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Impact of Some Selected ARC Welding Variables on the Hardness and Tensile Properties of Steel Welds

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Abstract
The impact of some selected arc welding variables such as welding speed and power input on the hardness and tensile properties of low carbon steel welded joints was studied. Twenty-four (24) samples of the low carbon steel rod with the dimension Ø12mm × 50mm were prepared for each of the two-welding geometry; plane face and double-v edge respectively. Electric arc welding was used for welding each pair of the samples under three selected welding speed and power input to give twelve (12) welded joints for each of the plain face and double-V geometry. Brinell hardness test was carried out on the whole of weldment of welded joints. Tensile test was also carried out to determine the tensile properties of additional set of twelve welded joints for both welding geometries. It was discovered from the study that the hardness of the two shapes considered is higher at medium power input and welding speed of 16.5KW and 12cm/min while it drastically reduces at higher power input and welding speed. Similarly, maximum tensile stress of 827.47MPa and 847.03MPa were obtained for plain face and double-v welded joints respectively at 16.5KW power input and welding speed 12cm/min. The tensile stress reduces with further increase in power input and welding speed. The Young modulus of elasticity of both plane face and double-V edge welded joints increases from the welding speed of 10cm/min to 12cm/min at 16.5KW power input but reduces at higher power input. The results show that arc welding speed and power input have effect on either increasing or reducing the hardness and tensile strength of steel welds.

Keywords: Welding Speed, Power Input, Electric ARC Welding, Welded Joints, Hardness, Tensile Properties, Tensile Stress, Young Modulus of Elasticity

1. Introduction

Welding is a wide process used for fabrication to join two materials (Sharma and Mchdi, 2013) [9]. It is an efficient and economical method for joining of metals. Welding has made significant impact on the large number of industry by raising their operational efficiency, productivity and service life of the plant and relevant equipment. Welding is one of the most common fabrication techniques which is extensively used to obtain good quality weld joints for various structural components (Boob and Gattani, 2013) [2].

Arc welding, which is heat-type welding, is one of the most important manufacturing operations for the joining of structural elements for a wide range of applications, including guide way for trains, ships, bridges, building structures, automobiles and nuclear reactors, to name a few. It requires a continuous supply of direct or alternating electric current, which create an electric arc to generate enough heat to melt the metal and form a weld.

Welding process involves a wide range of scientific variables such as time, temperature, electrode, power input and welding speed (Jariyabon *et al*., 2007; Lothongkum *et al*., 2001; Lothongkum *et al*. 1999; Karadeniz *et al*., 2007; Oyetunji and Nwigboji, 2014; Afolabi, 2008) [3, 5, 6, 4, 8, 1]. To consistently produce high quality welds, arc welding requires experienced welding personnel. One reason for this is the need to properly select welding variables for a given task to provide a good weld quality (Tewari *et al*., 2010).

Talabi *et al*. (2014) [10] studied the effect of welding variables on the mechanical properties of welded 10mm thick low carbon steel plate welded using the Shielded Metal Arc Welding (SMAW) method. Welding current, arc voltage, welding speed and electrode diameter were their investigated welding parameters. Their result showed that the selected welding parameters had significant effects on the mechanical properties of the welded samples. Increase in the arc voltage and welding current resulted in increased hardness. They also showed that increasing the welding speed from 40 - 66.67mm/min caused an increase in the hardness characteristics of the welded samples.

Similarly, Olabisi *et al*. (2022) [7] investigated the effects of welding parameters such as welding current and electrode specifications on the hardness properties of welded mild steel rod (Ø12) using shielded metal arc welding. Their result showed that increased in the arc welding current resulted in increased hardness of the welded joints for all the selected welding geometries. It was also noted from their study that electrode gauge 12 gave higher hardness value of the welded joints than gauge 10 at the various selected welding currents 120, 160, 200 and 240A.

The present study is expected to carry out a comprehensive investigation on the impact of welding speed and power input on the hardness and tensile strength of steel welds.

2. Materials and Methods

2.1 Materials

Low carbon steel carbon steel rod of diameter Ø12mm was selected for this study because of its availability in the market and its use by most industries, engineers and fabricators in most of the engineering production. The chemical analysis of the steel rod was evaluated in order to ascertain its composition and the result was presented in Table 1. The table shows that the rod contains 0.1821% carbon and 98.1339% iron.

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		

2.2 Sample Preparation

The low carbon steel rod (Ø12mm) used for this study was cut into forty-eight (48) samples of dimension Ø12mm × 50mm with the aid of hacksaw. Edge preparation were done through machining in order to have the forty-eight (48) samples categorized as twenty-four (24) samples for each of plane face and double-v edge welding geometry as shown in Fig 1 (Afolabi, 2008) [1]. Twelve (12) welded joints were prepared for the hardness test (i.e., 6 welded joints for each of plane face and double-V edge geometry). Ditto to the tensile test.

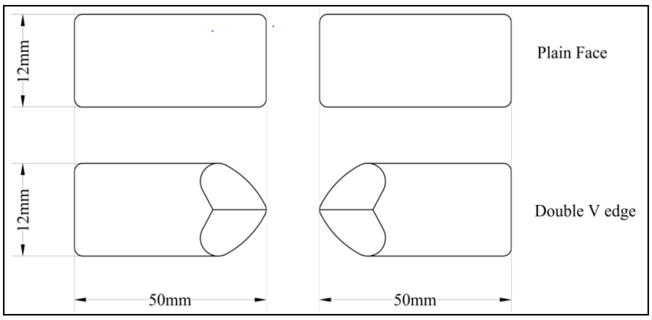

Fig 1: Joint Samples

2.3 Welding Technique

The electric arc welding was used for this work and electrode gauge 12 employed as the welding electrode. Welding current was varied with the voltage fixed at 220V to obtain welding at different power input and welding speed.

2.4 Hardness Test

The hardness test was carried out on the whole width of weldment at Material Science and Engineering Department, Obafemi Awolowo University, Ile-Ife in order to determine the hardness properties of the welded joints. The hardness test was performed using Brinell Hardness Testing Machine.

2.5 Tensile Test

The tensile test was carried out in order to determine the tensile properties of the welded joints using Universal Tensile Testing Machine at Material Science and Engineering Department, Obafemi Awolowo University, Ile-Ife.

3. Results and Discussion

Table 2 and Fig 2 show the Brinell hardness number for the plane face and double-V edge welded joints.

Table 2: Brinell Hardness Number of Plane Face and Double-V edge Welded Joints

Power Input, Welding Speed	Brinell Hardness Number (BHN)	
	Plane Face	Double-V
16.5KW, 15cm/min	140	146
16.5KW, 12cm/min	144	154
16.5KW, 10cm/min	143	150
19.8KW, 15cm/min	131	146
19.8KW, 12cm/min	135	149
19.8KW, 10cm/min	132	148

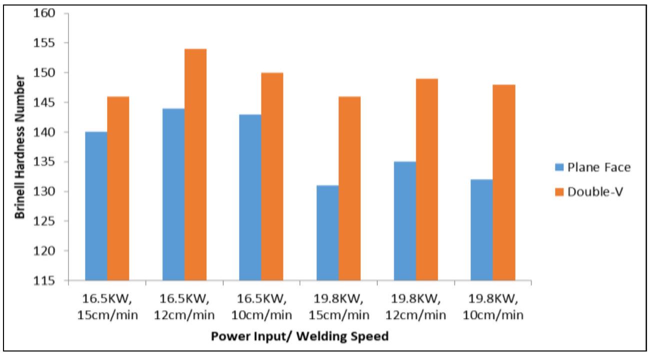

Fig 2: Brinell Hardness Number of Plane face and Double-V edge Welded Joints

It can be deduced from the Table 2 and Fig 2 that the Brinell hardness number of the plane face welded joint got the highest value of 144 at 16.5KW power input and welding speed of 12cm/min. Likewise, the double-V welded joint had its maximum Brinell hardness number of 154 at 16.5KW power input and welding speed 12cm/min. The hardness number of both welding geometry increases as the welding speed increases from 10cm/min to 12cm/min at 16.5KW. This implies that welding at higher power input and welding speed than 16.5KW and 12cm/min respectively might not be necessary if higher hardness value of the welded joint is required. Also, welding at higher power input of 19.8KW at all the selected welding speed gives lower Brinell hardness number.

Tables 3 and Fig 3 show the tensile properties of the plane face welded joints at different power input and welding speed.

Table 3: Tensile Properties of Plane Face Welded Joints

Power Input, Welding Speed	Load @ Max. Tensile Stress (N)	Maximum Tensile Stress (Mpa)	Tensile Extension @ Max. Tensile Stress (mm)	Tensile Strain @ Max. Tensile Stress (mm/mm)	Young Modulus (Mpa)
16.5KW, 15cm/min	9525.16	757.89	5.32084	0.19003	3988.27
16.5KW, 12cm/min	10398.27	827.47	5.90031	0.19668	4207.19
16.5KW, 10cm/min	7357.68	585.51	5.83369	0.19446	3010.95
19.8KW, 15cm/min	10003.63	796.06	5.81669	0.20774	3832.00
19.8KW, 12cm/min	9635.27	766.67	5.32519	0.19019	4031.07
19.8KW, 10cm/min	9470.69	753.65	5.46681	0.19524	3860.12

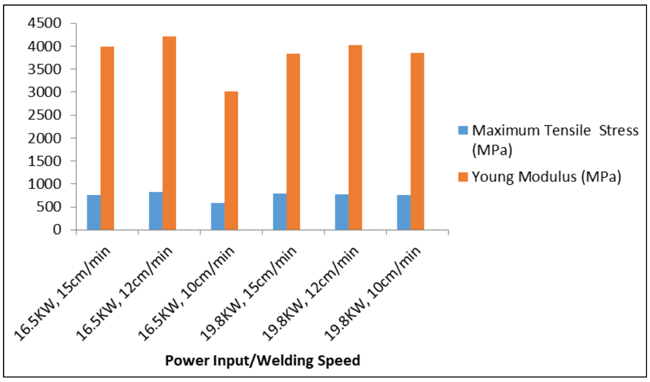

Fig 3: Tensile Properties of Plane Face Welded Joints

Table 4 and Fig 4 show the tensile properties of the double-V edge Welded Joints at different power input and welding speed.

Table 4: Tensile Properties of Double-V edge Welded Joints

Power Input, Welding Speed	Load @ Max. Tensile Stress (N)	Maximum Tensile Stress (Mpa)	Tensile Extension @ Max. Tensile Stress (mm)	Tensile Strain @ Max. Tensile Stress (mm/mm)	Young Modulus (Mpa)
16.5KW, 15cm/min	9905.77	788.28	5.50025	0.19644	4012.83
16.5KW, 12cm/min	10644.07	847.03	5.02519	0.17947	4719.62
16.5KW, 10cm/min	10204.58	812.06	5.32525	0.19019	4269.73
19.8KW, 15cm/min	9489.18	755.12	5.13344	0.18334	4118.69
19.8KW, 12cm/min	9874.24	785.77	4.77525	0.17054	1884.09
19.8KW, 10cm/min	9880.8	786.29	5.18344	0.18512	4247.41

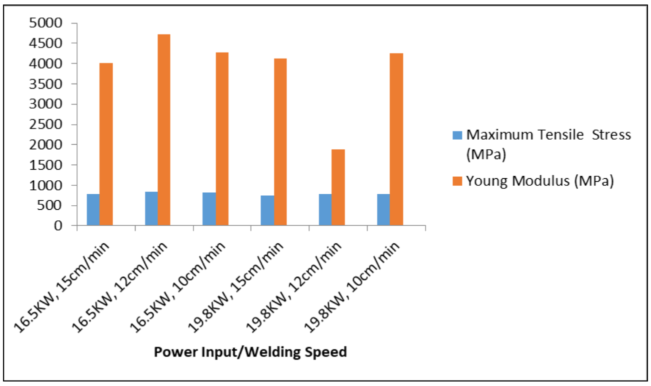

Fig 4: Tensile Properties of Double-V edge Welded Joints

Maximum tensile stress and Young Modulus of elasticity were the two significant tensile properties considered. It is worthy of note that maximum tensile stress and highest value of Young Modulus of elasticity were obtained for both plane face and double-V edge welded joints at both medium power input 16.5KW and welding speed 12cm/min as indicated in Tables 3 and 4 and Figs 3 and 4. 827.47MPa and 4207.19MPa were obtained as the maximum tensile stress and highest Young Modulus of elasticity at power input 16.5KW and welding speed 12cm/min for plane face welded joint. Similarly, the double-V edge welded joints had 847.03MPa and 4719.62MPa as maximum tensile stress and highest value of Young Modulus of elasticity respectively at 16.5KW power input and welding speed 12cm/min.

4. Conclusion

The study reveals that:

- Welding speed and power input play a significant role in determining the Brinell hardnes number, ultimate tensile stress and Young modulus of elasticity of arc welded steel joints.
- Brinell hardness number, ultimate tensile stress and Young modulus of elasticity of both plane face and double-V edge welded joints increases from the welding speed of 10cm/min to 12cm/min at 16.5KW power input but reduces at higher power input.

5. Acknowledgements

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