International Journal of Emerging Engineering Research and Technology
Volume 7, Issue 7, 2019, PP 8-12
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Evaluation of the Effect of Corrosion Rate of Welded Annealed Low Carbon Steel in Chloride Environment

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ABSTRACT

This research work is focused on the effect of corrosion rate of welded annealed low carbon steel in chloride environment. Samples of low carbon steel were bought from local market in Nigeria. The samples were properly machined using lathe machine into dimensioned of 30 mm diameter and 50 mm length for welded annealed and wedded but not annealed that served as control. The samples of low carbon steel were annealed at a varied temperature of 900 °C, 920 °C, and 940 °C with a soaking time of 60 minutes along with the control samples. The results obtained revealed that corrosion rate and weight losses were rapid for annealed samples. Also, it was observed that the higher the annealing temperature, the fast the rate of corrosion and the samples that were not annealed showed better corrosion resistance. The annealed samples showed their rate of corrosion resistance in the following order; 900°C<920 °C<940 °C.

Keywords: *Corrosion Rate, Weight Loss, Annealing Heat Treatment, Welding, Chloride Environment*

INTRODUCTION

Low carbon steels (0.002-0.25%) account for a large proportion of the total output of steel [1]. They are the most vital alloys used in petroleum and petrochemical industries since they account for over 98% of the construction materials [2-3]. The wide application of low-carbon steel range from chemical, oil gas storage tanks and transportation pipelines is due to its moderate strength, good weld-ability and formability [4-5]. Nevertheless, this material is susceptible to corrosion when used in chemical and sour crude oil environments such as sea water [6].

The use of low carbon steel as construction material in industrial sectors has become a great challenge for corrosion engineers or scientists nowadays. In practice, most of the acidic industrial applications such as refining crude oil, acid pickling, industrial cleaning, acid descaling, oil–well acid in oil recovery and petrochemical processes use mild steel as their material. A corrosion phenomenon is a natural process that results in considerable waste of industrial investment. This phenomenon can easily be found in different types of surfaces causing major economic losses in the industrial sector. Corrosion is an electrochemical process by which metallic surfaces react with their environment causing the metal to lose its material properties due to surface deterioration [7]. Corrosion is a constant and continuous problem, often difficult to eliminate completely [8-9].

Prevention would be more practical and achievable than complete elimination. Corrosion processes develop fast after disruption of the protective barrier and are accompanied by a number of reactions that change the composition and properties of both the metal surface and the local environment.

The corrosion of low carbon steel in natural environments such as sea water is of practical importance.

Generally, the chemistry of corrosion processes is shown in equation (1), and equation (2) [6].

$$Fe\,(s) \longleftrightarrow Fe^{2+} + 2e^{-} \text{ (Material Dissociation)} \quad (1)$$

$$O_2 + 4H_2O + 4e^{-} \longleftrightarrow 4OH^{-} \text{ (Oxygen Dissociation)} \quad (2)$$

The corrosion characteristic of low carbon steel in chloride environment is the formation and growth of compact and thick layers composed of oxides, insoluble salts and organic materials [7]. The result of surrounding environmental conditions such as chloride, oxygen supply, ionic species, bacteria and organic matter are the formed layer. The exchange of various species (ions, molecules, gas) between chloride and the rust layers or the metal depends both on the kinetics of the Faradaic reactions of the entities with either the oxides or the metal, as well as on their transport properties through the different strata of the rust layers[8].

Heat treatment is a heating and cooling operation applied to metals and alloys in solid state to impact desirable properties to the metal or alloy. Heat treatment of metals is an important operation in the final fabrication process of many engineering components. Heat treatment is of various forms which include annealing, normalizing, tempering, hardening and isothermal operations [10]. Heat treatment improves the microstructure of the metal, and this is what gives the metal desired properties for different service conditions. Annealing is the heating to and holding at a suitable temperature above re-crystallization, followed by cooling at a suitable rate in a switched off furnace for such purposes as inducing softness and enhancing cold work [11]. Corrosion, like taxes and death is inevitable especially in the manufacturing, chemical, and petroleum industries.

Hence, if one considers the mammoth amount of money spent in fighting corrosion and the attendant severe consequences of corrosion disasters, then, this research work is a right step in the right direction.

Thus, this research work was carried out to evaluate the effect of annealing on welded low carbon steel in chloride environment with a view to obtaining best route(s) for optimum service performance of materials produced from low carbon steel in this medium.

MATERIALS AND METHODS

Materials

The material used for this research work includes low carbon steel of diameter 30 mm and length 50 mm. It was obtained in Warri, Delta State, Nigeria. The chemical composition of the low carbon steel is shown in Table 1. The equipment used includes; lathe machine for machining of the low carbon steel, power saw, muffle furnace for annealing heat treatment, wire brush, tong, electronic precision weighing balance, table vice. The electrode used for welding operation is low hydrogen electrode gauge of 2.5mm internal core and flux covering making it up to 4.3mm.

Methods

The low carbon steel was used in as received condition. The bought samples were machined into cylindrical pieces of 30 mm diameter and 50 mm long for welding annealed and welding but not annealed. The welding samples were cut into two equal half and the chamfered in preparation for welding. The chosen welding geometry is selected for adequate welding penetration.

Preparation of Chloride Environment

The chloride environment was prepared using 48.45g of sodium chloride salt dissolved in1000ml of deionized or distilled water and stored for usage.

Welding of Low Carbon Steel

The edges of the low carbon steel samples were firmly clamped together with a root gap of 2.5mm between them. The samples were welded together in pairs with the aid of a manual electric arc welding. The pieces of the low carbon steel were welded together.

However, during the welding operation, the electrode is run through the butt until reasonable penetration and development of the weld pool was achieved to the required thickness of the rod. The welded portion was thoroughly cleaned with wire brush to remove the covering slag and welded samples were allowed to cool.

Grouping of Samples

The samples were grouped as follow;

Set A= Welded samples but not annealed that served as control

Set B = welded and annealed samples at 900^{0}C

Set C = Welded and annealed samples at 920^{0}C

Set D = Welded and annealed samples at 940^{0}C

Annealing Process

The welded low carbon steel samples were annealed at varying temperatures of 900ºC, 920ºC and 940ºC and soaked for duration of one hour (60 minutes).

Determination of Weight Loss and Corrosion Rate

The prepared low carbon steel samples and the chloride environment were used for the experiment to determine the corrosion rate of the low carbon steel. Four plastic bowls were filled with sodium chloride solution that served as corrosion environment and labeled A to D. The various low carbon steel samples were weighed and recorded as (W_1) before being immersed into their respective labeled plastic bowls. After fifteen days interval, each of the steel samples were retrieved, properly cleaned and allowed to dry for about ten minute. They were then placed on a weighing balance to record their weights (W_2) which is the final weight of the used samples. This procedure was repeated at 20day interval for a period of 80 days.Equation (3) was used to calculate the weight loss.

$$W_L = W_I - W_F \quad (3)$$

Where,

W_L = Weight loss

W_I = Initial weight

W_F = Final weight

Equation (4) was used to calculate the corrosion rate.

$$C_r = \frac{87.6W_L}{DAT} \quad (4)$$

Where,

C_r = Corrosion Rate (mm/y) W = Weight loss (mg)

D = Density of Low Carbon Steel = 7.85g/cm3

A = Area of medium carbon steel samples used (cm2) T = Exposure time to sea water (days)

Results and Discussion

Table 1 shows the results of the chemical composition of percentage weight of low carbon steel. The results obtained showed that by total percentage weight composition, Iron has the highest percentage. Other element present in low carbon steel include; Carbon (0.16%), Silicon (0.29%), Manganese (0.85%), Phosphorous (0.025%), Sulphur (0.027%), Titanium (0.001%), Copper (0.33%), Nickel (0.04%), Chromium (0.07%), Molybdenum (0.04%), Vanadium (0.002%), Aluminium (0.023%), Tungsten (0.005%), Niobium (0.001), and Nitrogen (0.005%).Figure 1 show the graph of weight loss of low carbon steel of welded and not annealed, welded and annealed at 900^0C, welded and annealed at 920^0C, and welded and annealed at 940^0C against duration of exposure time of 80 days in Chloride environment. The effect of weight loss on the samples was evaluated at interval of every 20 days. It was observed that the samples loss in weight was increasing with exposure time with increased in welded and annealed samples at the varied temperature. Also, the results obtained show that the higher the annealed temperature on the welded samples, the rapid the effect of weight loss on the low carbon steel. The effect of weight loss was least in the samples of low carbon steel that were welded but not annealed.

Table1. *Chemical composition of the Low Carbon Steel Sample (wt. %)*

Element Present	Percentage Weight (%)
Carbon (C)	0.16
Silicon (Si)	0.29
Manganese (Mn)	0.85
Phosphorous (P)	0.025
Sulphur (S)	0.027
Titanium (Ti)	0.001
Copper (Cu)	0.33
Nickel (Ni)	0.04
Chromium (Cr)	0.07
Molybdenum (Mo)	0.004
Vanadium (V)	0.002
Aluminium (Al)	0.023
Tungsten (W)	0.005
Niobium (Nb)	0.001
Nitrogen (N)	0.005

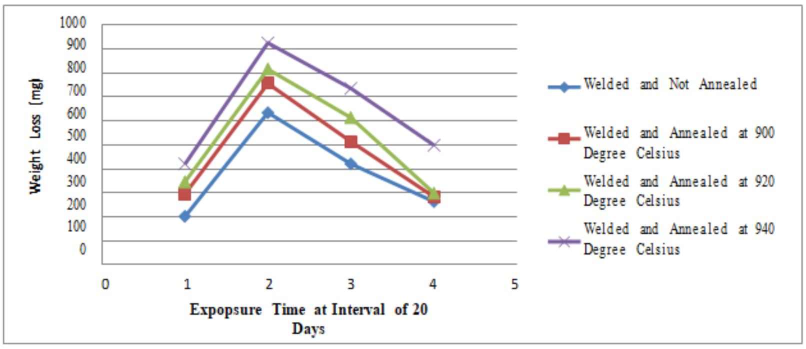

Figure1. *Evaluation of Weight Loss*

Figure 2 shows the graph of corrosion rate of welded annealed and welded but not annealed low carbon steel when exposed to chloride environment. The outcome of the results revealed that the rate of corrosion of all the samples increases steadily for the first 40 days before it started to decreased gradually. This rapid increased before gradual decreased in the corrosion rate from the 1st day to day 40th (increased) and from day 40th to day 80th (decreased) can be attributed to the transport properties of the corrosion medium, pH of the corrosion medium which is within neutral, concentration of the corrosion species in the used the chloride environment, and the aggressiveness of the chemical reactivity. Also, the continuous decreased in corrosion rate for of the samples after 40th day was due to the formation brown coloration formed on the samples surfaces which on the other possess inhibitive property on the low carbon steel and the chloride environment.

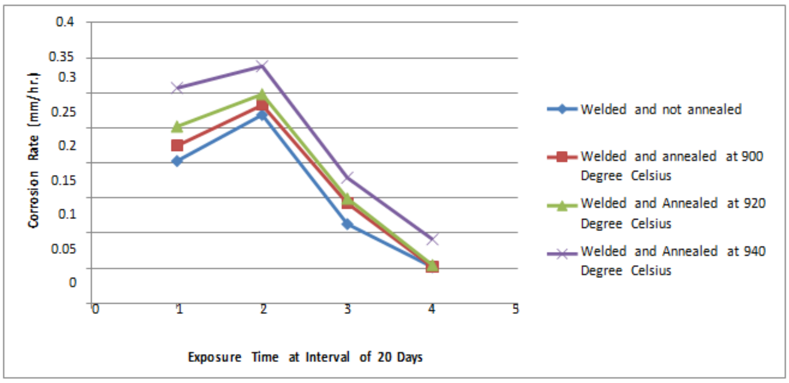

Figure2. *Corrosion rate of welded annealed and welded*

CONCLUSION

Corrosion remains one of the most severe limitations to the use of low carbon steel in the manufacturing, construction, chemical, petrochemical industries, etc. Low carbon steel is a versatile and indispensable material in the industry. In this research work, having investigated the effect of annealing at varied temperature of 900^0C, 920^0C, and 940^0C on welded low carbon steel, the outcome of the results showed that welded annealed low carbon steel samples experienced rapid corrosion rate and weight loss unlike welded but not annealed low carbon steel samples. The welded and not annealed low carbon steel samples showed better corrosion resistance and weight loss, and this was followed by the welded annealed samples in the following order; 900^0C<920^0C<940^0C. Thus, the welded and annealed sample at 900^0C annealed temperature of was suitable for chloride environment. On the other hand, welded and annealed sample at 940^0C annealed temperature of was not suitable for chloride environment. Therefore, if annealing heat treatment must be carried out on low carbon steel, annealing temperature of 900^0C is recommended.

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Citation: *Atadious D. and Onwuamaeze I. K., "Evaluation of the Effect of Corrosion Rate of Welded Annealed Low Carbon Steel in Chloride Environment", International Journal of Emerging Engineering Research and Technology, 7(7), 2019, pp. 8-12.*