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Effect of welding variables on mechanical properties of low carbon steel welded joint

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A B S T R A C T

This paper discussed the effect of welding variables on the mechanical properties of welded 10 mm thick low carbon steel plate, welded using the Shielded Metal Arc Welding (SMAW) method. Welding current, arc voltage, welding speed and electrode diameter were the investigated welding parameters. The welded samples were cut and machined to standard configurations for tensile, impact toughness, and hardness tests. The results showed that the selected welding parameters had significant effects on the mechanical properties of the welded samples. Increases in the arc voltage and welding current resulted in increased hardness and decrease in yield strength, tensile strength and impact toughness. Increasing the welding speed from 40-66.67 mm/min caused an increase in the hardness characteristic of the welded samples. Initial decrease in tensile and yield strengths were observed which thereafter increased as the welding speed increased. An electrode diameter of 2.5 mm provided the best combination of mechanical properties when compared to the as received samples. This behaviour was attributed to the fact that increased current and voltage meant increased heat input which could create room for defect formation, thus the observed reduced mechanical properties.

A R T I C L E I N F O

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1. Introduction

Steel is an important engineering material. It has found applications in many areas such as vehicle parts, truck bed floors, automobile doors, domestic appliances etc. It is capable of presenting economically a very wide range of mechanical and other properties.

Traditionally mechanical components has been joined through fasteners, rivet joints etc. In other to reduce time for manufacturing, weight reduction and improvement in mechanical properties, welding process is usually adopted. Today, a variety of different welding processes are available, such that welding is extensively used as a fabrication process for joining materials in a wide range of compositions, part shapes and sizes. Welding is an important joining process because of high joint efficiency, simple set up, flexibility and low fabrication costs [1]. Welding is an efficient, dependable and economical process.

Welded joints are finding applications in critical components where failures are catastrophe. Hence, inspection methods and adherence to acceptable standards are increasing. These acceptance standards represent the minimum weld quality which is based upon test of welded specimen containing some discontinuities. Welding involves a wide range of variables such as time, temperature, electrode, pulse frequency, power input and welding speed that influence the eventual properties of the weld metal [2-9]. Welding of steel is not always easy. There is the need to properly select welding parameters for a given task to provide a good weld quality.

Therefore, the use of the control system in arc welding can eliminate much of the "guess work" often employed by welders to specify welding parameters for a given task [10]. There is therefore need for experimental research to generate data for the design of a welding control system that can give optimized properties.

The effect of welding variables on the mechanical properties of low carbon steel arc welded joints was studied in this research. The experiment was carried out with the object of knowing how these individual variables affect the mechanical properties of the welded steel sample.

2. Materials and methods

The composition of the sample is shown in Table 1. Fig. 1 shows, the welded plate and the geometry of the 10 mm plates butt welded with a weld gap of 3 mm. Specimens of dimensions 60 mm × 40 mm × 10 mm were prepared as suggested by Agarwal [11]. Work piece surfaces and edges were suitably prepared using wire brush prior to the welding processes. The plates were welded together by the SMAW process employing basic coated electrodes. A 7018 low hydrogen electrode rod was used for the welding operation. A high voltage DC generators with rectifiers, capable of supplying current of up to 600 A, air and water cooled electrode holder was used for the welding operation. Pair of prepared metal plates were abutted leaving a gap of about 3 mm in between, while the gap is filled completely, putting into consideration the root, hot pass, fill, cap and bead. The welding was done under controlled and varying welding variables. The welded samples were allowed to cool and tapped with hammer to remove the slag in other to ensure the gap was perfectly filled. The completely filled welded joints were thereafter ground with grinding machine to standard dimension. Four independent process variables, i.e. welding current, welding voltage, welding speed and electrode diameter were selected for study.

Impact tests were conducted using the Avery-Dennison impact-testing machine. Each experiment was repeated at least three times and the average values recorded. Brinell hardness tester under a static load of 3000 kg with a ball indenter of 10 mm diameter was used for the determination of the hardness of the welded joint specimens at a dwell time of 15 s. The diameter of indentation on the specimen was measured with the aid of a calibrated microscope and determined according to ASTM E 10-08 standard and the corresponding hardness obtained. A transverse tensile test specimen was cut from a welded butt joint to determine its transverse tensile strength according to BS EN 895 standard. A Mosanto tensiometer was used to determine the ultimate tensile strength and yield strength of the welded specimen using ISO 6892 standard.

Table 1 Chemical analysis result of as-received low carbon steel (LCS)

Element	C	Si	Mn	P	S	Cr	Nb	Ni	Al	Cu	V
Percentage	0.08	0.35	1.49	0.013	0.002	0.03	0.004	0.17	0.047	0.03	0.001

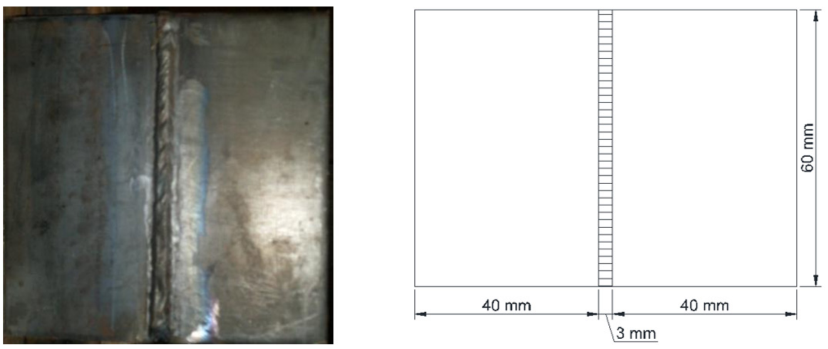

Fig. 1 Welded Plate and the geometry of the 10 mm plates butt welded with a weld gap of 3 mm

3. Result and discussions

3.1 Hardness

Fig. 2 shows the effect of the welding variables on the hardness of welded joint of low carbon steel samples. Fig. 2(a) shows that the hardness of the welded samples changed slightly with changes in voltage values between 20 V and 35 V. The sample welded at 20 V shows a considerable increase in hardness as compared to the unwelded sample which decreased slightly above this voltage value. As seen in Fig. 2(b), increase in the welding current from 95 A to 155 A resulted in increase in hardness. This is similar to the effect of the welding voltage. In Figs. 2(c) and 2(d), the hardness of the samples increased with increasing welding speed while the highest hardness value was obtained with 3.5 mm electrode diameter. Increasing the welding speed from 40 mm/min to 66.67 mm/min caused an increase in the hardness characteristic of the welded samples. This phenomenon can be related to structural changes of weld metal during solidification and chances of formation of defect in the various welding conditions. The weldment increased hardness value may be due to carburization. These increased hardness values indicates that the welded joint will be prone to brittleness than the base metal; hence post-welding heat treated will be required to optimize the mechanical property [12]. The results obtained are similar to the work of other researchers [12-14].

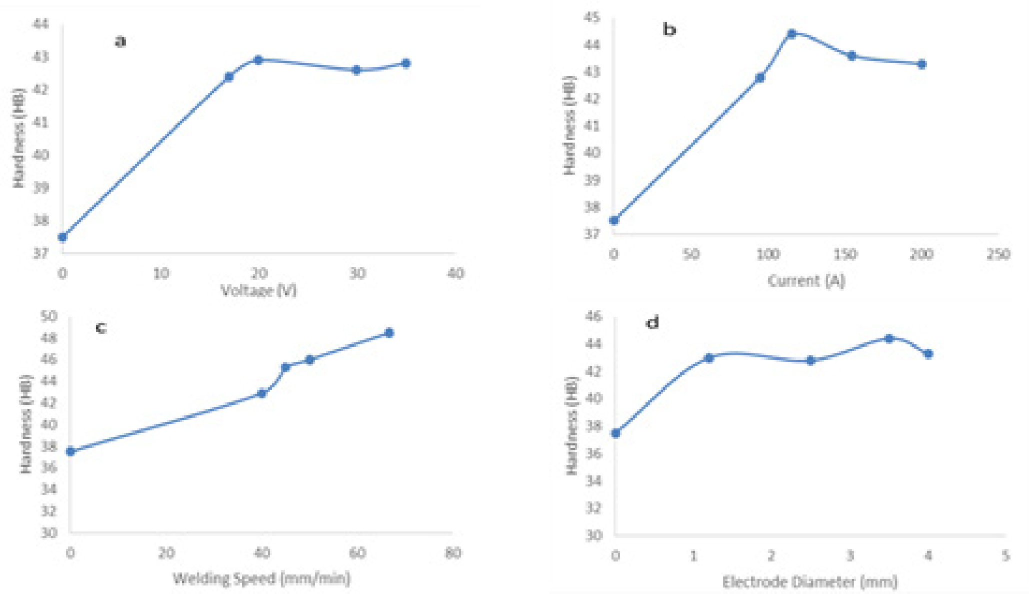

Fig. 2 Effect of welding parameters on the hardness of the welded joint

3.2 Tensile properties

The effect of welding voltage, current, speed and electrode diameter variations with yield strength (MPa) and ultimate tensile strength (UTS, MPa) of the welded joints are shown in Fig. 3 and Fig. 4, respectively. Both figures show that the yield strength and UTS of all the joints decreased with increased voltage. However, increase in welding speed increases both the UTS and yield strength of the welded joints. The current value of 95 A gives the UTS (643.91 MPa) which is closest to the UTS value of unwelded sample (654.91 MPa). Afterward, a significant decrease in UTS value was recorded as the current increased. The decrease in strength may be associated with the presence of void and other defects occurring as a result of increasing current. Excessive grain growth could also lead to the decrease in the tensile properties [15]. This result is also similar to the work of another author [13].

Yield strength decrease of 19.8 %, 34.2 %, 28.4 % and 34.2 % were obtained for the voltage, current, speed, and electrode diameter, respectively, while UTS decreased by 27.8 %, 29.9 %, 27.8 % and 29.8 % for the various welding parameters. It is evident from here that welding current and electrode diameter are important parameters that must be monitored for tensile properties of steel. The welding current must not be too high and electrode diameter of 2.5 mm gave better combination of the tensile properties. It could also be deduced for the figures that the travel speed of 66.67 mm/min has the best tensile properties combination which is close to the as-received samples.

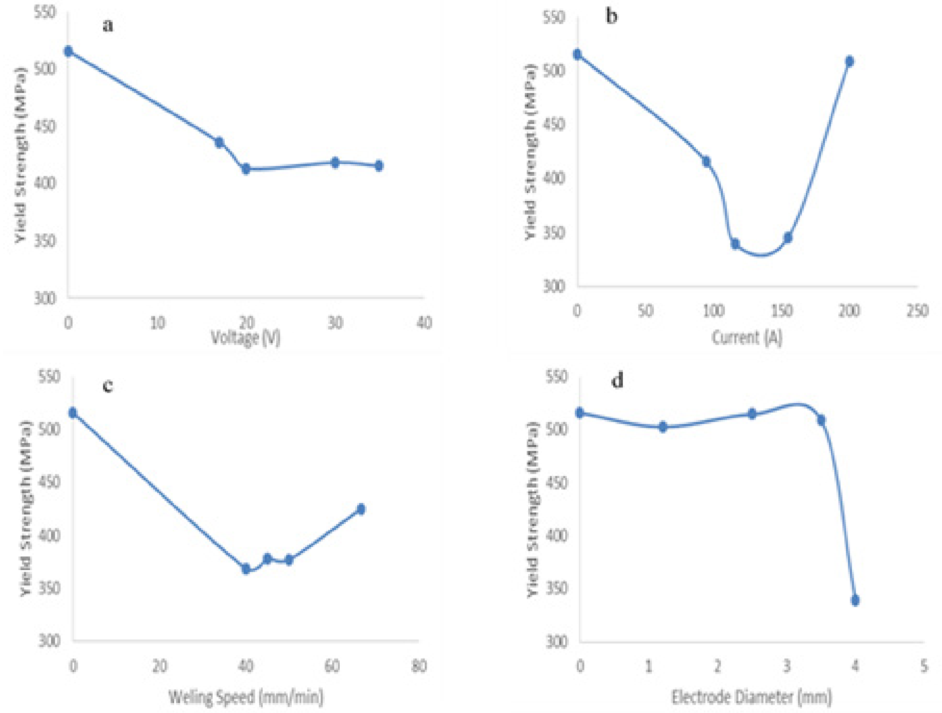

Fig. 3 Effect of welding parameters on the ultimate tensile strength of the welded joint

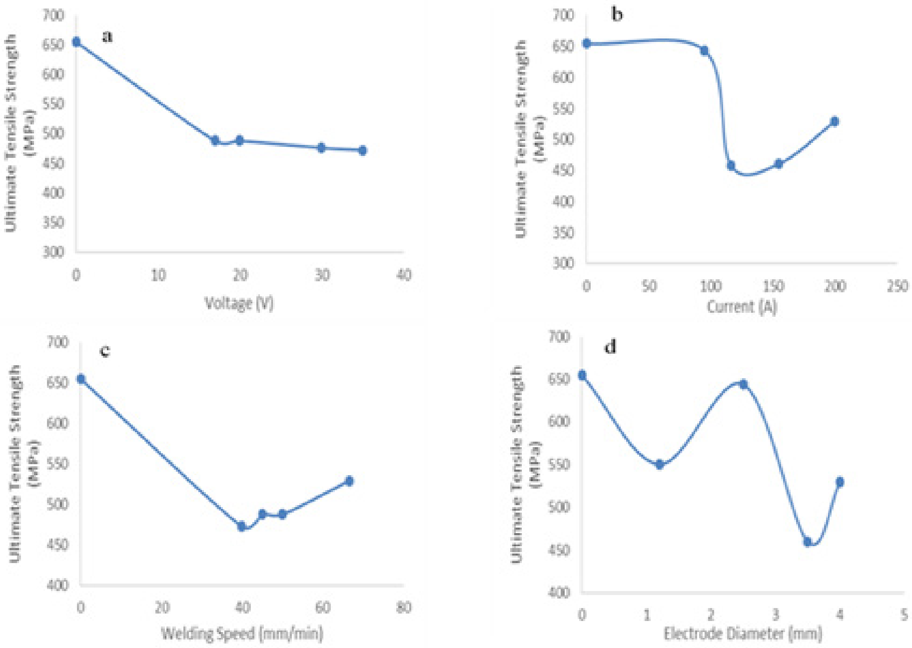

Fig. 4 Effect of welding parameters on the yield strength of the welded joint

3.3 Impact toughness

Fig. 5 shows the effect of welding parameters on the impact toughness of the welded joint made by SMAW. The impact toughness values of all the welded joints are lower than that of the base metal irrespective of the welding parameters. The figure shows similar profile with those of the tensile properties except for welding voltage and electrode diameter. Impact toughness decrease of 12.0 %, 9.1 %, 12.9 %, and 9.5 % were also obtained for welding voltage, current, speed and electrode diameter, respectively, compared with that of the base metal. This shows that welding voltage and speed must be synergistically selected to obtain the best impact toughness value. Electrode diameter of 2.5 mm also gave the best impact value for the welded joints.

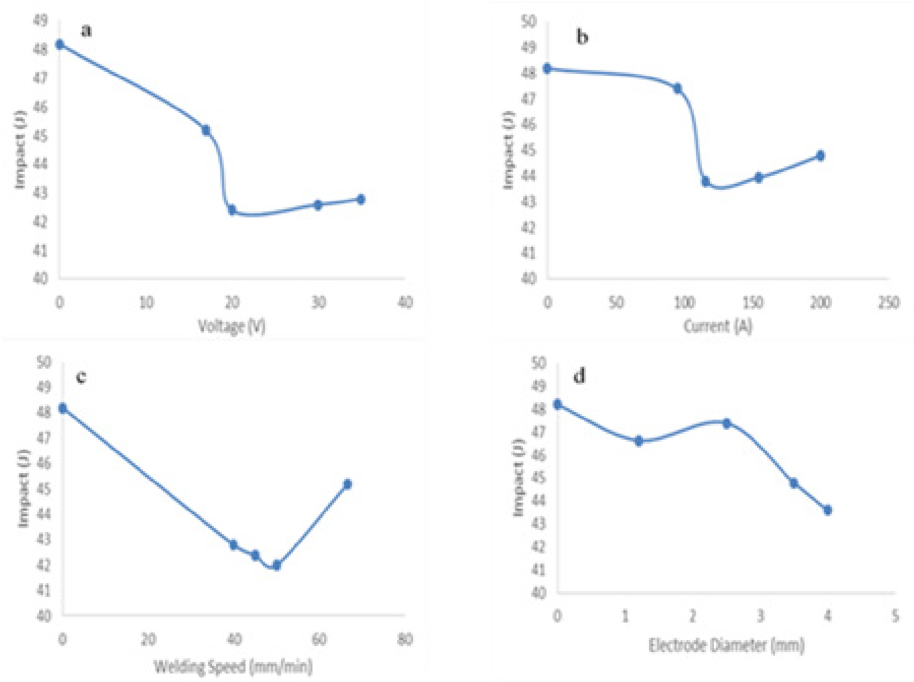

Fig. 5 Effect of the welding parameters on the Impact strength of the weld metal

4. Conclusion

The effect of varied welding parameters was examined and discussed in other to be able to predict the service behaviour (performance) of welded low carbon steel samples. The results have shown that the selected welding parameters have significant effect on the mechanical properties of the welded samples. Increase in the arc voltage and welding current result in increased hardness values and decreased yield strength, tensile strength and impact toughness. This behaviour was attributed to the fact that increased current and voltage means increase in the heat input which can create room for defect formation, thus the observed reduced mechanical properties. The increased hardness may be due to electrode coating which provides alloy addition to the weld deposit. In the future work, the authors plan to report the effect of this welding variable on the microstructure of the steel sample. The structure-properties relationship will also be characterised.

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