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Effect of Welding Constraints on the Mechanical Characteristic of ASTM A36 Mild Steel

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Abstract: This study investigated the outcome of heat input on the mechanical characteristics of mild steel using the flux-coated electrode welding process on 6 mm thick plates with two edge preparations. Welding parameters comprised of 100 and 220 Voltages, currents of 70 A, 80 A, and 90 A, and electrode gauges of 10 and 12. The results show that increasing heat input decreases hardness and tensile strength due to grain coarsening, while ductility and impact strength improve. Lower heat input promotes finer grain structure and higher hardness. These findings agree with Singh & Kumar (2019), who testified higher hardness at lower voltage and upgraded ductility at higher voltage, and Rahangmetan et al. (2020), who highlighted the influence of electrode type and current on tensile strength and optimal welding performance in ASTM A36 steel joints.

Keywords: ASTM A36 Steel, Welding Current, Welding Voltage, Microstructure.

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1. Introduction

1.1 Background

ASTM A36 is one type of mild steel that is popular in the construction and industrial marketplace. It is classified as low-carbon steel that has moderate strength and quite a high formability, and thus can be put to use in many industries. The organization known as the American Standards Testing Methods (ASTM) also has a standard specification, A36. The reasons for using A36 steel are the mechanical properties, affordability, and ease of application. To obtain the necessary mechanical characteristics and overall performance, ASTM A36 steel's chemical composition is meticulously regulated. Iron makes up the majority of this substance, with carbon, manganese, phosphorus, sulfur, silicon, and copper being important alloying elements. In order to preserve a balance between strength and ductility, the carbon concentration is restricted to 0.25%. While phosphorus and sulfur are limited to maximum amounts of 0.04% and 0.05%, respectively, to prevent brittleness, manganese, which ranges from 0.80% to 1.20%, improves strength and toughness. Copper is added with a minimum content of 0.20% to improve corrosion resistance, and silicon is present up to 0.40% to improve strength and deoxidation. To guarantee the best possible balance of strength, ductility, and weldability, these components are mixed in precise ratios [1].

1.2 Literature Review

The A36 Steel tensile strength is usually between 400-550 MPa or simply 58,000-80,000 psi. This property predicts the amount of stress the steel will experience before it breaks under tension. [2].As reported in the study, the elongation is a measure of elongation, which presents the percentage in 200 mm (6 inches) for A36 steel at about 20% and in 50 mm (2 inches) at about 23%. This feature measures the ability of the steel to lengthen before breaking, which is quite important for procedures requiring noticeable deformation without breaking [3]. It was observed that the density of A36 steel is near about 7.85 g/cm^3 (0.284 lb/in^3). Density is a critical factor in weight calculations for structural applications and material selection for projects where weight is a concern [4]. ASTM A36 steel's combination of mechanical and physical properties makes it appropriate for a varied range of applications. It is most commonly used for the civil construction of buildings, bridges, and other structures because of its excellent weldability and formability. Some specific applications include [5]. Similarly found that A36 steel is commonly used in general fabrication applications, such as the production of tanks, enclosures, and other custom structures. Its versatility allows for easy shaping, welding, and machining to meet specific project requirements [6]. Previous studies have shown that mathematical modeling tools are useful to manage welding parameters so that welded connections in A36 carbon steel can perform better. Finally, it is established that higher arc welding currents (70-120A) influence microstructure properties and mechanical properties of A36 mild steel welds by the reduction in toughness and hardness. It has provided the most significant findings of the welding current and the mechanical characteristics of the welded joints, and also the possible directions for further research in welding operations [7]. As reported by this study examines how heat input and groove angle affect the welding properties of A36 and A53 steels using Flux Core Arc Welding (FCAW), as determined by metallography and bending tests. The findings indicate that greater heat input and groove angles (~60°) enhance weld quality by boosting pearlite production and decreasing flaws, resulting in stronger joints. Lower specifications, on the other hand, result in higher flaws and ferrite content, making the welds more brittle [8]. The experimental procedure included grinding of the plates, MIG welding, and tensile testing in order to obtain results on tensile strength. All the steps taken were made with a strong consideration of the best way to measure and analyze the welding parameters. The other independent variables did not reveal any effects since their p-values were greater than the stipulated alpha level, and the null hypotheses were accepted. The Response Optimizer in Minitab identified optimal welding parameters: A wire speed of 40 inches p/m, voltage at 3, and travel speed at 9 inches p/m. [9]. This study uses shielded metal arc welding (SMAW) to investigate the effects of welding current and position on the mechanical properties of A36 steel. The findings indicate that while vertical (3G) position produces higher hardness, higher current increases heat input, which causes grain coarsening, residual stresses, and decreased strength. In the 3G position, the ideal condition was discovered at 90A, emphasizing the necessity of controlling welding conditions for improved performance [10]. To investigate impacts on temperature and microstructure, two 6 mm low-carbon steel plates were welded utilizing a single V-groove connection at different welding powers (2.6–9.9 kW) and speeds. The findings demonstrated that wire feed rate has a major impact on heat input, with an ideal rate of about 7 m/min resulting in a homogeneous weld structure and improved ferrite-pearlite distribution. Controlling welding settings is crucial since higher heat input results in coarser grains and slower cooling, while lower heat input creates finer microstructures [11].

2. Materials and Methods/Methodology

Hot-rolled plates of Mild steel purchased from a local metal market. Samples with a thickness of 06 mm of the steel plate were cut into pieces and arranged for welding purposes. E6013 electrode with SWG 10 and 12 was taken for the shielded metal arc welding (SMAW) process. Mild steel ASTM A36 plate of 3000 mm in length, 50 mm in breadth, and 6 mm in thickness was bought.

Table 01 Nomenclature of Samples

Samples	Type of Joint used	Welding Current (Amp)	Type of Rod used	Voltage
1	Butt (Flat faces)	70	SWG 10,12	220
2	Butt (Single Bavel)	70	SWG 10,12	220
3	Butt (Flat Faces).	80	SWG 10,12	220
4	Butt (Single Bavel)	80	SWG 10,12	220
5	Butt (Flat)	90	SWG 10,12	220
6	Butt (Bevel)	90	SWG 10,12	220
7	Butt (Flat faces)	70	SWG 10,12	100
8	Butt (Single Bavel)	70	SWG 10,12	100
9	Butt (Flat Faces)	80	SWG 10,12	100
10	Butt (Single Bavel)	80	SWG 10,12	100
11	Butt (Flat)	90	SWG 10,12	100
12	Butt (Bevel)	90	SWG 10,12	100

Figure 01: Two plates with V Bevel Edge

Figure 02: Two plates with Straight Edge

It was then segmented into specimens with dimensions of 150 mm in length, 50 mm in width, and 6 mm in thickness, as shown in Figures 1 and 2. A total of twelve samples have been created. Tri squares and other measurement instruments were used to determine each sample's squareness. Polishers and grinders were used to create smooth surfaces. Select electrode E6013 for shield metal arc welding, with 10 and 12 SWG. To do welding on Butt Straight and single V groove joints, two edge preparations were carried out. The specimen for testing was made up of two 200 × 50 × 6 mm thick steel plate portions that were welded together to create a final test plate that measured 200 × 100 × 6 mm. The metal plates whose edges were prepared were taken in the first step in order to make the welded joint or a junction. The angle of bevel between the two plates was 70 degrees. The root gap between the two plates was 2mm. The root of the plate was 1.2mm as per the standards, as shown in Figure 3. Flux-coated rods of 2.5mm and 3.2mm of Perfect Bridge (Brand) were used for the welding. (3.2mm flux-coated rods were only used for 90Amp, and 2.5mm thick rods were used for the 50-90 Amp range).

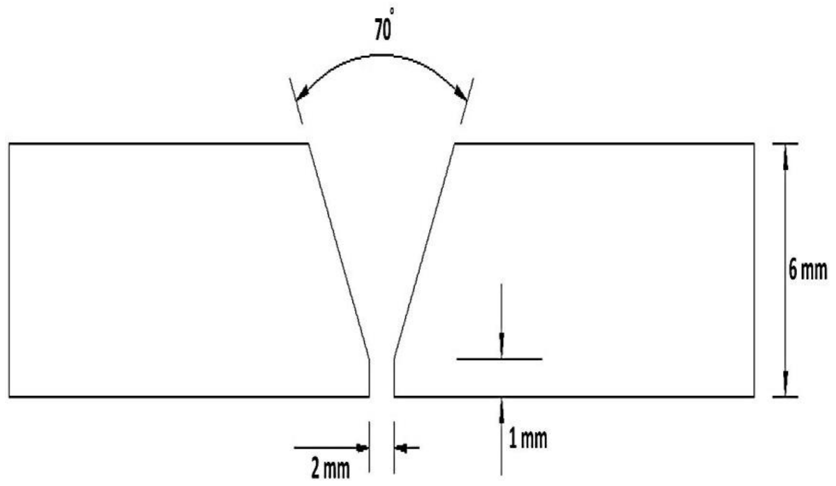


Figure 01: Fit-up of two plates.

The welding procedure and formation of the joint employing various parameters constituted the second stage. In this stage, the travel speed range is from 76 to 102mm/min. The third step was to investigate how the mechanical characteristics and microstructure of the welded junction were affected by the different welding parameters. Using an angle iron, the cut steel pieces were matched and positioned on a table before the welding circuit was set up. Samples were continuously welded in a horizontal position using a SMAW with several welding settings, such as a dual voltage device with 100 V and 220 V, and welding currents of different ranges at 70, 80, and 90Amperes.

3. Results and Discussions

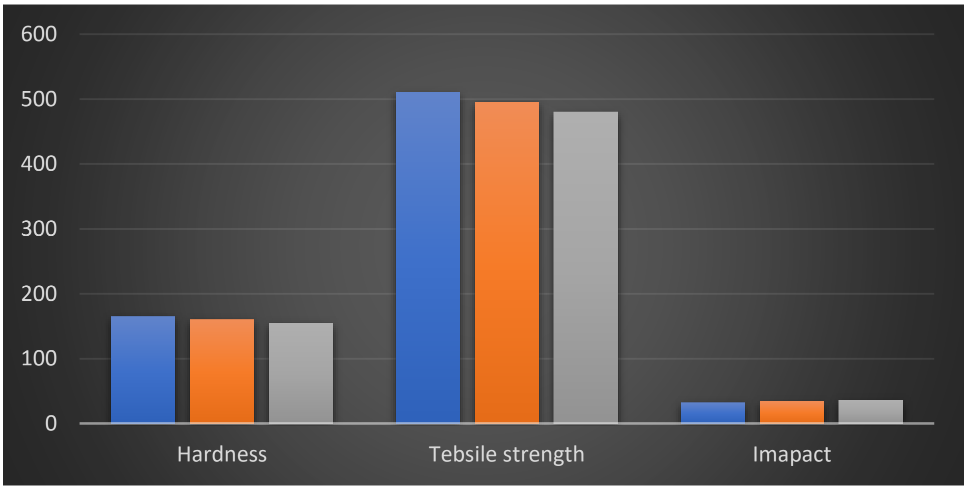
3.1 Results

The mechanical characteristics of the welded steel in the straight edge preparation welded sample are clearly displayed in a graph at a fixed voltage (220 V) and variable current. It was found that the weld bead's size, its appearance, and its strength are all impacted by the current adjustment. As the current was raised, the welded steel's hardness and tensile strength decreased. The grain is recrystallized and grows in size as the current rose because of the increasing heat created. The graph illustrates how the impact strength (toughness) of a weld rises with increased grain size, but the hardness, tensile strength, and heat-affected zone decrease. Likewise, the heat source's input amount of heat is given.

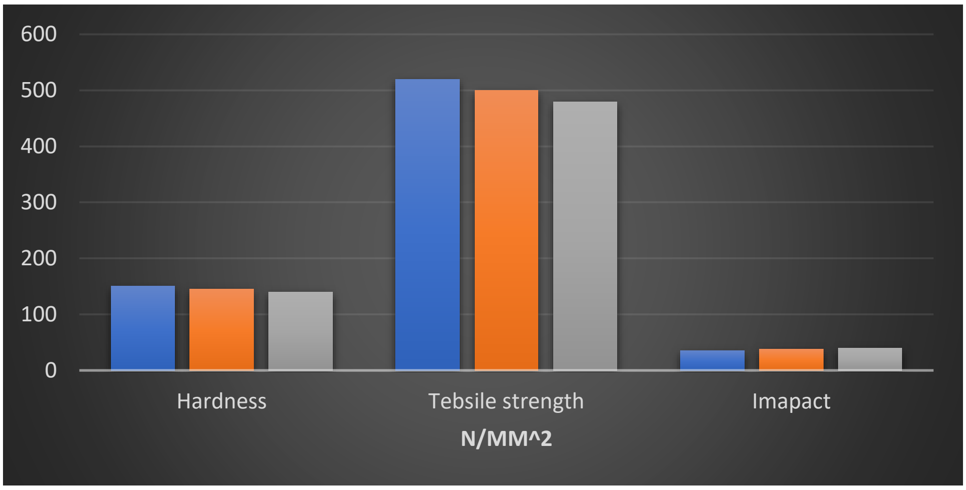
This demonstrates that when the current rises, the weld produces more heat, which causes the weldment and base metal to expand and contract more. Lower mechanical characteristics were the result of an increase in residual stresses.

The mechanical characteristics of the welded steel in the V groove edge welded sample are displayed in a graph at a constant voltage (220 V) and variable current. As the current increased, the hardness and tensile strength of the heat-affected zone and weldment declined.

Once more, this is the result of the weldment receiving more heat input. Due to the low power density of the welding, the heat lingered for a while before being swiftly transmitted into the base metal.

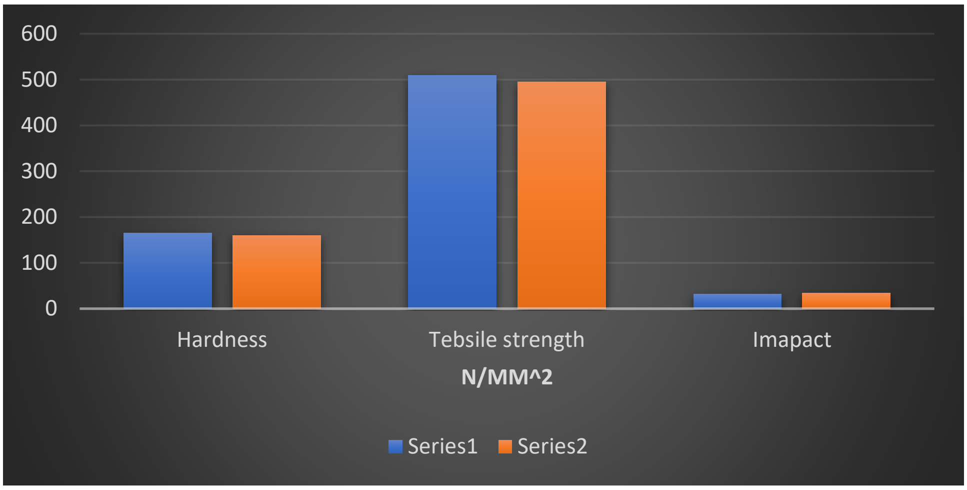


Graph 01 Straight Edge at 70Amp (Blue), 80Amp (Orange) and 90Amp (Gray) 220V



Graph 02 V Edge at 70Amp (Blue), 80Amp (Orange) and 90Amp (Gray) 220V

In this first graph, the increase in current results in decreasing of hardness and tensile strength, but the impact increases with an increase in current. The voltage was varied from 100 V to 200 V, with the current fixed at 100 A. As the voltage increases, the weldment's hardness, tensile strength, and heat-affected zone decrease. Given that they all complied with the mathematical model equation connecting the heat source and parameters of welding (current and voltage). Furthermore, the system is self-adjusting so that an increase in voltage won't result in a noticeably higher welding current because it is challenging to keep a constant distance between the arc and the weldment when welding by hand. There have been notable alterations due to variations in edge preparation.



Graph 3. Fixed voltage at 100Amp (Blue), 110Amp (Orange) 220V

The hardness, tensile strength, and impact strength of two materials, Series 1 and Series 2, are compared in the provided graph. Series 1 is found to have somewhat higher hardness (approximately 160) than Series 2 (about 150), suggesting superior resistance to deformation. In a similar vein, Series 1's tensile strength is roughly 510 N/mm² while Series 2's is marginally lower, roughly 490 N/mm², indicating that Series 1 can sustain higher applied loads before failing. However, Series 2 outperforms Series 1 in terms of impact strength, with a score of about 35 as opposed to 30 for Series 1, suggesting a stronger capacity to withstand impact loading or rapid shock.

The study revealed that both types of welds exhibited similar trends with constant heat input; however, because of improved bonding, V-grooved edges produced somewhat higher tensile strength and impact toughness. At fixed welding conditions, electrode modification had no discernible effect on hardness or tensile strength. Weld cooling behavior was affected by the use of still air cooling (natural convection) for low to medium current welding.

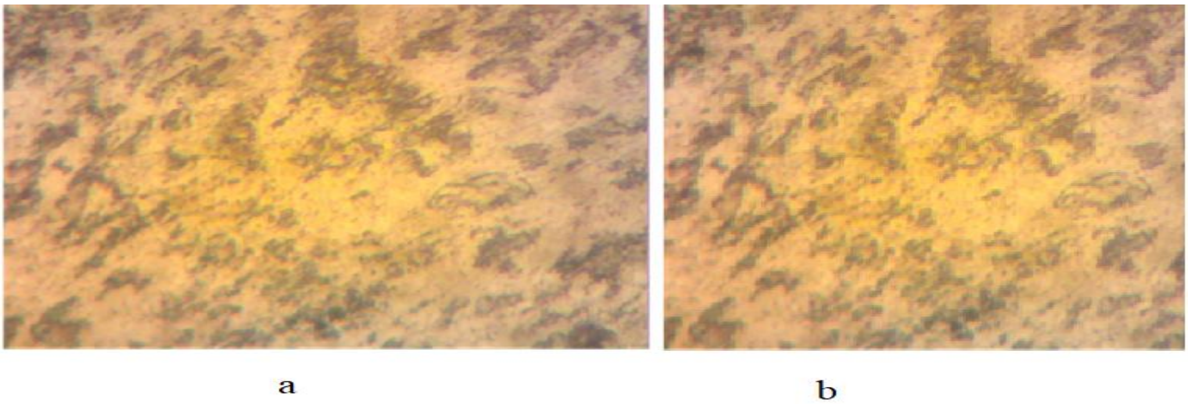
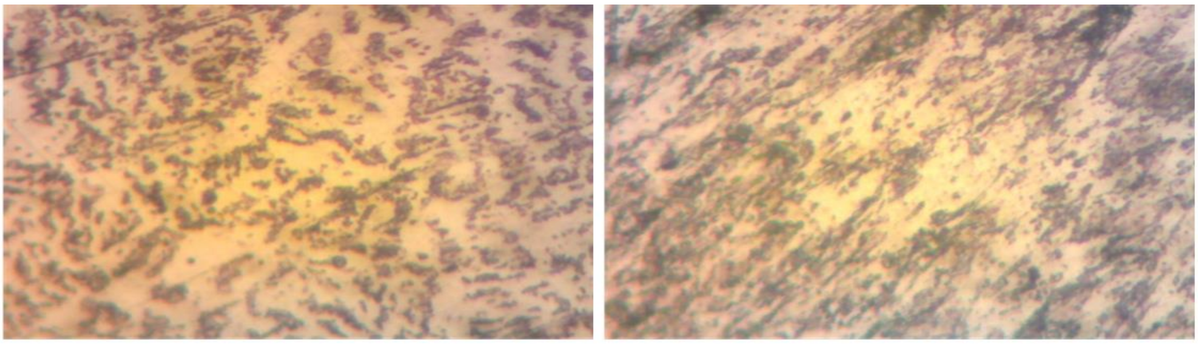


Figure 4 (a, b) 220V Fixed Voltage and straight edge of (Base Metal)



a

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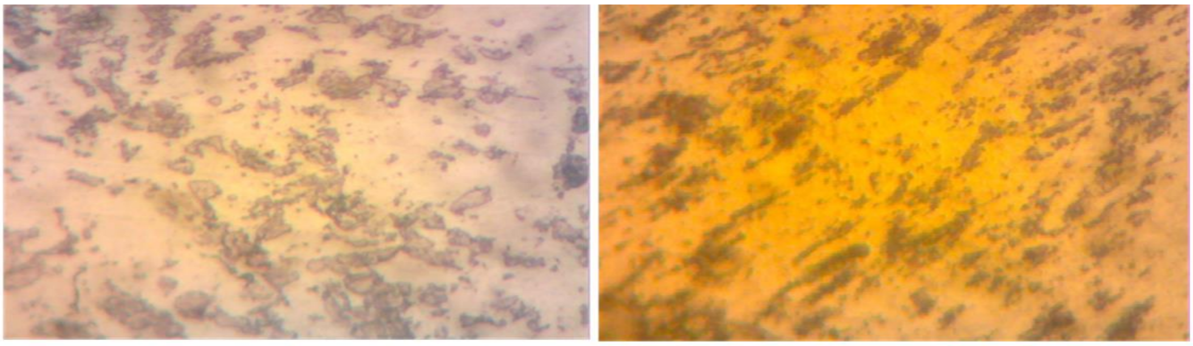
Figure 5(a, b) 220V Fixed Voltage and V edge of (Base Metal)



a

b

Figure 06 (a) Fixed voltage for straight edge (b) Fixed current and voltage for Bevelled edge

The impact of the size of the electrode on the microstructure was further demonstrated by examining the Welded Zones in Figures 3(a) and 3(b). With an increase in grain size, the observed structure of coarse pearlite in the ferrite matrix grew coarser. This finding clarified why the hardness and tensile strength ratings decreased as the energy input of heat increased. Figures 4(a) and 4(b) depict the microstructure of samples that were welded using fixed voltage and current settings for various cooling media. These plates demonstrated how the steel's properties were affected by the rate at which it cooled after welding. While cooling in draft air provides a fine grain size, cooling in still air produces a coarse grain structure of both ferrite and pearlite. This results from the weldment slowly cooling in still air. Comparing this region to the base metal microstructure, fine-grain ferrite and pearlite were seen in Figures 5(a) and (b). This demonstrates unequivocally that the FZ forms an extremely fine-grained structure during the heating and cooling cycles. The term "grain-refined area" is commonly used to describe this area. The microstructures with a larger concentration of the pearlite phase will be harder and stronger, but they will also be less ductile, based on the observation of the plates. When low-carbon steel cooled from the austenitic state, a transition occurred that resulted in ferrite crystals.

Table 02 Comparative Analysis

Authors	Title of Research	Welding Parameters (Current, /Voltage)	I. Tensile Strength (MPa) ii. Impact Strength (J) iii. Hardness (HV)	Key Findings	Performance
Ahmed Nadeem (2025)	Effect of Welding Constraints on the Mechanical Characteristic of ASTM A36 Mild Steel	70A, 80A, 90A 110V, 220V	i.488 ii. 36 iii. 149-189	Similarly found that the weld hardness and tensile strength decreased as the welding current increased due to an increase in heat input, and impact increases with an increase in heat.	V-grooved edge preparation offers superior mechanical qualities to straight edge preparation.
Singh & Kumar 2019 [12]	Influence of Welding Voltage on Mechanical Properties	80A, 90A / 110V, 220V	i. 390-420 ii. 40-55 iii. 145-185	110V produced finer grains, increasing hardness. 220V enhanced ductility but reduced hardness slightly.	80A, 110V (Best hardness), 90A, 220V (Best ductility)
Klemens Alrin Rahangmetan, Christian Wely Wullur2, (2020). [13]	Effect of Variations and Types of SMAW Welding Electrodes on A36 Steel to Tensile Test.	70A, 80A, 90A	i. 355-472	The tensile strength of the ASTM A36 steel weld joining with the major variation of electrode type and welding current is at LB 52 2.6 electrode with a welding current of 90 A, with a tensile strength of 485,152 MPa.	The electrode and good current strength from the welding outcomes on ASTM A36 steel type LB 52 2.6 electrode with a welding current of 90 A.

4. Discussion

According to the earliest investigation, the welds' hardness and tensile strength reduced as the welding current increased due to an increase in heat input, and impact strength increased with an increase in heat. But in this study, the lower heat input is used to get better results. It has been checked that, under the same circumstances, V-grooved edge preparation offers superior mechanical qualities to straight edge preparation. As per this research, it is also found that edge profiling offers superior mechanical Characteristic then straight edge preparation.

5. Conclusion

This study investigated the performance of welded joints, such as hardness, impact strength, and tensile strength, which are essentially influenced by heat input and edge preparation. The primary discovery of this research is that.

1. The welding heat input is likely to have an impact on the joints created throughout the procedure.
2. It is observed that welds' hardness and tensile strength decreased as the welding current increased due to an upsurge in heat input, and impact increases with an increase in heat.
3. This behavior might be caused by grain development at higher temperatures, which would compromise the quality of the welded joint. On the other hand, impact strength decreased as welding temperatures increased, suggesting increased toughness.
4. Additionally, it has been checked that, under the same circumstances, V-grooved edge preparation offers superior mechanical qualities to straight edge preparation.

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