# An Investigation of the Effect of Welding Current on the Mechanical Properties of Mild Steel Joints When Using Arc Welding

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*Abstract*—**Welding is a fabrication process in which two or more parts are fused together by means of heat, pressure, or both, forming a join as the parts cool. This paper aims to investigate the effects of current on the mechanical properties and microstructure of mild steel joints when using arc welding. The arc welding experiment was carried out using different currents (100 A, 150 A and 200 A). The hardness and impact tests were conducted according to ASTM E384 and ASTM E23-12C standards. The results show that a high welding current generates a high surface temperature during the arc welding process. The increase in surface temperature negatively affects the mechanical properties of the welding zone. The highest hardness and toughness were obtained at a low welding current and reported to be 269 HV and 205.71 J, respectively.**

***Keywords—current, properties, arc welding, mild steel, temperature***

## I. INTRODUCTION

In the process industry welding is very widely used by metal workers in fabrication, maintenance and repairs of parts and structures [1]. A welding process is a very common manufacturing stage to utilize the steel into a functional and useful product with an additional coating [2]. It is a fabrication process in which two or more parts are fused together by means of heat, pressure, or both, forming a join as the parts cool [3]. It is considered the most ideal method among generally used assembly methods in present mechanical applications [4]. Extreme heat is applied to the parts to be welded, keeping the two bits of metals together, to frame a liquid puddle at the spot of weld which, during cooling, join by metallurgical particle to form a molecular bond [5]. There are several arc welding processes in which the shielded metal arc welding is a promising joining process and is used by several small scale industries for making products [1]. Possibly the most well-known technique for welding metal is arc welding, which is a heat-type welding [6]. It is the main assembling operation for the joining of components for a wide scope of utilisations, including guideways for trains, ships, bridges, cars, and atomic reactors, to name a few. It requires a persistent supply of alternating or direct current flow, which makes an electric arc to produce sufficient heat to soften the metal and structure a weld [7]. Any arc welding needs heat to dissolve the metal work piece and the welding cathode, which can be produced by applying an appropriate welding current and voltage in the welding system [8]. The welding current has enormous impact on the construction and properties of the weld. Because of welding, a portion of the properties of the weld lessen, however, the properties can be improved by adding some additional material in the covering of the anodes [9]. Mild steel is one of the common metals joined together using arc welding. It is utilised in a few engineering applications to manufacture auto parts, structural shapes and sheets that are utilised in pipelines, structures, plants, scaffolds, and metal jars. It is significantly utilised as a construction material. Mild steel is known for its high carbon content of about 0.2% to 2.1%, manganese (1.65%), copper (0.6%) and silicon (0.6%) [10].

Study on Effect of Manual Metal Arc Welding Process Parameters on Width of Heat Affected Zone (Haz) For Ms 1005 Steel was conducted by [7]. The results shows that the original austenite grain size increases with the increase of heat input. In 2010, [11] found that when heat input increases, fatigue life of weld metal decreases whereas impact energy of weld metal increases in first and then drops significantly. They were conducting a study on Effect of arc voltage, welding current and welding speed on fatigue life, impact energy and bead penetration of AA6061 joints produced by robotic MIG welding. A review on effect of arc welding parameters on mechanical behaviour of ferrous metal shows that the selection of the suitable process parameters are the primary means by which acceptable heat affected zone properties, optimized bead geometry and minimum residual stresses are created [12]. At 120A the grain size was most coarse with a hardness and toughness value of 60BHN and 11 Joules respectively indicating reduced strength and hardness. This was reported by [13] on the study of mechanical Properties of A36 Carbon Steel Weld Joints.

Material joining and welding plays a key role in the economic development of a country. It is essential for the construction of highly sophisticated devices and structures, including vehicles, among others [14]. productivity of welding process. Welding current and welding speed are considered as factors that determine the melting rate in Gas Metal Arc Welding (GMAW) welding process [15]. New innovation for effectively utilizing existing equipment technology that can improve quality of welded joint with higher productivity is in demand [15]. Correct welding parameters play an important part in Arc welding process. To produce a weld with high mechanical properties, the right welding current needs to be used. The objective of this paper is to investigate the welding current which will result in a joint with high mechanical properties through experimentation and mechanical tests.

## II. Material

S355JR mild steel plate samples with a thickness of 10 mm were used in this investigation as a base metal. A 0.9mm (ER70S-6) welding wire along with terral gas was used as joining material using MIG arc welding at different currents.

## III. Methodology

### *A. Arc Welding Experiment*

A Bekamak BMSY320 bandsaw cutting machine was used to cut six specimen samples of 30 x 30 x 10 mm rectangular dimensions with the use of emulsifier coolant. Each specimen was bevelled on one edge to a 20° angle as shown in Figure 1(a) using a 900 W hand grinder. The bevelled surfaces were cleaned using a rotating wire brush before being welded together. A PRO-MIG 350 welding machine which is presented in figure 1 was used to create butt weld joints between specimen samples at currents of 100 A, 150 A and 200 A as shown in Figure 2(b). ER70S-6 (0.9 mm) wire at a speed of 360 mm/min was used to create the joint and terral gas, which has a composition of 90% argon, 5% oxygen and 5% carbon dioxide, was also used as a shielding gas. Slag was chipped off from each welded sample and it was allowed to naturally cool down.


Fig. 1 Welding machine.

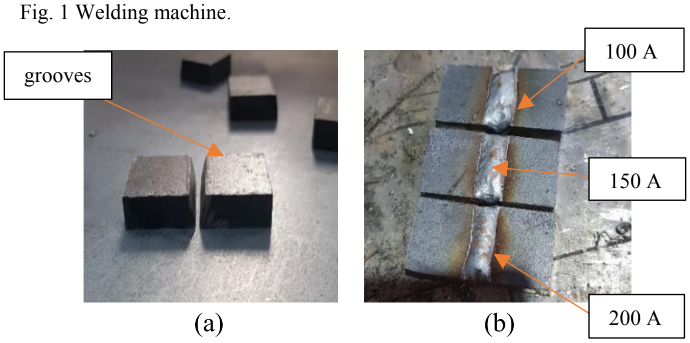


Fig. 2. (a) Bevelled specimen samples, (b) Butt welded samples.

### *B. Hardness Test*

A Vickers hardness test was performed on each welded sample using an EMCO test machine at the University of South Africa's mechanical engineering workshop. The ASTM E384 standard method was used on these samples. The test was conducted on the weld zone and for statistical consideration, five indentations were made per sample. A test force of 100 HV was used and the holding time was 10 seconds. Data were recorded and are presented in Table I.

TABLE I. Vickers Hardness Test Data

| Indentation number | 100 A sample (HV) | 150 A sample (HV) | 200 A sample (HV) |
|---|---|---|---|
| 1 | 274 | 182 | 172 |
| 2 | 279 | 192 | 170 |
| 3 | 263 | 203 | 174 |
| 4 | 267 | 204 | 170 |
| 5 | 262 | 194 | 174 |
| **Average** | **269** | **195** | **172** |

### *C. Impact Test*

An impact test was conducted on all welded samples using a Izod impact test machine. The samples were cut by water jet to the following dimensions, 55 mm long, 10 mm wide and 10 mm thick. A groove of 5 mm deep was machined at the centre of the weld zone. The ASTM 23-12C standard was followed when machining the samples. Three samples were machined per welded sample and were named 1 representing 100 A, 2 representing 150 A and 3 representing 200 A samples. Machined samples are presented in figure 3. Experimental data were recorded and are shown in Table II.

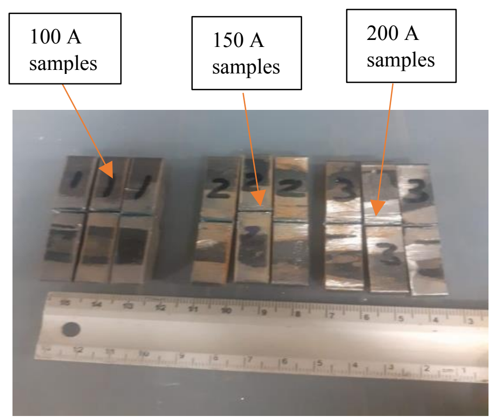


Fig. 3. Impact testing specimen

TABLE II. Impact Toughness Test Experimental Data

| **Samples** | **Potential energy (J) 100 A** | **Potential energy (J) 150 A** | **Potential energy (J) 200 A** |
|---|---|---|---|
| 1 | 232.54 | 177.12 | 144.34 |
| 2 | 198.60 | 214.21 | 173.96 |
| 3 | 182.44 | 226.39 | 208.46 |
| **Average** | **204** | **205.91** | **175.59** |

## IV. Results and Discussion

Experimental results from Tables I and II are graphically presented in figures 4 and 5, respectively.

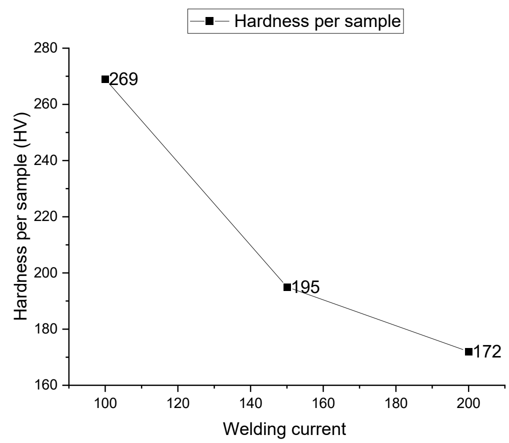


Fig. 4. Hardness per sample

Figure 4 presents the Vickers hardness 100 HV profile of sample 100 A, 150 A and 200 A. This figure shows that at the higher welding current, the weld becomes softer compared to when the current is low. The hardest weld was at 100 A, and it was reported to be 269 HV. When the welding current increases, it is observed that the weld becomes weak and softer. A higher welding current generates more heat on the material, which results in a high surface temperature. A high surface temperature has a negative impact on the mechanical properties of the material [16]. The same results were reported by [4] in the study of the effects of welding current on weldment properties in MIG and TIG welding. It was also found by [2] that the lowest hardness occurred in the welded sample using highest Ampere in the study of Welding current effect of welded joints of base metal st37 on characteristics: corrosion rate and hardness. Their results show that the temperature increases with an increase in current. The increase of heat input will see a decrease in strength and hardness of a welded joint [17], as well as [18].

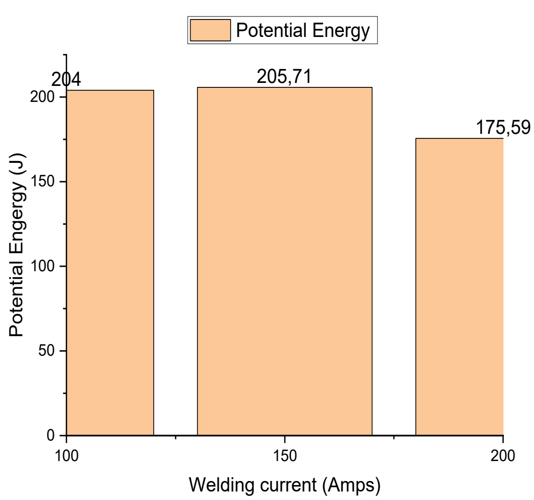


Fig. 5: Impact toughness

Figure 5, above, shows the impact toughness potential energy that each welded sample had during the impact testing. This figure shows that lower current (100 A and 150 A) welded joints have an average potential energy of 204 J and 205.71 J, respectively, while the 200 A joint has potential energy of 175.59 J. When the current is increased during welding, the toughness of the joint is reduced due to the increase in temperature. A continuous increase in surface temperature results in particle size growth [19]. Particle size growth has a negative impact on the mechanical properties of the material being welded. In the study of the influence of temperature on mechanical properties of the base material (BM) and welded joint (WJ) made of steel S690QL, [20] reported that the higher the temperature during the welding process, the more it decreases the mechanical properties of the joint.

## V. Conclusion

The investigation of the effect of current on the mechanical properties on mild steel joints when using arc welding was achieved in this study. The results show that current influences the mechanical properties of mild steel joints. The higher the current, the lower the mechanical properties of mild steel during the arc welding process. The joint that was created with a high current of 200 A reported a hardness and toughness of 172 HV and 175.59 J, which are low values compared to those of a lower welding current. During the welding process, a high welding current produces high surface temperature. This temperature results in particle size growth, which negatively affects the mechanical properties of butt joints. It can be concluded that the lower the welding current, the higher the mechanical properties of the weld zone.

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