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THE EFFECT OF WELDING CURRENT AND ELECTRODE SPECIFICATIONS ON MICROSTRUCTURE AND TENSILE PROPERTIES OF MILD STEEL WELDED JOINTS

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Abstract

Steel welded joints are finding applications in many engineering components where failures are catastrophes. Hence, the paper investigated how arc welding parameters such as welding current and electrode specifications could be tuned in order to ensure homogenous and satisfactory welds that will meet various service conditions. The mild steel rod (ϕ 10mm) used for this work was cut into various specimens ϕ 10mm by 50mm each with the aid of hacksaw. Edge preparations were done to have specimens categorised as single-v edge, chamfered and plain face. Electric arc welding machine was employed for welding those joints while tensile tests and microstructure analysis of the welded joints were carried out respectively. With respect to electrode specifications, electrode gauge 10 performs better than gauge 12 in terms of higher ultimate tensile stress for plain face welded joints, electrode gauge 12 could be of great benefit when high tensile stress is required in the chamfered face welded joints while welding v-edge joints with electrode gauge 10 between current 160 and 240A could be of better advantage than gauge 12 when high tensile stress is needed. In addition, welding at higher

current with electrode gauge 10 might not be appropriate if higher tensile stress is required in plain face welded joints while reverse be the case in chamfered face welded joints. Welding at higher current with electrode gauge 12 should be used when higher ultimate tensile stress is desired in plane face and v-edge welded joints while that of chamfered faces should be done at lower current whenever higher ultimate tensile stress of the welded joints is required. The microstructure analysis shows that the welded zone contained 35.159% pearlite and 64.841% ferrite respectively.

Keywords: Welding current, Electrode specification, Arc welding parameter, Ultimate tensile stress, Microstructure, Welded joints

Introduction

Steel is a metal alloy created from a mixture of iron, carbon and other alloys . Iron is a key component in steel and carbon content in the steel which varies between 0.2% until above 0.5% mass depending on the grade of steel. Mild steel is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications (Tewari *et al.*, 2010). It is the most widely used engineering material in the overall steel production worldwide. Mild steel can be described as an alloy of iron and carbon. It has outstanding ductility and toughness, high machinability and weldability which make its application possible in the engineering fields (Chinwuko *et al.*, 2014).

In the world today, mild steel is used in different engineering applications for the production of some automobile components, structural shapes (I-section beam and 90^o double leg iron) and mild steel sheets that are used in pipelines, buildings, plants, bridges and tin cans (Callister, 1997). Also, the use of locally available mild steel out of about 90% of all steels is conversant to most structural engineering works because of its excellent mechanical properties (Shuaib-Babata and Abdulqadir, 2012).

Welding is one of the most commonly employed methods of fabrication. It is basically a fusion of two or more pieces of metals by the application of heat and sometimes pressure (Agarwal, 1992). Thus, welding involves a wide range of scientific variables such as welding geometry, time, temperature, electrode, power input and welding speed (Jariyabon *et al.*, 2007; Lothongkum *et al.*, 2001; Lothongkum *et al.*, 1999; Karadeniz *et al.*, 2007).

Many research findings have proved that improper welding parameter could lead to serious consequences of the structures (Avery, 1963; Parijslaan, 2002). Failures as a result of poor mechanical properties and corrosion resistance have also found their places in the annals of times from household equipment to industrial structures. Hence, this study investigates the influence of welding parameters such as welding current and electrode types on microstructure and tensile properties of mild steel welded joints

Materilas and Methods

Materials and Equipment

The materials used for this study include mild steel rod (ϕ 10mm), emery cloth and gauge 10 and 12 electrodes. The equipment and apparatus used for this study include testometric machine M500 100AT for the tensile test, lathe machine, vice, hacksaw, file and arc welding machine.

Samples Preparation

The mild steel rod (ϕ 10mm) was cut into various samples ϕ 10mm by 50mm each with the aid of hacksaw. Facing of the samples were done on the lathe machine. The samples were cleaned from dirt, grease and other foreign materials to obtain a clean surface using emery cloth. Edge preparations were done to have samples categorised as single-v edge, chamfered and plain face as shown in Fig.1. The plain face had 16 samples (i.e 8 welded joints: 4 welded joints for each of the electrode gauge). Ditto to chamfered face and single-v edge.



Fig.1: Shape of the Mild Steel Rod Welding Samples.

Tensile Test

Tensile tests were carried out on the whole width of weldment in order to determine the tensile properties of the welded joints. The tests were done at NCAM (National Centre for Agricultural Mechanization, Ilorin) using Universal Tensile Testing Machine. The results were shown in Tables 2 and 3.

Specimens		UTS	Elongation	Stress @	Energy @	Yield	Young	
			@Break	Break	Break	Stress	Modulus	
		N/mm ²	(mm)	(Fracture)	Toughness	N/mm ²	N/mm ²	
				N/mm ²	(N.m)			
Current 120A	Plain Face	232.621	3.216	155.208	33.259	232.621	3007.544	
	Chamfered	131.016	1.815	125.274	10.895	131.016	3450.068	
	V-Edge	297.556	4.277	213.522	61.767	297.174	3219.464	
Current 160A	Plain Face	283.423	3.611	239.751	42.162	283.423	2843.805	
	Chamfered	226.509	2.926	186.148	28.231	226.509	2985.416	
	V-Edge	295.010	4.537	214.796	66.566	295.010	3367.703	
Current	Plain Face	219.379	3.211	176.598	31.581	219.379	2807.646	
200A	Chamfered	234.403	3.602	119.595	36.956	234.403	2724.100	
	V-Edge	359.690	12.325	196.970	258.681	265.343	3085.130	
Current 240A	Plain Face	242.934	3.781	218.870	41.853	242.934	2657.969	
	Chamfered	246.117	3.218	190.859	35.917	246.117	3406.849	
	V-Edge	317.037	7.852	287.752	136.039	230.711	3280.488	

Table 2: Some of the Tensile Properties of the Steel Welds with Electrode Gauge 10

Table 3: Some of the Tensile Properties of the Steel Welds with Electrode Gauge 12

Specimens		UTS	Elongation	Stress @	Energy @	Yield	Young
_		N/mm ²	@Break	Break	Break	Stress	Modulus
			(mm)	(Fracture)	Toughness	N/mm ²	N/mm ²
				N/mm ²	(N.m)		
Current 120A	Plain Face	170.232	2.189	162.465	16.642	3478.461	170.232
	Chamfered	272.601	3.274	250.574	37.541	272.601	3090.634
	V-Edge	318.183	5.075	160.937	80.069	318.183	3257.479
Current 160A	Plain Face	113.229	1.393	112.847	7.053	3214.774	113.229
	Chamfered	265.470	3.385	208.684	41.360	265.470	3601.234
	V-Edge	276.420	4.603	119.213	61.966	276.420	2892.393
Current 200A	Plain Face	179.145	2.332	135.600	17.624	3002.331	179.145
	Chamfered	268.908	3.818	200.917	49.157	268.908	3358.802
	V-Edge	311.816	7.190	266.234	120.125	248.536	3097.370
Current 240A	Plain Face	222.817	3.086	176.598	30.592	3031.310	222.817
	Chamfered	174.561	2.650	105.348	20.448	174.561	2955.829
	V-Edge	314.617	7.786	268.272	131.517	314.617	2913.564

Results and Discussion

The chemical composition of the mild steel as it was revealed by the x-ray spectrometer

are shown in Table 1.

Table 1: Chemical Composition of the As-Received Mild Steel

Element	С	Si	Mn	Р	S	Cr	Ni	Mo	Al
%	0.0041	0.0001	0.347	0.0022	0.020	0.018	0.045	0.0029	0.013
Element	Cu	Со	Ti	Nb	V	W	Pb	В	Sn
%	0.053	0.0011	0.0001	0.0031	0.0011	0.0056	0.0012	0.0007	0.0022
Element	Zn	As	Bi	Ca	Ce	Zr	La	Fe	
%	0.0022	0.0001	0.0009	0.0001	0.0001	0.0001	0.0001	99.4	

It can be confirmed from the table that the type of steel used for this work is a mild steel.

Table 2 revealed the tensile properties of the steel welds while welding between current 120 to 240A with electrode E6013 (Electrode Gauge 10). Ultimate tensile stress, yield stress, elongation, stress at break (facture), energy at break (toughness) and young modules of the steel welds were considered. The ultimate tensile stress of those samples with plain face welded joint

increases from 232.621N/mm² (120A, EG10) to 283.423N/mm² (160A, EG10) and decreases down the current range. This means that welding at higher current might not be approprite if higher tensile stress of the weld joint is required.

For the samples with chamfered face, ultimate tensile stress increase considerably in an ascending order throughout the range of the selected current from 131.016N/mm (120A, EG 10) to 246.117N/mm (240A, EG 10). Hence the higher the welding current for the chamfered face the higher the ultimate tensile stress of the weld joints. In addition, there is significant increment in the chamfered face joint toughness from 10.895Nm (120A, EG 10) to 36.956Nm (200A, EG 10) with a sudden decrese at the welding current 240A.

There is a considerable increment in the ultimate tensile stress of those samples with V-edge weld joint from 297.556N/mm² (120A, EG 10) to 359.690N/mm² (200A, E. G 10) with a sudden decrease at the welding current 240A. Their toughness increases steadily along the current range from 61.767Nm (120A, EG 10) to 66.566Nm with a sudden increase to 258.681Nm (200A, EG 10) and a further decrement to 136.039Nm² (240A, EG10).

Table 3 also revealed the tensile properties of the steel welds with electrode gauge 12. For the plain face weld joints, the ultimate stress had maximum value of 222.817N/mm² at welding current 240A. This shows that welding at higher current should be used when higher value of ultimate tensile stress is desired in the plain shape weld joints. The toughness of the place face weld joints was at its peak at 240A welding current.

The chamfered face weld joints had maximum ultimate tensile stress of 272.601Nmm² at the welding current 120A. the ultimate tensile stress of the chamfered face weld joints decreases as the welding current increase. Welding chamfered faces should be done at lower current whenever higher ultimate tensile stress of the welded joint is required. The toughness of

chamfered face weld joints increases in an ascending order from the welding current 120A to 200A with a sudden decrease at 240A. This shows that when maximum toughness is required in chamfered face joints welding should be done between current 120A and 200A.

The ultimate tensile stress of the V-edge weld joint increase from 276.420N/mm² (160A, EG 12) to 314.617Nmm² (240A, EG 12). This shows that welding should be done at higher current when higher ultimate tensile stress is required. The toughness of the V-edge weld joint increase in an ascending order.

Fig. 2 shows the chart comparing the ultimate tensile stress of various welded joints with electrode gauge 10 and 12.



Fig. 2: Chart Comparing the Ultimate Tensile of Various Welded Joints with Electrode Gauges

The electrode gauge 10 plain face welded joints at various welding current 120, 160, 200 and 240A had higher values of ultimate tensile stress than those of electrode gauge 12 plain face welded joints. This means that welding plain face joints with electrode gauge 10 should be considered when higher value of ultimate tensile stree is needed. Electrode gauge 12 gives higher ultimate tensile stress than gauge 10 while welding chamfered faces joints except at current 240A where gauge 10 takes the lead. In view of this, welding at lower current with electrode gauge 12 could be of great benefit when high tensile stress is required in the chamfered face welded joints. Welding V-edge joints with electrode gauge 10 between current 160 and 240A could be of better advantage in terms of high tensile stress than that of electrode gauge 12.

Fig. 3-8 shows microstructure of the plain face, chamfered and single v-edge welded joints with the aid of electron microscope.



Fig. 3: Microstructure of the Chamfered Face Welded Joint with Electrode Gauge 10

(Hint: Test 1: Current 120A, Test 2: Current 160A, Test 3: Current 200A, Test 4: Current 240A.







Fig.5: Microstructure of the Plain Face Welded Joint with Electrode Gauge 10



Fig.8: Microstructure of the Single V-Edge Shape weld Joint with Electrode Gauge 12

Digital imaging was done with optical magnification from 50X to 1000X while ASTM E2142 was used as standard. From the microstructure analysis, the welded zone contained 35.159% pearlite and 64.841% ferrite respectively. This shows that the welded joints were dominated by ferrite than pearlite.

Conclusion

The following facts can be derived from the study:

- The ultimate tensile stress of those samples with plain face welded joint increases from 232.621N/mm² (120A, EG10) to 283.423N/mm² (160A, EG10) and decreases down the current range. This means that welding at higher current might not be approprite if higher tensile stress of the plain face weld joint is required.
- The ultimate tensile stress of the chamfered face welded joints increase in an ascending order throughout the current range. Hence, the higher the welding current for the chamfered face the higher the ultimate tensile stress of the weld joints.
- Welding at hgher current with electrode gauge 12 should be used when higher value of ultimate tensile stress is desired in the plain face weld joints.
- Electrode gauge 10 performs better than gauge 12 in terms of higher ultimate tensile stress for plain face weld joints. This means that welding plain face joints with electrode gauge 10 should be considered when higher ultimate tensile stress is needed.
- Electrode gauge 12 gives higher ultimate tensile stress than gauge 10 while welding chamfered faces joints except at current 240A where gauge 10 takes the lead. In view of this, welding at lower current with electrode gauge 12 could be of great benefit when high tensile stress is required in the chamfered face welded joints.
- Welding V-edge joints with electrode gauge 10 between current 160 and 240A could be of better advantage in terms of high tensile stress than that of electrode gauge 12.

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