ISSN - 2277 - 0593

Journal of Natural Sciences, Engineering and Technology

INFLUENCE OF ELECTRODE DIAMETER ON THE CORROSION RATE OF WELDED MILD STEEL IN CASSAVA JUICE

***S.I. KUYE AND S.I. FALETI**

Department of Mechanical Engineering, University of Agriculture, Abeokuta, Nigeria.
***Corresponding author:** ibiyemikuye@yahoo.com **Tel:** +2348033018030

ABSTRACT

Welding is the major form of assemblage of cassava processing machines. It has been observed that most of the machines often fail in service due to corrosion. This study was carried out to investigate the effect of electrode diameter on this phenomenon. The mild steel samples used in this study were welded with electrodes of gauges 2.5mm, 3.5mm and 4.0mm respectively. Cassava juice was used as corroding medium. An electronic weighing balance was used to take the weights at 4 days interval progressively for 32 days. The least weight loss was obtained in gauge 2.5mm sample (3.45g), followed by 3.5mm (4.96g) and greatest loss was recorded for 4.0mm sample (11.46g). This shows that corrosion rate in cassava processing plant can be minimised through the choice of electrodes. In this case, gauge 2.5mm is recommended for the construction of cassava processing machines.

Keywords: Cassava juice, corrosion, electrode diameter, welding, processing plant.

INTRODUCTION

Steel is an alloy of iron and with small amounts of carbon (up to a maximum of 1.5%) widely used in construction and its mechanical properties can be varied over a wide range. It is arguably the world's most "advanced" material. It is very versatile and can be produced at a very competitive production cost (Keehan, 2004). It accounts for a great deal of metallic construction in the building of machines/equipment for process and allied industries (Loto and Matanmi, 1989).

The main stages in failure investigation are investigation at site of failure (which include taking photos making sketches and collection samples) assembling of records for office study (to evaluate collapse load, ascertain possible cause of failure and establish material strength), carrying out of laboratory tests and analysis of failure (Fontana, 1986). Generally, welding is the preferred joining method for metals since it forms a continuous joint, it alleviates corrosion problems often associated with fasteners to a great extent and it offers greater beauty to the application (Keehan, 2004). In many circumstances, it is a structural requirement that the weld metal has over-matching strength in comparison with the steel in order to avoid design limitations.

Weakening of iron due to oxidation of the iron atoms is a well-known example of electrochemical corrosion. This is commonly known as rust.

Most structural alloys corrode merely from exposure to moisture in the air, but the process can be strongly affected by exposure to certain substances.

According to Ifeadi and Nwankwo, (1987) oil spill incident due to corrosion involved 18.4% of the total spill incidents in Nigeria between 1976 and 1986. They also stated that for this same period, a total of 2005 oil spill incidence were recorded while the estimated total quantity of spill was 2,038,711 barrels. The cheapest and most rapidly available metal for agro-processing equipment fabrication in Nigeria is plain carbon steel. However, there are some aggressive ions present in raw agricultural and food products, which may attack the steel components of processing machinery, resulting in their untimely failure in service. Corrosion has been established in uncoated mild steel used in machinery for agro-processing (Jekayinfa *et al.,* 2005). Corrosion of cassava processing equipment has equally been observed in cassava processing plants (Jekayinfa *et al.,* 2005).

Welding is extensively used for the fabrication and erection of steel structure in industrial construction and civil engineering, vessels of welded-plate construction, e.t.c. The wide use of welding at present is due to its economic advantages over other methods such as riveting, casting, e.t.c. The type of welding employed depends on both material and application of such components (Charlotte, 1976). However, weld-joints are composite of the parent metal, the filler rod (not applicable to some welding processes), heat-affected zone and unaffected base metal (George, 1981). Because of the nature of weld-joints, there is usually discontinuity and inhomogenuity in the properties of the welded components to such extent that this may affect the mechanical properties (i.e. strength, toughness, ductility, elasticity, etc.) of such components. By this, weld joints become areas where stresses are usually initiated or propagated in a welded component (Hertzberg, 1976).

Present day welding technology comprises several methods and techniques of improving the technical and economic effectiveness of SMAW. These include the use of higher welding current, the use of larger diameter electrodes, welding at low temperature (Keehan, 2004).

Somehow, the welded metal quality and corrosion will be influenced by the welding parameters stated above and in addition, parameters such as energy input, interpass temperature, preheat temperature will also play prominent role etc. (Keehan, 2004).

Lord (1999) analysed the variation of mechanical properties of high strength weld metals and concluded that variations in yield strength were not alone due to compositional variations, but also to process parameters. Sivensson (1994) pointed out the fact that control of microstructures and properties in steel arc welds is possible by playing around with some parameters.

Keehan (2004) studied the effect of varying welding parameters and discovered that it will cause variation in the micro-structures of steel which in turn affects the properties of the steel. Several works have been carried out on corrosion prevention. These dated back to probably when human beings first started using metals. Loto and Matanmi (1989) investigated the effect of heat treatment on corrosion of mild steel in cassava juice. He concluded that post heat treatment of the weld metal would reduce the corrosion rate of the metal. Oladeji (2005) studied the effect of mango juice extraction on the corrosion inhibition of mild steel in aqueous solution and arrived at the conclusion that some certain concentration of mango juice would inhibit corrosion of mild steel in aqueous solution. Kuye (2007) carried out an investigation on the effect of preheat treatment on corrosion of welded mild steel and concluded that mild steel must be heated to between 100°C and 125°C before welding to obtain microstructures that will aid least weight loss and reduction in corrosion rates. Kuye and Faleti (2009) investigated the effect of variation of electrode diameter on the corrosion behaviour of welded mild steel in salty environment and concluded that electrode of gauge 2.5mm gave the least weight loss.

Cassava plant originated from North-east Brazil, with likelihood of an additional centre of origin in Central America. However, Nigeria is the world's largest producer of cassava. Numerous cultivars exist wherever it is cultivated. The cultivars have been distinguished on the basis of morphology (for example, leaf shape, and size, plant size and petiole colour), tuber shape, and earliness of maturity, yield and the content of cyanogenic glucosides of the roots (Koch et al, 1994). It has also been reported that hydrogen cyanide concentration in cassava tuber ranges from 10 to 450 mg/kg. Tuber cyanogenic glucoside of 1500mg HCN equivalent was reported in fresh cassava roots of bitter cassava (Koch et al, 1994). According to Loto and Matanmi (1989), cassava juice contain 93% of cyanogenic linamarin 2-β d-glucopyranisyloxy isobutyronitrile and 7% of the closely related lotanstalin 2-β,d-glucopyranisyloxy, 2- methyl butyronile.

The present extensive industrial uses of cassava and its other anticipated industrial utilization could also justify an investigation into the corrosion behaviour of welded mild steel since mild steel is used in production of machineries, storage facilities, and other processing equipment).

The specific objective of this study was to evaluate the effect of variation of electrode diameter on the corrosion behaviour of welded mild steel. It aimed at determining the resistance of each of the welded joints placed in cassava juice using different electrode diameters and by comparing the resistances, make recommendations based on the obtained results on the best electrode diameter that could be used in order to reduce corrosion.

MATERIALS AND METHODS

Materials sourcing and preparation

Sample Sourcing

The mild steel specimen used for this research work was obtained from the workshop of SONA Breweries Plc., Sango, Ota, Ogun State in form of a rectangular plate of 300mm x 100mm x 8.5mm.

Sample Preparation

Ten pieces of 50mm x 20mm x 8.5mm were cut from the parent plate, and were welded together in twos using electrode. Each of the welded specimens were labeled with letter punches corresponding to the electrode gauge used in welding them. Each electrode was used to produce two (2) welded joints. The remaining unwelded specimen was used for chemical composition analysis.

The end surfaces of each of the specimens were ground with silicon carbide abrasive papers in increasing order of fineness. The surface was subsequently pickled and degreased by washing in acetone, weighed on a sensitive analytical balance and placed in a dessicator to prevent atmospheric corrosion before experimentation.

Corrodant sourcing

The test medium used for this research was cassava juice. Cassava fluid was obtained from cassava tubers got from Abule Owe village near the main gate of University of Agriculture, Abeokuta.

Corrodant preparation

The freshly harvested cassava tubers were peeled, washed and grated. The grated mash was pressed to extract the fluid which was collected and stored in a clean bottle and kept in the refrigerator.

Experimental procedure

The experimental procedure adopted for this study was the total immersion test method. This method was adopted because according to Okpala (1997), it has good reproducibility of results. The samples were immersed in 150ml containers for the period of 32 days at ambient temperature through which the experiment lasted. The samples were removed every four days, the corrosion products formed on the specimens were removed by gently brushing with a soft plastic brush. The specimens were then dipped in a mixture of distilled water and acetone to facilitate drying of the samples and water-deposited film before taking measurements. The weight recorded is the average of two readings.

Atomic spectroscopy and composition analysis

This was done at Material Science Laboratory of Obafemi Awolowo University, Ile-Ife, Osun State. The steps used in the spectroscopy are:

- Rough grinding
- Grinding – 240, 320, 400, 600 quality paper
- Initial polishing with emery cloth
- Final polishing with emery cloth
- Etching (2% Nitric acid + 98% Ethyl Alcohol)
- Micrograph (at magnification of 400) using Metallurgical Microscope Machine.

Experimental details

The compositional analysis of mild steel was determined by atomic spectroscopy. The geometric surface area of the specimens exposed was 3190 mm^2 and the average weight of the samples before exposure was 133.27g. The technique of Shielded Metal Arc Welding (SMAW) was employed to produce all experimental weld metals analyzed in this research work. It was decided to name the samples according to the electrode diameter used in welding them.

Weight Loss Determination

The weighed test pieces were totally immersed in cassava juice in the containers for 32 days. They were taken out every four days for weight loss measurement on electronic digital weighing balance correct to the nearest 0.01g.

Plots of corrosion rate (calculated) against time of exposure were made.

Theoretical Analysis

The corrosion rate was evaluated using the formula proposed by Fontana (1986):

$$\text{Corrosion rate (mm/yr)} = \frac{87.6W}{DAT} \quad (1)$$

where:

W = Weight loss in milligrammes

D = Density of specimen in g/cm^3
A = Total exposed area in cm^2
T = Exposure time in hours

Statistical analysis

The data collected were subjected to statistical analysis using Microsoft excel and the results plotted.

RESULTS AND DISCUSSION

Table 3.1: Chemical composition of mild steel sample used

Element	Fe	C	Mn	Si	Ni	Cr	P	S	Mo
% Composition	99.10	0.126	0.452	0.057	0.034	0.029	0.036	0.042	0.002

Table 3.2: Gravimetric data of gauge 2.5 mm sample

	Corrosion medium	Cassava Juice			
S/N	Time (hours)	Initial weight (g)	Final Weight (g)	Weight Loss (mg)	Corrosion Rate (mm/yr)
	0	127.72	-	-	-
1	96		127.41	310	51.98
2	192		127.22	500	41.73
3	288		127.05	670	37.22
4	384		126.62	1100	45.90
5	480		126.60	1120	37.35
6	576		126.61	1110	30.83
7	672		126.59	1130	26.79
8	768		124.27	3450	71.89

Table 3.3: Gravimetric data of gauge 3.5 mm sample

	Corrosion medium	Cassava Juice			
S/N	Time (hours)	Initial weight (g)	Final Weight (g)	Weight Loss (mg)	Corrosion Rate (mm/yr)
	0	131.96	-	-	-
1	96		131.66	300	48.68
2	192		131.57	390	31.50
3	288		131.37	590	31.72
4	384		131.20	760	30.69
5	480		131.01	950	30.66
6	576		128.57	3390	91.13
7	672		128.21	3750	86.03
8	768		127.0	4960	100.04

Table 4: Gravimetric data of gauge 4.0 mm sample

	Corrosion medium	Cassava Juice			
S/N	Time (hours)	Initial weight (g)	Final Weight (g)	Weight Loss (mg)	Corrosion Rate (mm/yr)
	0	130.67	-	-	-
1	96		130.54	130	21.31
2	192		130.25	420	34.26
3	288		130.01	660	35.84
4	384		129.63	1040	42.42
5	480		121.43	9240	301.20
6	576		121.06	10610	288.04
7	672		120.17	11500	266.44
8	768		119.21	11460	233.42

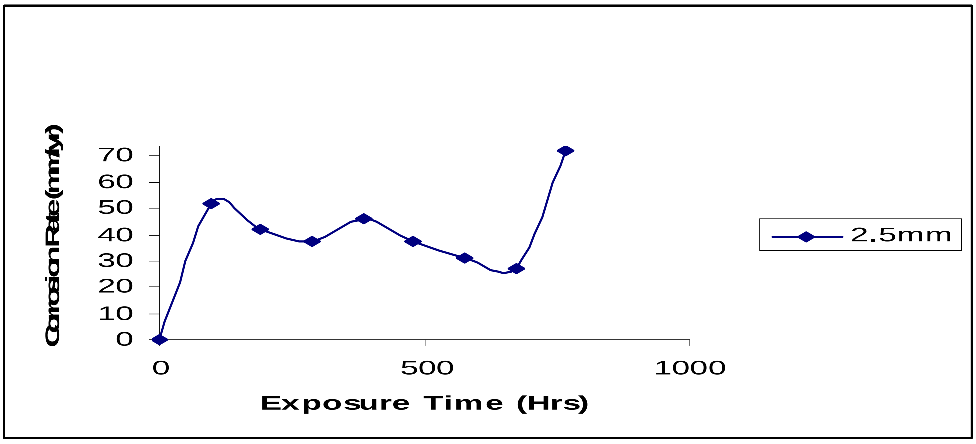

Figure 3.1: Corrosion Rate Against Exposure Time For Gauge 2.5mm

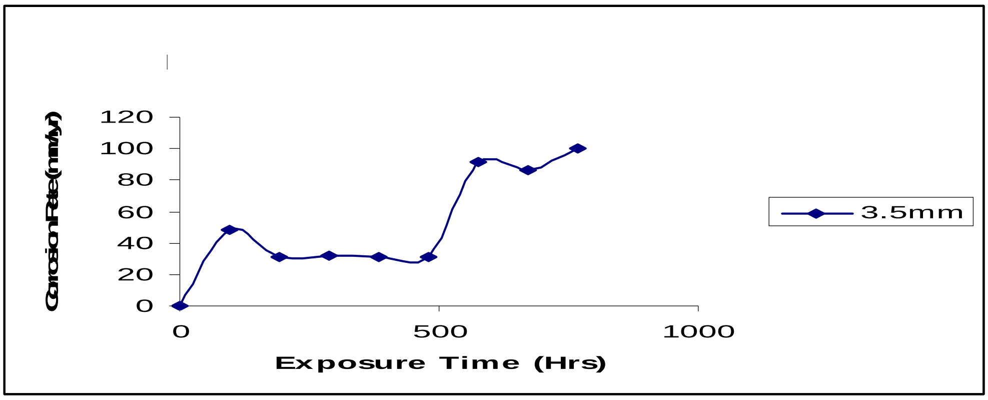

Figure 3.2: Corrosion Rate Against Exposure Time For Gauge 3.5mm

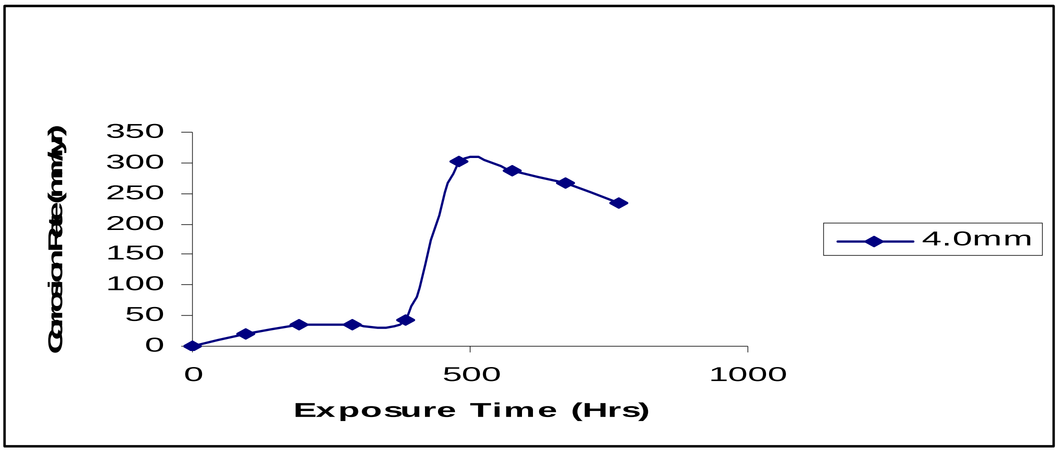

Figure 3.3: Corrosion Rate Against Exposure Time For Gauge 4.0mm

The spectroscopic analysis revealed that the sample is mild steel (Table 1). The graphs of the corrosion behaviour of the welded mild steel are presented in Figures 3.1 - 3.3. Fig. 3.1 illustrates the behaviour of sample with 2.5mm gauge electrode, corrosion rate rose from 0mm/yr to 51.98mm/yr in 96hours and then decreased gradually to 26.79mm/yr in 672hours; it then rose sharply to 71.89mm/yr in 768hours. Weight loss rose gradually from 310mg in 96hours to 1130mg in 672hours. Total weight loss for the sample is 3450mg. Fig. 3.2 illustrates the corrosion behaviour of sample with 3.5mm gauge electrode, corrosion rate rose from 0mm/yr to 48.68mm/yr in 96hrs and gradually decreased to 30.66mm/yr in 480hrs and then rose sharply to 91.13mm/yr in 576hrs, then to 100.04mm/yr in 768hrs. Weight loss increased gradually from 300mg in 96hrs to 950mg in 480hrs and then sharply to 3390mg in 576hrs and 4960 in 768hrs. Total weight loss is 4960mg.

Fig. 3.3 illustrates the corrosion behaviour of sample with 4.0mm gauge electrode, corrosion rate rose from 0mm/yr to 21.31mm/yr in 96hrs and gradually increased to 42.42mm/yr in 384hrs, then there was a jump to 301.2mm/yr in 480hrs and then it reduced gradually to 233.42mm/yr in 768hrs. Weight loss increased gradually from 130mg in 96hrs to 1040mg in 384hrs and then sharply to 9240mg in 480hrs and 11460mg in 768hrs. Total weight loss is 11460mg.

This study has shown that electrode of gauge 2.5mm will give lowest corrosion rate and lowest weight loss when used in the construction of cassava processing plants. Though more time is taken for the construction but the corrosion rate will make up for it.

CONCLUSION

The results of this investigation show that choice of electrodes can play a very prominent role in the reduction of corrosion rates of mild steel used for the construction of cassava processing plant. According to this research, mild steel electrode of gauge 2.5mm is the most suitable for the construction of machinery to be deployed for this purpose.

REFERENCES

Charlotte, W. 1976. Welding Handbook. Fundamentals of Welding, Macmillan, London.

Enda Keehan 2004. Effect of Microstructure on Mechanical Properties of High Strength Steel Weld Metals; Ph.D. Thesis, Chalmers University of Technology and Goteborg University, Goteborg, Sweden.

George, E.D. 1981. Mechanical Metallurgy, McGraw Hill, New York. Hertzberg 1976. Deformation and Fracture Mechanics of Engineering, John Wiley and Sons, New York.

Fontana, M.G. 1986. Corrosion Engineering, 3rd Edition, McGraw Hill Book Company, U.S.A.

Ifeadi, C.N., Nwankwo, J.N. 1987. Oil Spill Incidents in Nigerian Petroleum Industry- A Critical Analysis, Quarterly magazine of the NNPC, Fourth Quarter, 8(4): 5-11.

Jekayinfa, S.O., Waheed, M. A., Adebiyi, K.A. Adebiyi, F.T., 2005. Effect of Cassava fluid on Corrosion Performance of Mild Steel. *Anti-Corrosion Methods and Materials,* 52(5): 286-292

Kuye, S.I. 2007. Effect of Preheat Temperature on the Corrosion Behaviour of Welded Mild Steel, M. Sc. Thesis, University of Lagos, Lagos State.

Koch, M.B. Ole, S., Swain, E., Kahn, A. R. Liancheng, Bak Soren, Halkier A., Lindberg B. 1994. Possible Use of a Biotechnological Approach to Optimize and Regulate the Content and Distribution of Cyanogenic Glucosides in Cassava.

Kuye, S.I. 2007. Effect of Preheat Temperature on Corrosion of Welded Mild Steel. M.Sc., Thesis, University of Lagos, Akoka.

Kuye, S.I., Faleti, S.I. 2009. Effect of Variation of Electrode Diameter on the Corrosion Behaviour of Welded Mild Steel. Science Focus, *An International Journal of Biological and Physical Sciences.*

Lord, M. 1999. Design and Modeling of Ultra-High Strength Steel Deposits, Ph.D. Thesis; Material Science and Metallurgy, University of Cambridge, U.K.

Loto, C.A., Matanim, M.A. 1989. Effect of Heat Treatment in Corrosion of Mild Steel in Cassava Juice. *The Journal of Science and Engineering Corrosion,* 24(1): 36-38.

Okpala, A.N. 1997. The Effect of Surface Finish on the Efficiency of Inhibitors for Steel corroding in 3% NaCl. M. Eng. Thesis, FUT. Akure.

Oladeji, K.O. 2005. The effect of Mango Juice Extraction on the Corrosion of Mild Steel in Aqueous Solution; B. Technology. Thesis, Ladoke Akintola University of Technology, Ogbomosho.

Sivensson, L.E. 1994. Control of Microstructures and Properties in Steel Arc Welds. CRC Press, Inc.

(Manuscript received: 29th October , 2009; accepted:, 4th August, 2010).