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Experimental Investigation of Electric Arc Welding Variables on the Corrosion Behaviour of Steel Welds in Acidic Medium

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This work investigated the effects of power input and welding speed on the corrosion rate of low carbon steel welds in one molar tetraoxosulphate (VI) acid (H_2SO_4) solution. Locally available low carbon steel rod (Ø12mm) used for this study was cut into twenty four samples Ø12mm × 50mm with the aid of hacksaw for both plane face and double V shape. The samples were further processed through machining to get twelve samples for plane face and double-V edge shape respectively. Electric arc welding was used for welding the samples to produce six welded joints for each of plane face and double V shape at different power input and welding speed. Weight loss method was employed to evaluate the corrosion rate of the welded joints in the tested medium. It was discovered from the study that welding speed and power input have significant roles to play in either lowering or increasing the corrosion rate of the low carbon steel welded joints in one molar tetraoxosulphate (VI) acid solution. The plane face and double-V edge low carbon steel welded joints corrodes less at power input and welding speed of 16.5kW and 12cm/min respectively. Their corrosion rate is more aggressive at higher power input and welding speed.

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1. INTRODUCTION

Steels are mainly joined by welding process and mostly by arc welding due to its ease to operate and availability. Welding is a most widely used permanent joining process in pipelines, nuclear power plants, boilers, aircrafts, and rail road equipment construction. A quality weld joint is that which has the properties nearly equivalent to the base metal [1,2]. Welding involves a wide range of scientific variables such as time, temperature, electrode, power input and welding speed.

Many researchers have proved that improper techniques employed in welding may lead to serious consequences of the structures. Asibeluo and Emifoniye [3] studied the effect of current and temperature on mechanical properties of steel welds using shielded metal arc welding process. Investigation was done on a varying range of current. Increase in current resulted to increase in temperature input which affect the microstructure and mechanical properties of the steel weldments [4].

Omiogbemi [5] investigated the effect gas metal arc welding parameters on the mechanical and corrosion behavior of austenitic stainless steel in some environments using design expert software. Gharibshahiyan et al. [6] investigated that with the increase in voltage, the grain size number decreased in case of low carbon welded steel using inert gas welding.

Afolabi [7] investigated the effects of electric arc welding parameters such as power input, welding speed, weld geometry and post weld heat treatment on the corrosion behavior of austenitic stainless steel in chloride medium. Electrode potential measurement coupled with zinc rod reference electrode was used by him to evaluate the corrosion behavior of his samples. It was found from his work that 3.6kW power input produces the highest resistance weld corrosion while chamfered face edge preparation is the best corrosion resistant sample in the chloride medium.

Olabisi and Akeju [8] investigated the effects of electric arc welding parameters such as welding current and electrode specifications on microstructure and tensile properties of mild steel welded joints. It was discovered from their study that welding at higher current with electrode gauge 12 should be used when ultimate tensile stress is desired in plane face and V-edge welded joints while that of chamfered face should be done at lower current whenever higher ultimate tensile stress of the welded joints is required.

Salim et. al. [9] studied the effect of welding electrode, welding current and corrosion media on corrosion behavior of three kinds stainless steel (AISI 304, AISI 316 and AISI 410). Their study revealed that increment in heat input by increasing welding current caused reduction in corrosion resistance by facilitating carbon diffusion and formation of chromium carbides in the weld area.

It is therefore of great importance to study the effects of power input and welding speed on the corrosion behavior of steel welds in one molar tetraoxosulphate (VI) acid solution. The results obtained from this investigation are expected to provide more knowledge on the influence of welding variables on the corrosion behavior of steel welded structures during and after fabrication.

2. MATERIALS AND METHODS

2.1 Materials and Equipment

The materials used for this study include mild steel rod Ø12mm, emery cloth, electrode gauge 12 and one molar tetraoxosulphate (VI) acid solution (H_2SO_4). The equipment used includes electric arc welding machine, measuring cylinders, beakers, vice, hacksaw, digital weighing machine and blower. The chemical analysis of the steel rod was carried out to show its composition and the result is presented in Table 1. The table shows that the rod contains 0.1821% carbon and 98.1339% iron.

2.2 Sample Preparation

Locally available low carbon steel rod (Ø12mm) used for this study was cut into twenty four samples Ø12mm × 50mm with the aid of hacksaw for both plane face and double V shape. The samples were further processed through machining to get twelve samples for plane face and double-V edge shape respectively. The samples were cleaned from dirt using emery cloth. Edge preparations were carried out in order to have samples such as double V edge and plane face as shown in Fig. 1 [7].

Table 1. Chemical composition of the low carbon steel used

Elements	Composition (%)	Element	Composition (%)
C	0.1821	As	0.0044
Si	0.2412	W	0.0032
Mn	0.7210	Pb	0.0017
P	0.0341	Sn	0.0428
S	0.0398	Co	0.0095
Cr	0.1082	Al	0.0092
Ni	0.1120	Ca	0.0001
Mo	0.0140	Zn	0.0064
Cu	0.3412	Fe	98.1339
V	0.00165		

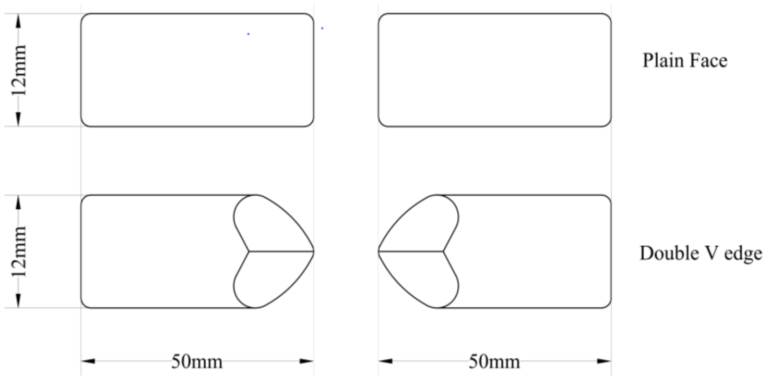

Fig. 1. Shapes of the low carbon steel welding samples

2.3 Welding Technique

The welding technique employed in this work is electric arc welding. Electrode gauge 12 was used as welding electrode while the welding current were varied with the voltage fixed at 220V to obtain welding at different power input and welding speed.

2.4 Corrosion Test

The method of corrosion test employed is laboratory test which involves full immersion of the samples and coupons weight loss determination. Weight loss method was used to evaluate the corrosion rate. Weight loss is the measure of difference between the original mass of the sample before immersion (m_1) and the mass of the same sample after immersion and cleaning (m_2). The corrosion rate is calculated in mils per year using the formula given by:

$$Corrosion\ Rate = \frac{KW}{DAT} \text{mpy} \ [10]$$

Where K = 534 (corrosion rate constant), W = weight loss in gram, D = 7.86g/cm^3 for mild steel (density of the material), A = total area of exposure = 4cm^2, T = exposure time in hours, mpy = mils per year (corrosion rate unit).

3. RESULTS AND DISCUSSION

The chemical analysis of the steel rod was carried out to show its composition and the result is shown in Table 1. The table shows that the rod is low carbon steel that contains 0.182% carbon and 98.1339% iron.

Tables 2 and 3 show the corrosion rate of the various welded joints obtained by weight loss method at an interval of 120 hours (5 days) and for a period of 840 hours (35 days) of full immersion of each welded joint in tetraoxosulphate (VI) acid solution.

Table 4 shows the average corrosion rates of both plane face and double V edge welded joints at different power input and welding speed in tetraoxosulphate (VI) acid solution.

Figs. 2 and 3 present further result processing of the corrosion rates of the two considered welding geometries in tetraoxosulphate (VI) acid solution at the various power input and welding speed.

Fig. 4 gives the average corrosion rates of both welding geometries.

It can be deduced from Tables 2 and 4, Figs. 2 and 4 that the corrosion rate of the plane face welded joints at 16.5KW power input in conc. H_2SO_4 increases in the order of the welding speed 12 cm/min (0.1415mpy) < 10 cm/min (0.1506mpy) < 15 cm/min (0.1598mpy). This implies that welding the plane face welded joint at medium power input and welding speed of 16.5KW and 12 cm/min respectively lowers the corrosion rate of the welded joints.

In addition, Tables 3 and 4, Figs. 3 and 4 also reveal the corrosion rate of double V shape welded joints in conc. H_2SO_4. The corrosion rate of double V edge welded joint at 16.5KW power input has the least value of 0.0645mpy at the welding speed of 12 cm/min. The corrosion rate of the double V welded joint increases in the order of the welding speed 12 cm/min (0.0645mpy) < 15 cm/min (0.1126mpy) < 10cm/min (0.1166mpy). Welding double V edge joints at medium power input 16.5KW and welding speed 12 cm/min lowers the corrosion rate of double V joint than any other welding speed at the same power input.

Welding at higher power input of 19.8KW at all the selected welding speed gives higher corrosion rates than welding at lower power input 16.5 KW for both plane face double V welded joints in conc. H_2SO_4 as shown in Tables 2, 3 and 4 and Figs. 2, 3 and 4.

Table 2. Corrosion rate of plain face welded samples at different power input and welding speed in tetraoxosulphate (VI) acid solution

POWER INPUT/	**CORROSION RATE (mpy)**						
WELDING SPEED	**120hrs**	**240hrs**	**360hrs**	**480hrs**	**600hrs**	**720hrs**	**840hrs**
16.5kW 15cm/min	0.1597	0.1598	0.1598	0.1598	0.1598	0.1598	0.1599
16.5kW 12cm/min	0.1413	0.1415	0.1415	0.1415	0.1415	0.1415	0.1415
16.5kW 10cm/min	0.149	0.149	0.149	0.149	0.1605	0.149	0.149
19.8kW 15cm/min	0.3002	0.3003	0.3004	0.3007	0.3003	0.3005	0.3004
19.8kW 12cm/min	0.1731	0.1731	0.1744	0.1745	0.1747	0.1747	0.1745
19.8kW 10cm/min	0.1995	0.1995	0.1995	0.1995	0.1995	0.1995	0.1997

Table 3. Corrosion rate of double-v edge welded samples at different power input and welding speed in tetraoxosulphate (VI) acid solution

POWER INPUT/	**CORROSION RATE (mpy)**						
WELDING SPEED	**120hrs**	**240hrs**	**360hrs**	**480hrs**	**600hrs**	**720hrs**	**840hrs**
16.5kW 15cm/min	0.1119	0.1125	0.1127	0.1128	0.1128	0.1128	0.1129
16.5kW 12cm/min	0.0644	0.0644	0.0644	0.0645	0.0645	0.0645	0.0645
16.5kW 10cm/min	0.1245	0.1182	0.1161	0.1151	0.1145	0.1141	0.1138
19.8kW 15cm/min	0.1376	0.1377	0.138	0.1381	0.1381	0.1381	0.1382
19.8kW 12cm/min	0.0914	0.1079	0.1134	0.1162	0.1179	0.119	0.1198
19.8kW 10cm/min	0.1327	0.1328	0.1329	0.1328	0.1328	0.1328	0.1328

Table 4. Average corrosion rates of both plain face and double-v edge shape welded samples at different power inputs and welding speeds in tetraoxosulphate (VI) acid solution

POWER INPUT/	AVERAGE CORROSION RATE (mpy)	
WELDING SPEED	PLAIN FACE	DOUBLE V EDGE
16.5kW 15cm/min	0.1598	0.1126
16.5kW 12cm/min	0.1415	0.0645
16.5kW 10cm/min	0.1506	0.1166
19.8kW 15cm/min	0.3004	0.138
19.8kW 12cm/min	0.1741	0.1122
19.8kW 10cm/min	0.1995	0.1328

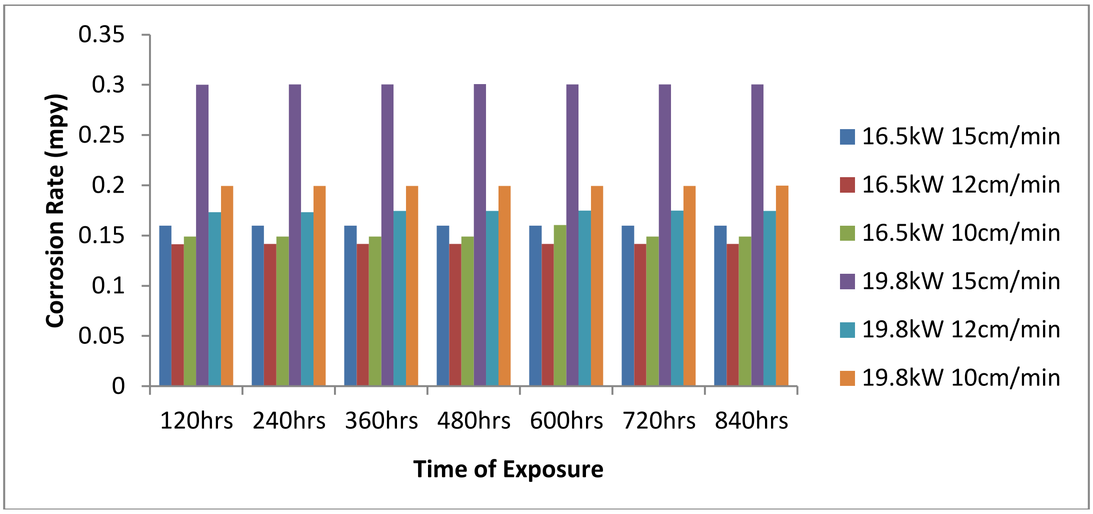

Fig. 2. Corrosion rate of plain face welded samples at different power input and welding speed in tetraoxosulphate (VI) acid solution

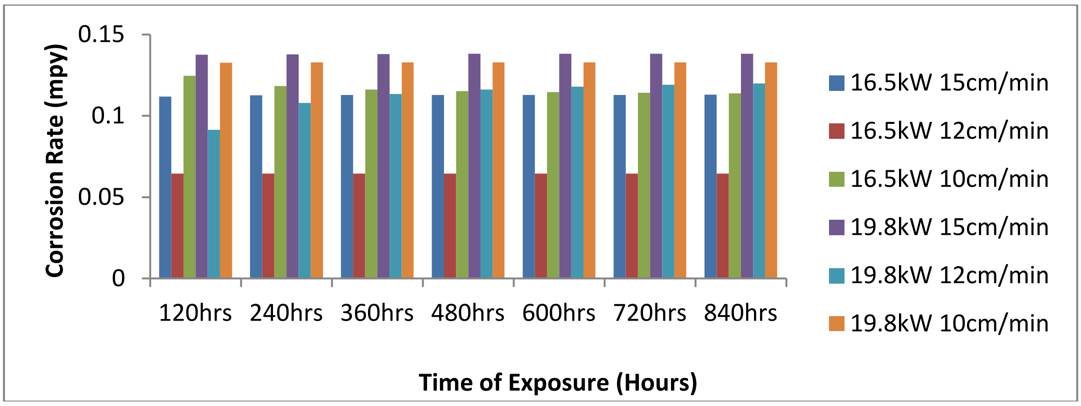

Fig. 3. Corrosion rate of double-v edge welded samples at different power input and welding speed in tetraoxosulphate (VI) acid solution

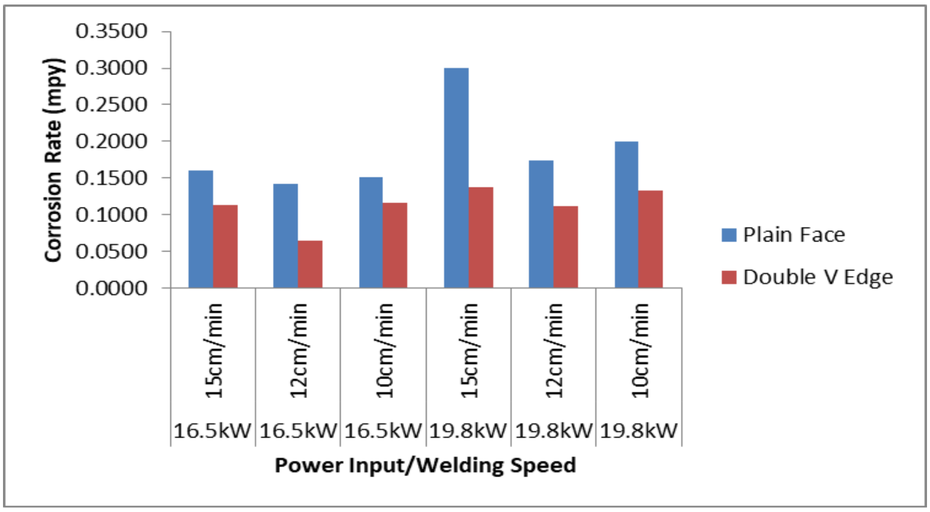

Fig. 4. Average corrosion rates of both plain face and double-v edge shape welded samples at different power inputs and welding speeds in h_2so_4 solution

Welding current which is a derivative of power input has great influence on corrosion rate. Higher corrosion rate recorded for both plain face and double-V shape welded joints at higher power input 19.8KW shows that corrosion rate increases with increasing welding current [9]. This is also in line with the discussion of Afolabi [7] who discovered that the corrosion rate increases with increase in power inputs while studying the effect of various power inputs on the corrosion behaviour of austenitic stainless steel in sodium chloride.

Table 4 and Fig. 4 show the effect of the selected welding speed 10cm/min, 12cm/min and 15cm/min on the corrosion rate of both plane face and double-V edge welded joints in the acidic medium. It can be seen that the low and medium speed welded samples displayed the lowest corrosion rate while the high speed welded samples show the highest corrosion rate throughout the exposure period. The speed the electrode travels along the joint has a direct influence on bead shape, depth of fusion, cosmetic appearance and heat input into the base metal [7, 11].

5. CONCLUSION

It can be concluded from the study that:

- Welding variables such as power input, welding speed and welding geometry have a vital role to play in either lowering or increasing the corrosion rate of low carbon steel welded joints in a corrosion medium.
- Plane face and double V edge low carbon steel welded joints corrode less when produced at moderate medium power input and welding speed.
- Plane face and double V edge low carbon steel welded joints corrodes more when formed at higher power input and welding speed.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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