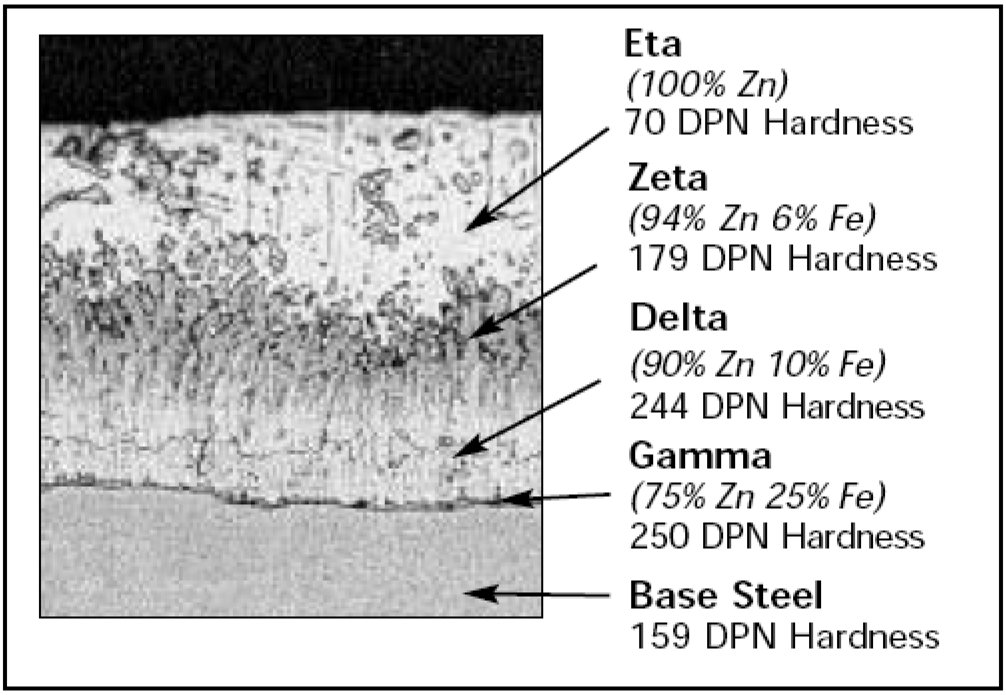


Figure 1: Photomicrograph of galvanized coating (source: American Galvanizers Association report 2000)

Zamanzadeh et al. ( ), The three case histories presented in this paper concern defects and causes of failure associated with galvanized steel sheet material. Optical metallography and micro-indentation hardness testing were the principal methods employed in determining the causes of failure but were supplemented as necessary by scanning electron microscopy and energy-dispersive X-ray spectrometry. One of the case histories presents defects associated with the actual hot-dip galvanizing process itself. In one instance, tiny hydrogen blisters were observed to have occurred at oxide scale deposits at the interface between the steel and galvanized coatings. When galvanized sheet steel cracks in bending during forming operations, most end users tend to place the blame on the galvanized material. However, several separate investigations of formed
and cracked galvanized steel parts have revealed that the cracking often initiates at the sheared edges of the part where plastic deformation has produced a local increase in hardness and a corresponding decrease in ductility. Ductility is the property of steel required to successfully withstand forming operations. The final case history present some observations made during failure analysis of corroded galvanized and painted panels at a utility plant. The coating system was composed of a galvanizing layer, a thin primer, and a final top coat. The problem was identified as localized development of white rust. The problem was found to be caused by the presence of a second phase precipitate in the galvanizing layer that adversely affected its ductility allowing it to crack
during forming. This produced localized stress in the paint layer that then cracked, permitting moisture to come into direct contact with the zinc, resulting in white rust formation. K R Evans,1997 This paper, as the title suggests, is to provide a basic understanding of the process of hot dip galvanizing, properties of the galvanized coating and how to prepare this surface mechanically prior to powder coating. To achieve this I will provide a brief discussion on the following topics.

• History of Galvanizing

• Process of Galvanizing

• Abrasion Resistance of Galvanizing

• Main Advantages of Hot Dip Galvanizing

• Recommended method of Mechanical Preparation Prior to Powder Coating
Mehrooz Z. **, 2005**, A review of galvanized steel and painted galvanized steel processes is provided, as well as the fundamentals and requirements for painted galvanized steel products. The corrosion processes found with both galvanized steel and painted galvanized steels are discussed. In the evaluation of painted galvanized steels, various laboratory techniques have proven most useful, with electrochemical impedance spectroscopy (EIS) as a sensitive quantitative technique for measuring coating degradation and corrosion protection. A detailed overview of the EIS technique is provided. Two case studies are provided for the

laboratory evaluation of replacement and repair coatings for painted galvanized structures, featuring EIS and other laboratory techniques. John Krzywicki, 2006, The performance of hot-dip galvanizing and zinc-rich paint is often viewed as equivalent due to the false perception that all zinc coatings are ‘galvanizing’ (e.g. zinc-rich paints are commonly referred to as “cold galvanizing”). The interchangeable use of the word ‘galvanizing,’ to represent a family of coatings that use zinc as a means of corrosion protection, has falsely portrayed all zinc coatings as being equal with regard to their corrosion performance. This article will examine the basis of the comparison of zinc-rich paints to hot-dip galvanizing, specifically the testing applied to support the comparison, and finally ten characteristics that distinguish the two corrosion protection systems.

-Hardness Measurement Method

There are three types of tests used with accuracy by the metals industry; they are the Rockwell hardness test, the Brinell hardness test, and the Vickers hardness test. The way the three of these hardness tests measure a metal's hardness is to determine the metal's resistance to the penetration of a non-deformable ball or cone. The tests determine the depth or area which such a ball or cone will sink into the metal, under a load, within a specific period of time.

-Materials and methods

The followings are the most common hardness test methods used in today`s technology:

1. Rockwell hardness test
2. Brinell hardness
3. Vickers/Micro Hardness Test
4. Knoop hardness

Vicker’s/Micro Hardness Test

A method of determining the hardness of steel whereby a diamond pyramid is pressed into the polished surface of the specimen and the diagonals of the impression are measured with a microscope fitted with a micrometer eye piece. The rate of application and duration are automatically controlled and the load can be varied. **Fig.2.**

Fig.2 hardness test equipments

Two types of indenters are generally used for the Vickers test family, a square base pyramid shaped diamond for testing in a Vickers hardness tester and a narrow rhombus shaped indenter for a Knoop hardness test.

RESULTS AND DISCUSSION

Heat treated layer, carbonized layer, hardened hard layers, superficial coating, steels, non- ferrous metal, micro and thin shaped components.

Table (1) Results of HV:

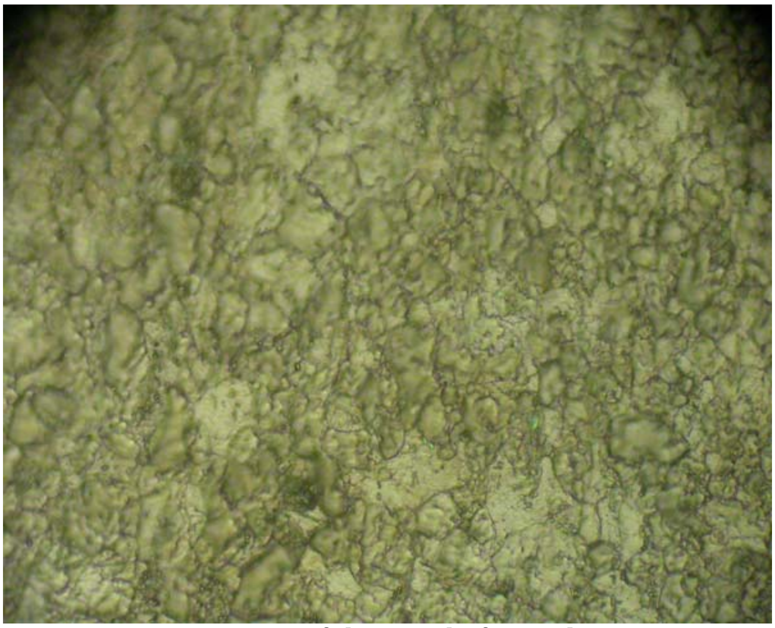
Vickers Hardness Number

Sample	HV	Properties	Shape
A	143.6	Galvanized	Plate
B	158.25	Galvanized	Plate
C	158.61	Galvanized	Plate
P	171.13	Galvanized	Pipe
R2	107.7	Raw	Pipe

Fig.3 shows the microstructure of raw plate before galvanization.

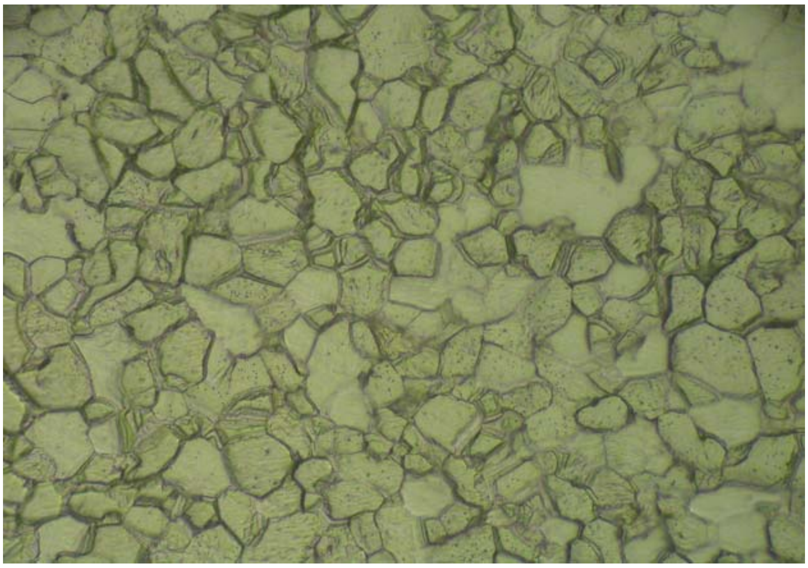
Fig(3) microstructure of raw plate before galvanization

Figure (4) shows the microstructure of the pipe before galvanization process.

Figure  (4)

microstructure of the pipe before galvanization

Figure (5) shows the microstructure after galvanization process.

Figure  (5)

microstructure of the plate after galvanization process

Table 2 and 3 show the original chemical composition and some of mechanical properties of the specimens before galvanization.

Table (2) properties of studied samples

N:Russia
T:Turkey
K:Korea

Chemical Composition Test for Galvanized Steel

Coil Inlet NO.	Batch No. Of Inlet	Coil Outlet NO.	Batch No. Of outlet	Origin Of steel	Zn 99%	Al	Cr 0.15	Sb	Fe	Mn 0.6	Si	S 0.035	P 0.03	Ti 0.025	Ni 0.2	Cu 0.25
CRCFHRUN 0.4*1250	3	4N442/2	45	N	99.371	0.029	0.049	0.372	99.891	0.000	0.000	0.005	0.055	0.028	0.012	0.009
CRCFHRUN 0.4*1250	16	4N440/2	41	N	99.794	0.055	0.026	0.126	99.788	0.053	0.014	0.002	0.050	0.025	0.023	0.045
CRCFHRUN 0.4*1250	9	4N441/2	43	N	99.712	0.000	0.051	0.237	99.135	0.621	0.130	0.017	0.010	0.025	0.027	0.035
CRCFHRUN 0.4*1250	13	4N443/2	47	N	99.883	0.065	0.046	0.006	99.739	0.016	0.000	0.012	0.158	0.030	0.033	0.011
CRCFHRUN 0.4*1250	10	4N446/2	52	N	99.650	0.122	0.000	0.229	99.820	0.000	0.005	0.094	0. 004	0.028	0.018	0.031
HRCSPTRE 1.8*1000	12	4T295	26	T	99.812	0.125	0.025	0.038	99.825	0.023	0.000	0.049	0.021	0.029	0.024	0.029
HRCSPTRE 1.8*1000	28	4T296	27	T	99.651	0.191	0.037	0.121	99.772	0.067	0.000	0.044	0.002	0.019	0.061	0.034
HRCSPTRE 1.8*1000	27	4T297	28	T	99.678	0.103	0.089	0.13	99.718	0.071	0.004	0.012	0.033	0.024	0.041	0.095
HRCSPTRE 1.8*1000	67	4T300	33	T	99.717	0.166	0.061	0.056	99.651	0.156	0.006	0.046	0.023	0.030	0.081	0.007
HRCSPTRE 1.8*1000	44	4T304	37	T	99.749	0.164	0.035	0.052	99.31	0.064	0.51	0.051	0.005	0.013	0.048	0.000
CRCFHKRS 0.87*1250	2	4K376/2	69	K	99.605	0.168	0.058	0.175	99.846	0.079	0.000	0.003	0.040	0.025	0.008	0.000
CRCFHKRS 0.87*1250	9	4K382/2	87	K	99.836	0.108	0.056	0.000	99.849	0.009	0.000	0.057	0.034	0.026	0.022	0.004
CRCFHKRS 0.87*1250	7	4K383/2	90	K	99.617	0.122	0.087	0.174	99.760	0.080	0.006	0.057	0.049	0.019	0.024	0.005
CRCFHKRS 0.87*1250	5	4K380/2	81	K	99.733	0.180	0.039	0.048	98.705	0.106	0.004	0.044	0.072	0.022	0.026	0.020

Table (3) properties of sample before galvanization

Raw Material

N:Russia
T:Turkey
K:Korea

Coil Inlet NO.	Batch inlet	Hardness HRB	Origin Of steel	C 0.15	Si	P 0.03	S 0.035	Ti 0.025	Cr 0.15	Mn 0.6	Fe	Ni 0.2	Cu 0.25	B	Al
CRCFHRUN0.4*1250	3	95.6	N	0.000	0.027	0.079	0.024	0.022	0.144	0.600	99.494	0.125	0.024	0.056	0.006
CRCFHRUN0.4*1250	16	96.2	N	0.000	0.040	0.000	0.066	0.027	0.018	0.090	99.690	0.050	0.016	0.000	0.002
CRCFHRUN0.4*1250	9	98.5	N	0.000	0.032	0.000	0.052	0.020	0.006	0.149	99.496	0.166	0.002	0.073	0.054
CRCFHRUN0.4*1250	13	99	N	0.000	0.020	0.002	0.050	0.032	0.007	0.148	99.517	0.142	0.018	0.057	0.007
CRCFHRUN0.4*1250	10	99.6	N	0.000	0.025	0.000	0.085	0.029	0.018	0.165	98.814	0. 107	0.003	0.172	0.582
HRCSPTRE 1.8*1000	12	92.5	T	0.000	0.048	0.000	0.103	0.032	0.012	0.089	99.678	0.004	0.028	0.000	0.007
HRCSPTRE 1.8*1000	28	91.4	T	0.000	0.037	0.005	0.077	0.029	0.015	0.178	99.633	0.015	0.009	0.000	0.003
HRCSPTRE 1.8*1000	27	92	T	0.000	0.011	0.001	0.075	0.028	0.016	0.221	99.320	0.307	0.006	0.000	0.016
HRCSPTRE 1.8*1000	67	74.5	T	0.000	0.024	0.002	0.067	0.025	0.014	0.209	99.411	0.020	0.008	0.000	0.009
HRCSPTRE 1.8*1000	44	75	T	0.000	0.020	0.006	0.143	0.019	0.012	0.177	99.504	0.049	0.016	0.000	0.005
CRCFHKRS 0.87*1250	2	98	K	0.000	0.009	0.002	0.026	0.017	0.018	0.164	99.625	0.101	0.020	0.018	0.000
CRCFHKRS 0.87*1250	9	98.5	K	0.000	0.011	0.017	0.017	0.025	0.020	0.172	99.581	0.036	0.012	0.092	0.017
CRCFHKRS 0.87*1250	7	98	K	0.000	0.009	0.000	0.035	0.022	0.009	0.157	99.700	0.028	0.011	0.025	0.005
CRCFHKRS 0.87*1250	5	98.5	K	0.000	0.010	0.021	0.047	0.026	0.025	0.125	99.625	0.069	0.017	0.034	0.000

Fig. 6 shows a comparison of hardness of some studied sample before and after galvanization.

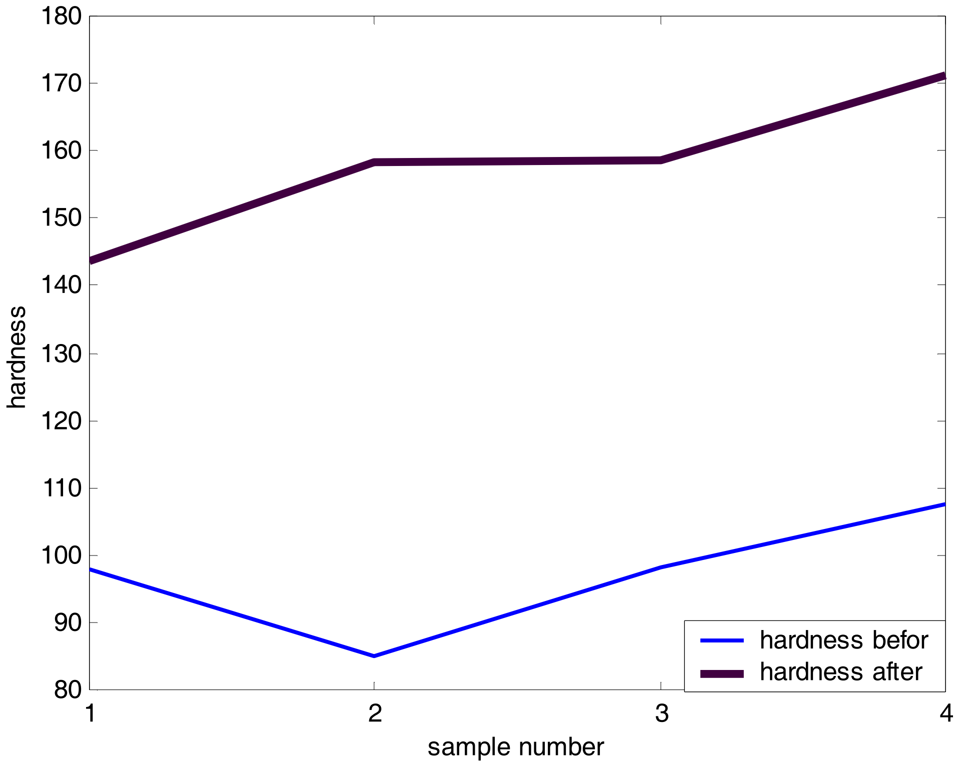


Fig.6 comparing hardness values before and after galvanization

CONCLUSIONS

Galvanization increases the hardness of the specimens and also it may be change the microstructure of the samples.

REFERENCES

[1] Zamanzadeh and Ed Larkin Matco, Some Failure Analysis Case Histories in Galvanized Steel Products , Pittsburgh, PA unpublished paper.

[2] American Galvanizers Association,2000, Galvanizing For Corrosion Protection of Steel Products, www.galvanizeit.org, e-mail: aga@galvanizeit.org, Hot-Dip.

[3] K R Evans, Sunstate Coatings Pty Ltd (1997) GALVANIZING AND MECHANICAL PREPARATION OF STEEL FOR POWDER COATING.

[4] Mehrooz Zamanzadeh, Dr. George T. Bayer, Gordon Kirkwood, 2005, USING ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY TO EVALUATE CORROSION BEHAVIOR OF PAINTED GALVANIZED STEEL IN ATMOSPHERIC AND SOIL EXPOSURE Matco Associates, Inc. Pittsburgh, Pennsylvania, U.S.A.

[5] John Krzywicki , 2006, The Performance of Zinc-Rich Paint vs. Hot-Dip Galvanizing , Marketing Manager American Galvanizers Association 6881 S. Holly Circle. Ste. 108. Centennial, CO 80112. Phone 720.554.0900 Fax 720.554.0909 www.galvanizeit.org American Galvanizers Association.

[6] J.O'M. Bockris, A.K.N. Reddy, M.Gamboa-Aldeco,2000, Modern Electrochemistry, Second Edition, Kluwer Academic, Norwell, MA.

[7]. J. R. Macdonald, Impedance Spectroscopy, emphasizing solid materials and systems, John Wiley & Sons,
New York, 1987.

[8] ASTM B 117-03, “Standard Practice for Operating Salt Spray (Fog) Apparatus,” American Society for Testing and Materials (ASTM) International, West Conshohocken, PA, 2003.

[9]. ASTM G 85-02e1, “Standard Practice for Modified Salt Spray Testing,” American Society for Testing and Materials (ASTM) International, West Conshohocken, PA, 2002.

[10]. ASTM G 8-86(2003), “Standard Test Methods for Cathodic Disbonding of Pipeline Coatings,” American Society for Testing and Materials (ASTM) International, West Conshohocken, PA, 2003.

[11]. ASTM G 154-04, “Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials,” American Society for Testing and Materials (ASTM) International, West Conshohocken, PA, 2004.

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