IOP Conf. Series: Materials Science and Engineering **454** (2018) 012106 doi:10.1088/1757-899X/454/1/012106

Mechanical Properties Studies of Lower Part of Electric Poles that Support the Electrical Distribution Networks

Saad M. Potrous

College of Engineering, University of Basra, IRAQ
Email; saadpotrous@yahoo.com

Abstract. Galvanized steel has a long history as an effective and economical material for manufacturing electrical poles. The purpose of this work is to study the corrosion of the lower part of the electric poles which support the electrical distribution networks. Microstructure and Mechanical properties have been studied for two samples, (A) is plate carbon steel and (B) is pipe carbon steel which are used in manufacturing the electrical poles. Furthermore, samples (A', B') and (A'', B'') are used to study the corrosion rates in air and burred in soil respectively. Results of mechanical properties have shown the Vicker hardness for sample (A) is (206) and for sample (B) is (185.4). Chemical compositional analysis has confirmed the carbon wt% for samples (A) and (B) are (0.24%) and (0.30%) respectively, leading to find that the sample (A) is identical to the (plate – A537), while sample (B) is identical to the (pipe – API 5L-X46) in the international examination (ASTM) for plate and pipe – carbon steel. The Corrosion rates (C.R.) of samples under study were tested where the values are (0.33 MPY) for sample (A') and (0.39 MPY) for sample (B') while the values are (0.45 MPY) for both samples (A'') and (B'').

1. Introduction

Galvanized steel has a long history as an effective and economical material for manufacturing electrical poles. Galvanized steel consists of a thin coating of zinc fused to a steel substrate. This combination provides the pole high mechanical properties as the mechanical properties of steel enhanced with the corrosion resistance of zinc [1].

The purpose of the research is to use the galvanized steel in the manufacture of electric columns to have good properties and high corrosion resistance under normal conditions suffer column wear after several years of service which consists of three parts. The main part is the part of the current study focused on the lower part, which is proved in soil because it is the most corroded part with respect to the other parts because of the nature of the mean of the soil, which can be considered a more hostile center of air that surrounds the other two parts.

Soil resistance which is the inverse of electrical conductivity one of the variables that affect the rate of corrosion where it was noted that the parts of electric columns buried in the soil can behave as anodic behavior relative to the soil of high-resistance behavior as cathodic [2].

Figure (1) shows the corrosion effected on the lower part of the splendid galvanized (pipe steel pole) and (I-section plate steel pole) which are under study.

IOP Conf. Series: Materials Science and Engineering **454** (2018) 012106 doi:10.1088/1757-899X/454/1/012106

Figure 1. Corrosion effected on the lower part of the electrical poles

2. Practical Part

2-a- Samples Preparation

Samples of (plate steel) and (pipe steel) were taken from the stores of the General Electricity Distribution Company of the Southern region of Iraq for the purpose to study the hardness, compositional analysis and corrosion rates measurements are given in this table;

Sample	Specification	Details
A	Plate Carbon Steel	For study hardness and compositional analysis
B	Pipe Carbon Steel	= = = = = = = = = = =
A'	Plate Carbon Steel	For measure the corrosion rate in (Air)
B'	Pipe Carbon Steel	= = = = = = = = = =
A"	Plate Carbon Steel	For measure the corrosion rate after burred the sample in soil
B"	Pipe Carbon Steel	= = = = = = = = =

2-b- Hardness Test

Vicker Hardness have been used to test samples (A) and (B) using instrument type Tokyo Testing Machine as shown in this Fig.(2).

Figure 2. Vickers hardness instrument

$$HV = 1.854\left(\frac{P}{d^2}\right)$$

Where;

P – load in (Kg)

d - Indenter diameter in (mm)

2-c- Compositional Analysis

Chemical composition analysis are carried out on two samples (A) and (B) to measure the (wt%) of carbon and other elements in these two samples.

2-d- Surface Structure Analysis

Surface structure at the spot welded regions have been examined for all samples using an optical microscope type CARL ZEISS with magnification of 400X as shown in figure (3);

Figure 3. Optical Microscope type Carl Zeiss

3. Results

3-a- Hardness Test
Vicker hardness (HV) numbers are calculated from the above formula when the load (P = 10Kg). The results arranged in Table (1) and the relationship between (HV) and types of samples are shown in Fig.(4).

Table 1. Values of H.V for the samples (A) and (B)

samples	d (mm)	$(d/12)^2$ $(mm)^2$	H.V
A	3.6	0.09	206
B	3.8	0.10	185.4

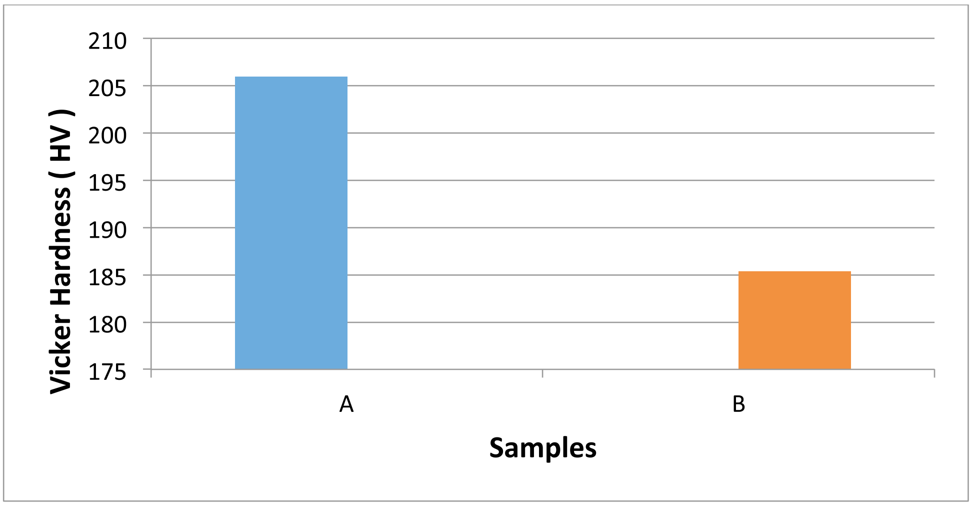

Figure 4. Vicker Hardness test for samples (A, B)

3-b- Chemical Composition Analysis Result
The result of Carbon (wt%) for both samples (A) and (B) are shown in the chart of figure (5) where its value for sample (A) is (0.24%) and for sample (B) is (0.30%).

Table 2. Chemical composition analysis for samples (A) and (B)

Sample	C %	S %	Mn %	P %	S %	Cr %	Mo %	Ni %	Al %	Co %	Cu %	Nb %	Fe %
A	0.24	0.28	0.70	0.004	0.024	0.023	0.003	0.008	0.002	0.008	0.022	0.005	98.6
B	0.30	0.19	0.98	0.066	0.051	0.019	0.003	0.008	0.037	0.008	0.011	0,023	98.2

3-c- Microstructure Examination Result
Mechanical methods are used for granding and polishing the two samples (A , B). Both samples are immersed in the (Nital) chemial solution for (10s) to examine the surface structure [3], the images of microstructure are show in figures (5) and (6);

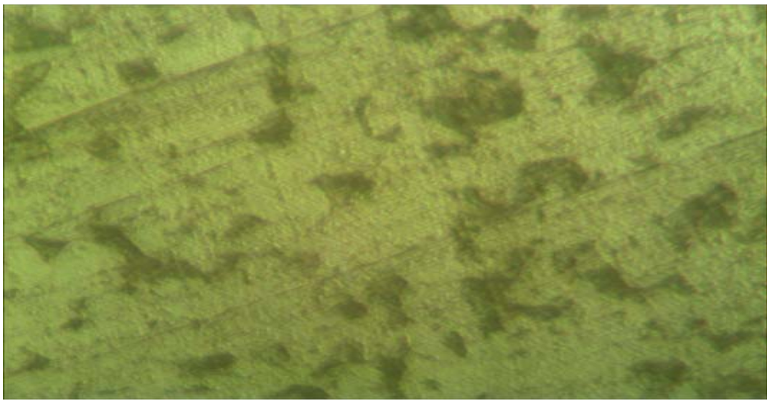

Figure 5. Microstructure examination for sample (A)

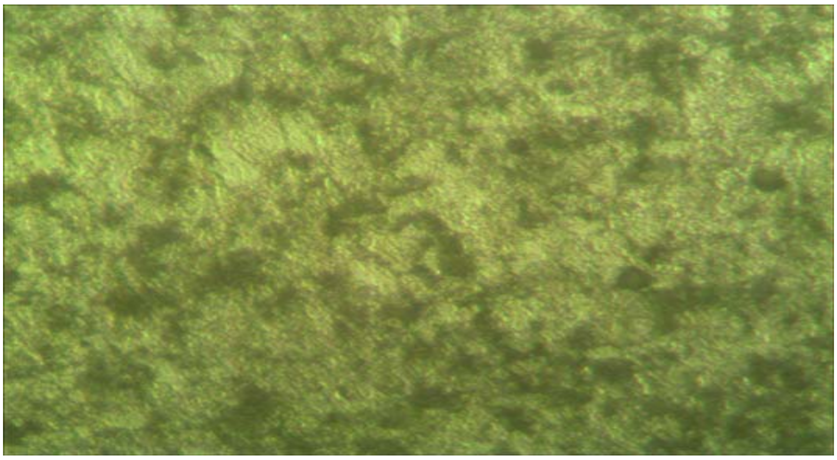

Figure 6. Microstructure examination for sample (B)

3-d- Corrosion Rate Test

Corrosion rates (C.R.) have been tested for the samples (A', B') in air and (A", B") after burred the samples for five months. Figure (7) shows the shapes of the test samples.

Figure 7. Shaped samples of (A), (A'), (B), (B') and burred samples (A''), (B'')

The corrosion rates (C.R) can be calculated from the following formula:

$$Corrosion\ rate\ (C.R.) = MPY\ \left(\frac{K.W}{A.T.D}\right)$$

Where: K (constant) = 3.45 x 10^6 , W = Weight Loss (gm) , A = Surface Area (cm^2)

D = Density (gm/cm^3) , T = Corrosion Time = 5m x 30d x 24h = 3600h

Table 3. The values of (C.R) for the samples. The relationship between these values are shown in Figure (8).

Samples Description	Corrosion Environment	W_1 (gm)	W_2 (gm)	Weight Loss (gm)	Surface Area (A), (cm^2)	Corrosion Rate (MPY)
(A') (Plate)	Air	49.6608	49.6110	0.05	18	0.33
(B') (Pipe)	Air	39.8576	39.8010	0.06	19	0.39
(A'') (Plate)	Soil	50.2923	50.2223	0.07	19	0.45
(B'') (Pipe)	Soil	52.5966	52.5066	0.09	19	0.45

Where; W_1 = original weight of sample.
W_2 = weight of sample after (5) months exposure to (air) or buried in(soil).

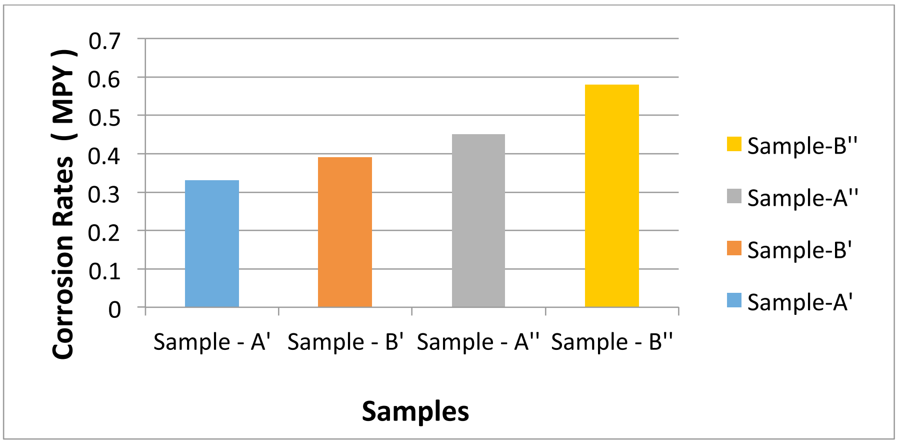

Figure 8. Values of the corrosion rates for samples (A', B', A'', B'')

4- Forces and Stresses Analysis of Electrical Pole

The electric pole contains (10) points for the suspension of (5) aluminum wires [3-Phases , Neutral , Light] lines in the electricity distribution network as shown in the Figure (9):

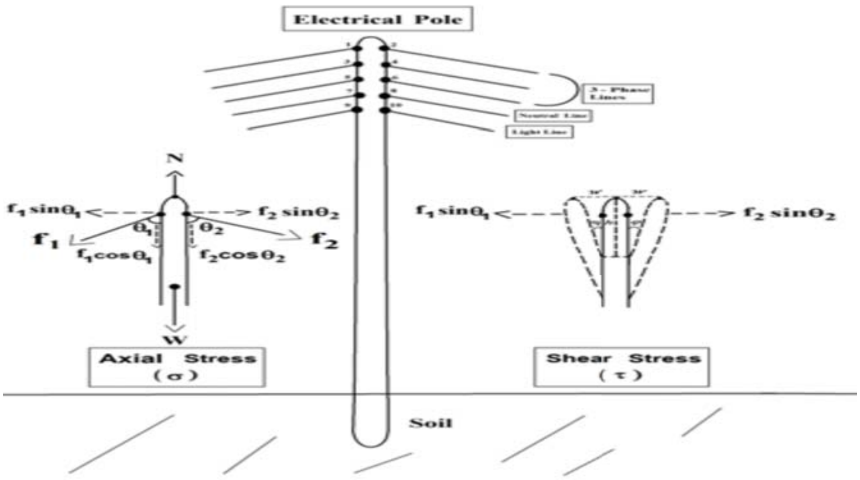

Figure 9. The five aluminum wires suspended to electric pole and the analysis of forces and stresses effected on the pole

The forces acting on the electrical pole by suspended wires can be analysis into two main forces, axial forces (F_1) and shear forces (F_2) as follows:

$$F_1 = f_1\cos\theta_1 + f_3\cos\theta_3 + f_5\cos\theta_5 + f_7\cos\theta_7 + f_9\cos\theta_9$$
$$+ f_2\cos\theta_2 + f_4\cos\theta_4 + f_6\cos\theta_6 + f_8\cos\theta_8 + f_{10}\cos\theta_{10}$$
$$+ W - N$$

Then;

$$F_1 = \sum^{9}_{i=1}(f_i\cos\theta_i) + \sum^{10}_{j=2}(f_j\cos\theta_j) + W - N \quad \ldots\ldots (1)$$

Where (W) is the weight of electric pole , (N) is the normal force

Also:

$$F_2 = f_1\sin\theta_1 + f_3\sin\theta_3 + f_5\sin\theta_5 + f_7\sin\theta_7 + f_9\sin\theta_9$$
$$- f_2\sin\theta_2 - f_4\sin\theta_4 - f_6\sin\theta_6 - f_8\sin\theta_8 - f_{10}\sin\theta_{10}$$

Then:

$$F = \sum^{9}_{i=1}(f_i\sin\theta_i) - \sum^{10}_{j=2}(f_j\sin\theta_j) \quad \ldots\ldots (2)$$

The axial stress (σ) and shear stress (τ) can be expressed in these following formulas:

axial stress (σ) = F_1 / A ……………….. (3)

shear stress (τ) = F_2 / A ………………. (4)

where (A) is the cross section area of electric pole. If (w) is the displacement by the action of the shear force, then the shear modulus (G) is defined as the ratio of the applied shear stress (τ) to the resultant shear strain (γ) as shown in this formula ;

$$G = \tau / \gamma \quad \text{…………………} \; (5)$$

where

$$\gamma = w/h = \tan\varphi$$

(h) is the length of edge by the action of the shear force [4].

5. Conclusion

Results of this work have confirmed the plate carbon steel , sample (A) is more hardness than pipe carbon steel , sample (B)[5]. Taking into consideration the ratio of (C) wt% [6] in both samples (A) and (B), it was found that the sample (A) is identical to the (plate – A537) pp. 24 in the international examination (ASTM) for plate – carbon steel, while for sample (B) is identical to the (pipe – API 5L-X46) pp. 28 in the international examination (ASTM) for pipe – carbon steel [7]. It can be deduced from this work, the corrosion at the lower part of the electric poles due to soil moisture at the location of installation of electric pole where moisture rises to the lower part of the pole by the action of Galvanic corrosion. Results of forces and stress analysis on the electric pole showing the sum of the forces towards the normal axis of the pole added to its weight has a strong impact towards the bottom of the pole. while the sum of the shear forces affect on the vibration of the pole at the upper end by the wind movement and because the bottom end of the pole is installed in the soil and affected by Galvanic corrosion and thus contribute to the curvature and fall the electric pole at the location of its lower part[8].

References:

[1] Diyala Jornal of Engineering Sciences, Vol. 8, Issue. 4, pp.713- 721, (2015).

[2] Peter A. Thornton, Vito J. Colangelo, " Fundamental of Engineering Materials" , Prentice Hall, New Jersey (1985).

[3] Lab. Metallographique, R.F. Dujarding Co., Dusseldorf , P.3 and P.9, (1965).

[4] Lames A. Schaffer et. al. , " The Science and Design of Engineering Materials ", New York , IRWIN , (1995).

[5] ASTM E28 of Mechanical Testing , November 13,(2011).

[6] ASTM Volume 01.01, Steel–Piping, Tubing, Fittings , January (2018).

[7] Atlas of Microstructure of Industrial Alloys , Metals Handbook , V. 7, 8th ed., (1972).

[8] "GPO", British Telecom Telephone poles". Archived from the original on April, (2017).