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A REVIEW PAPER ON EFFECT OF WELDING CURRENT ON THE TENSILE PROPERTIES OF SMAW WELDED MILD STEEL JOINT

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ABSTRACT
This major-project investigates the impact of welding current variations on the tensile properties of SMAW welded joints in mild steel. The study aimed to discern how changes in welding current affect the mechanical characteristics of the welded joints, specifically focusing on tensile strength, yield strength, and elongation. The effect of welding current on welding speed and hardness of heat effected zone. The test specimen was then grinded and hardness of each specimen was measured at three points i.e., parent metal, HAZ and weld metal by using Brinell Hardness Tester. Liquid Penetration Test is done to find the defects. Tensile test is done to find the Highest Tensile Strength of the specimen which, it can withstand.

Keywords:
Shielded Metal Arc Welding (SMAW), Tensile Strength, Welding Current, Mild Steel.

INTRODUCTION

Today a wide variety of metal joining processes are used in fabrication industries. The welding is majorly used for metal joining. In this process arc i.e., electric discharge between electrode and parent metal is established. Due to high electrical resistance of welding are high temperature is produced which is enough to melt the metal. SMAW- Shielded Metal Arc welding is one of the arc welding processes. Mild steel is widely applicable in fabrication of structure, process equipment, piping and ship building. The major factors affecting mechanical properties of weld joint are welding current, arc voltage, welding speed, polarity, edge preparation and welding technique. Out of these variables welding current, welding voltage and welding speed are primary variable which controls the fusion, depth of penetration, shape of weld puddle, reinforcement and heat input. Electrode polarity, inclination angle and welding technique are secondary variable which effect on energy absorbed, melting rate of base metal and weld metal.

1.1. Welding

Welding is a process that joins materials, normally metals or thermoplastics, by utilizing high hotness to soften the parts together and permitting them to cool, causing combination. Welding is particular from lower temperature metal-joining strategies, for example, brazing and patching, which don't soften the base metal.

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1.2. Classification Of Welding

1. Arc Welding
2. Shielded Metal Arc Welding (SMAW)
3. Submerged Arc Welding (SAW)
4. Metal Inert Gas Welding (MIG, GMAW);
5. Tungsten Inert Gas Arc Welding (TIG, GTAW);
6. Electros lag Welding (ESW)

1.2.1. Arc Welding

In curve welding process an electric power supply is utilized to create abed among cathode and the work-piece material to joint, so that work-piece metals soften at the interface and welding should be possible. Power supply for bend welding interaction could be AC or DC type. The anode utilized for bend welding could be consumable or non-consumable. For non-consumable anode outer filler material could be utilized.

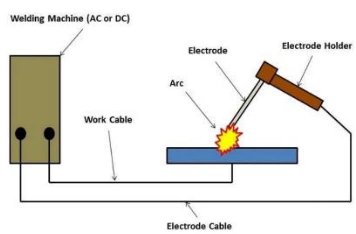

Fig 1. Basic arc welding

1.2.1.1. Manual Metal Arc Welding:
This is most normal sort circular segment welding process, where a transition covered consumable cathode is utilized. As the cathode softens, the motion breaks down and delivers safeguarding gas that shield the weld region from barometric oxygen and different gases and creates slag which covers the liquid filler metal as it moves from the anode to the weld pool. The slag floats to the outer-layer of weld pool and shields the weld from environment as it sets.

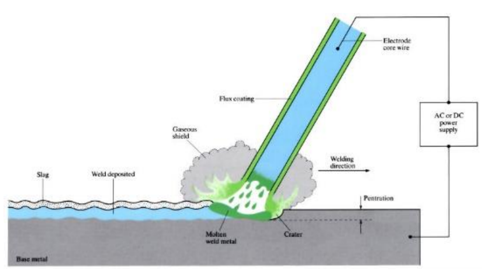

Fig 2. Manual Metal Arc Welding

1.2.1.2. Gas Metal Are Welding (GMAW)

In this type of welding process, a continuous and consumable wire electrode issued. In a shielding gas generally argon or sometimes mixture of argon and carbon dioxide are blown through a welding gun to the weld zone.

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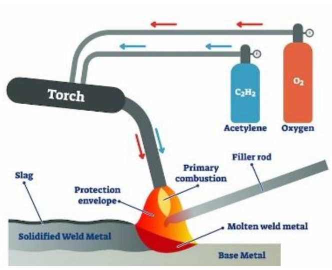

Fig 3. Gas Metal Arc Welding

1.2.1.3. Gas Tungsten Arc Welding (GTAW)

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area and electrode are protected from oxidation or other atmospheric contamination by an inert gas. A filler metal is normally used, though some welds, known as autogenous welds, or fusion welds do not require it. When helium is used, this is known as Heli arc welding. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapours known as plasma. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding. allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques

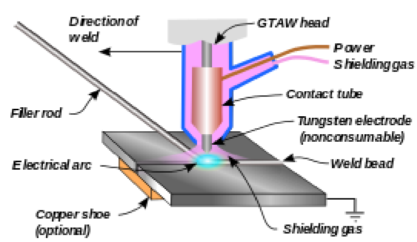

Fig.4. Gas Tungsten Arc Welding

1.2.2. Gas Welding:

In gas welding process a zeroed in high temperature fire delivered by ignition of gas or gas combination is utilized to liquefy the work pieces to be joined. An outer filler material is utilized for welding. Most normal sort gas welding process is Ox-acetylene gas welding where acetylene and oxygen responded delivering some hotness.

1.2.3. Resistance Welding:

In resistance welding heat is produced because of passing of high sum current (1000-100,000 A) through the obstruction brought about by the contact between two metal surfaces. Most normal sorts opposition welding is Spot-welding, where a sharp terminal is utilized. Persistent sort spot obstruction welding can be utilized for crease welding where a wheel formed cathode is utilized.

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1.2.4. High Energy Beam Welding:

In this sort of welding an engaged energy bar with extreme focus, for example, laser shaft or electron bar is utilized to soften the work pieces and combine them. These kinds of welding primarily utilized for accuracy welding or welding of cutting-edge material or now and again welding of divergent materials, which is unimaginable by traditional welding process.

1.2.5. Solid State Welding:

Solid-state welding processes don't include softening of the work piece materials to be joined. Normal kinds of strong state welding are ultrasonic welding, blast welding. electromagnetic heartbeat welding, contact welding, rubbing mix welding and so forth.

1.3. Shielded Metal Arc Welding (SMAW)-Stick Welding

Shielded metal arc welding (SMAW) also known as stick welding, is a manual process using a flux coated consumable electrode with a metal rod at the core. Alternating current or direct current forms an arc between the electrode and the base metal creates the required heat. In the United States it is the most common method used. The flux coating disintegrates and gives off vapours that serve as a shielding gas and provides a protective layer of slag. Both protect the weld area from atmospheric contamination. As the metal rod inside the electrode melts it forms a molten pool which becomes the weld. There are several variables the welder can control that will impact the width and height of the weld bead, the penetration of the weld and the quantity of spatter. Stick welding is inexpensive when compared with other methods such as TIG. It is portable and works with any thickness and in any position. The major downside is the slag created during the welding process along with slower speeds (unless you are highly skilled).

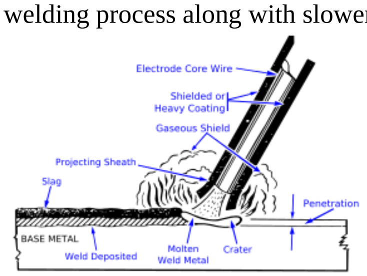

Fig.5. Shielded Metal Arc Welding

1.3.1. SMAW Arc Welding

Stick welding takes its name from the shape of the electrode, which looks like a stick. It can be used to weld many types of metals including steel, stainless steel and cast iron. Stick provides constant current (CC) using direct current (DC) or alternating current (AC). Direct current operates on different directions based on the polarity. Alternating current switches between directions. Power in the electrical circuit used to power the weld is measured in amperes. More current or amperage is needed for welding thicker metals or electrodes.

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1.3.2. SMAW are welding is primarily used to weld iron and steels.

It can be used in all positions:

1. Flat
2. Vertical
3. Horizontal
4. Overhead

1.4. Types Of Polarities

There are three main types of polarity: direct current straight polarity, direct current reverse polarity and alternating current polarity.

1. Direct Current Straight Polarity
2. Direct Current Reverse Polarity
3. Alternating Current Polarity

1.4.1. Direct Current Straight Polarity

Direct current straight polarity happens when the plates are positive and the electrode is negative. This causes the electrons to go from the electrode tip to the base plates. It's generally considered that two-thirds (66%) of the entire arc heat is generated at the electrode, whereas only one-third (33%) of the heat is generated at the base plate. As a result, the electrode melts down quickly and the metal deposition rate increases (for consumable electrodes only). On the other hand, base plates tend to not fuse properly due to lack of sufficient heat. Therefore, various defects arise, such as insufficient fusion, lack of penetration and high reinforcement. Weld reinforcement is a term used to describe metal in excess of that needed to fill a joint.

1.4.2. Direct Current Reverse Polarity

When the electrode is positive and the plates are negative, this results in direct current reverse polarity. The electrons switch directions and go from the base plates to the electrode. Consequently, more heat generates at the base plate as compared with DC straight polarity. This type of welding is less likely to cause inclusion defects (non- metallic particles trapped in the weld metal or at the weld interface) due to its arc cleaning action. It makes for faster welding and performs better for welding thin pieces of material. It's commonly chosen for joining metals like copper, which has a low melting point.

1.4.3. Alternating Current Polarity

If an AC current is supplied by the power source, reverse and straight polarity will take place one after the other. In half the cycle, the base plates will be positive and the electrode will be negative. In the other half, the electrode will be positive and the base plates will be negative. Depending on frequency of supply, this cycle repeats 50 to 60 times per second. Some power sources also provide provisions, which can alter frequency. AC polarity has attributes of straight and reverse polarity, since both are occurring in the same cycle. It is effective to use with most electrode types and is suitable for many different plate thicknesses, making it a great all-around choice.

1.4.4. Selecting Polarity

There are several factors to consider, such as the melting point and thickness of the material. For example, magnesium and aluminum work better with reverse polarity, as their melting point is low. For stainless steel or titanium, alternating current polarity might be a better choice, since it will provide the benefits of straight and reverse polarity while keeping the heat-affected zone from becoming too large.

1.5. Welding Current

Choice of welding current relies on tungsten cathode measurement, gas type, and welding extremity, High worth of current in TIG welding can prompt splatter and accordingly bring about a harmed work-piece. Lower current setting can prompt staying of the filler wire. Ideal worth of current in the middle of these cut off points ought to be utilized to get a satisfactory globule calculation. Dot math gets influenced by the welding current, as the dot width diminishes, stature increments, and dab infiltration stays consistent with expansion in current. In the decent current mode, voltage gets fluctuated to keep a steady circular segment current.

1.6. Welding Voltage

This is a controlling variable in manual cycles since it is hard to keep up with steady bend length. Voltage controls the length of the circular segment, and hence, with high beginning voltage, bend commencement is simpler. This likewise permits for a more noteworthy scope of working tip distance. Albeit amazingly high voltage can prompt unusual weld quality, it controls the state of the combination zone what's more, weld support. Profundity of entrance will be greatest at ideal circular segment voltage, and it straightforwardly influences the dab width. The subsequent micro structure and weld quality rely on the weld voltage.

1.7. Welding Electrode

A welder needs an electrode to generate an electric current to do in arc welding. In welding, an electric current is conducted through an electrode which is used to join the parent metals. When you keep electrode tip near the parent

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metal electric current jumps from the electrode tip to the parent metal. The main purpose of electrodes used in welding is to create an electric arc. These electrodes can be positively charged anode or they can be negatively charged cathode.

1.8. Types of Welding Electrodes

Basically, depending upon the process there are two types of welding electrodes:

1. Consumable Electrodes

2. Non-Consumable Electrodes

1.8.1. Consumable Electrodes

Consumable electrodes have low melting point. These types of welding electrodes are preferred to use in Metal inert gas (MIG) welding. For making consumable electrodes, materials such as mild steel and nickel steel are used. The one precaution that you must take is to replace consumable electrodes after regular intervals. The only disadvantage of using such electrodes is that they don't have a large number of industry applications but at the same time they are easy to use and maintain.

1.8.2. Non-Consumable Electrodes

On the other hand, alternative welding employs the regular use of non-consumable electrodes. These electrodes have higher melting points and do not directly melt into the metal throughout the welding process. Converse from consumable electrodes, non-consumables act solely as heat-generating arcs during metal fusion. That said, their coating deposit similarly determines utility. Traditionally, two separate categories of non-consumable or non-filler electrodes are available for project application: carbon or tungsten. Tungsten specifications are especially applicable in a wide array of industries. Utilizing tungsten inert gas (TIG) welding, non-consumable electrodes offer better arc stability, longer life, and superior resistance to contamination.

1.9. Types of Weld joints

The term "weld joint design" refers to the way pieces of metal are put together or aligned with each other. Each joint's design affects the quality and cost of the completed weld. Selecting the most appropriate joint design for a welding job requires special attention and skill. There are five basic welding joint types commonly used in the industry, according to the AWS:

1. Butt joint
2. Tee joint
3. Corner joint

4. Lap joint
5. Edge joint

1.9.1. Butt Joint

A butt joint, or butt weld, is a joint where two pieces of metal are placed together in the same plane, and the side of each metal is joined by welding. A butt weld is the most common type of joint that is used in the fabrication of structures and piping systems.

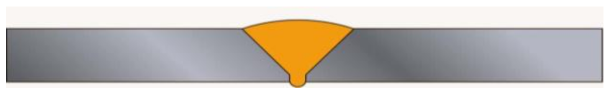

Fig 6. Butt Joint

1.9.2. Tee Joint

Tee welding joints are formed when two pieces intersect at a 90° angle. This results in the edges coming together in the center of a plate or component in a 'T' shape. Tee joints are considered to be a type of fillet weld, and they can also be formed when a tube or pipe is welded onto a base plate.

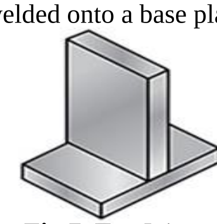

Fig 7. Tee Joint

1.9.3. Corner Joint

Corner joints have similarities to tee welding joints. However, the difference is the location of where the metal is positioned. In the tee joint, it's placed in the middle, whereas corner joints meet in the 'corner' in either an open or closed manner-forming an 'L' shape.

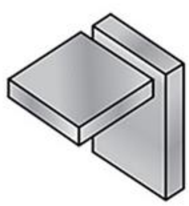

Fig 8. Corner Joint

1.9.4. Lap Joint

Lap welding joints are essentially a modified version of the butt joint. They are formed when two pieces of metal are placed in an overlapping pattern on top of each other. They are most commonly used to joint two pieces with differing thicknesses together. Welds can be made on one or both sides.

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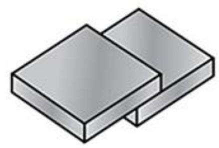

Fig 9. Lap Joint

1.9.5. Edge Joint

In an edge joint, the metal surfaces are placed together so that the edges are even. One or both plates may be formed by bending them at an angle.

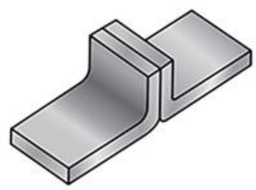

Fig 10. Edge joint

1.10. Alternative Current Welding

An alternating current is an electric current that reverses its direction many times per second. A 60hertz current will change its polarity 120 times per second. With AC welding, because the magnetic field and current rapidly reverse-direction, there is no net deflection of the arc.

Advantages

The advantages of AC welding are:

1. The alternating current between positive polarity and negative polarity allows for a steadier are for welding magnetic parts
2. Fixes problems with are blow
3. Enables effective aluminium welding
4. AC welding machines are cheaper than DC equipment

Disadvantages

The disadvantages of AC welding are:

1. More spatter
2. Weld quality is not as smooth as with DC welding

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3. Less reliable and therefore more difficult to handle than DC welding

Applications

1. When switched to AC positive, it also helps remove oxide from the metal surface - hence it is suitable for welding aluminum.
2. AC welding is also widely used in shipbuilding, particularly for seam welds, as it has the ability to set the current higher than with DC. AC welding also offers fast fills and is used for down hand heavy plate welds.
3. One of the main uses of AC welding is with materials that are magnetized. This makes it useful for repairing machinery.

1.11. Heat Input

Heat input rate or energy of arc was an important parameter in welding which can be calculated by following formula

HEAT INPUT J/Min = V x A x 60/S

Where V = arc voltage

A = welding current

S = welding speed or are travel speed(mm/min)

But for SMAW process the heat transfer efficiency is 0.65to 0.85. So, we have to multiply this equation by heat transfer efficiency then we will get actual heat input during welding.

1.12. Various Zones of Weld Joint

The steel weld joint mainly divided in three zones i.e. Weld metal zone, Heat affected zone (HAZ) and base metal zone as shown in fig. The HAZ was further classified in three regions i.e., grain growth region, grain refined region and transition region. The hardness during weld joint is not uniform. Steel is sensitive for thermal cycle and the metal of weld joint was having highest temperature i.e. above melting point and the parent metal was having temperature very less below the lower critical line. Due to high temperature difference between these two regions the cooling rate was very high and the solidification of weld metal was under non equilibrium conditions. Due to this from austenite to pearlite microconstituent transformation was not occurred and austenite to martensite or bainitic lathe was occurred. So, hardness of this region was very high and HAZ was become more susceptible to cracking.

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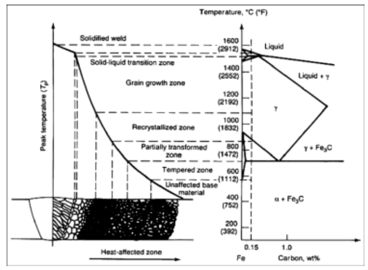

Fig 11. Various Zones of Weld Joint

1.13. Heat affected zone (HAZ)

In fusion welding, the heat-affected zone (HAZ) is the area of base material, either a metal or a thermoplastic, which is not melted but has had its microstructure and properties altered by welding or heat intensive cutting operations. The heat from the welding process and subsequent re-cooling causes this change from the weld interface to the termination of the sensitizing temperature in the base metal. The extent and magnitude of property change depends primarily on the base material, the weld filler metal, and the amount and concentration of heat input by the welding process.

The thermal diffusivity of the base material plays a large role if the diffusivity is high, the material cooling rate is high and the HAZ is relatively small. Alternatively, a low diffusivity leads to slower cooling and a larger HAZ. The amount of heat input during the welding process also plays an important role as well, as processes like oxyfuel welding use high heat input and increase the size of the HAZ. Processes like laser beam welding and electron beam welding give a highly concentrated, limited amount of heat, resulting in a small HAZ. Arc welding falls between these two extremes, with the individual processes varying somewhat in heat input. To calculate the heat input for arc welding procedures, the following formula is used:

where Q= heat input (kJ/mm), V-voltage (V), I-current (A), and S-welding speed (mm/min). The efficiency is dependent on the welding process used, with gas tungsten arc welding having a value of 0.6, shielded metal arc welding and gas metal arc welding having a value of 0.8, and submerged arc welding 1.0

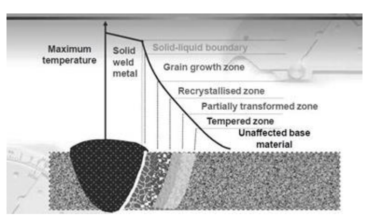

Fig 12. Heat affected zone (HAZ)

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1.14. Different types of weld joints

Weld Testing's are divided into two different types; non-destructive testing (NDT) and destructive testing.

Non-destructive tests

1. Visual Inspection.
2. Liquid or Dye Penetrant Inspection.
3. Magnetic Particle Inspection.
4. Eddy Current Inspection.
5. Ultrasonic Inspection.
6. Acoustic Emission Monitoring.
7. Industrial Radiography.

1.14.1. Visual Inspection

This method uses a qualified and trained observer watching the weld as the welder is working. The observer watches the weld pool and the cooling metal. They typically look for inclusions, undercutting (the weld height is below the parent metal height), depth of weld penetration and certainty of bonding to the parent metal. When a non- complying defect is observed the spot is marked. At the end of the weld run the defect is ground out and the weld is remade to the required quality.

Fig 13. Visual Inspection

1.14.2. Liquid or Dye Penetrant Inspection

As the name suggests a colouring agent is used to detect weld defects. This method will only find surface cracks and surface discontinuities. The weld surface is thoroughly cleaned of scale and splatter (but not shot blasted as it will close over the defects). A detergent wash is used to remove dirt, a pickling paste is used to remove paint or grease and a decrease or solvent is applied to remove oil. The system normally comes in two spray cans one is the penetrant and the other is the developer. The penetrant is sprayed over the weld and capillary action draws it into any minute surface cracks. The penetrant on the surface is wiped off and the penetrant in the cracks remains wet. After a

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short dwell time the developer is sprayed over the weld. The developer acts to draw-out the penetrant dye from the cracks and so changes colour. It behaves like blotting paper and magnifies the presence of the crack.

1.15. Destructive testing's

Destructive testing is a testing method that analyses the point at which a component, asset, or material fails. Destructive testing methods can identify physical properties of a component, like toughness, hardness, flexibility, and strength.

1.16. Tensile Test

Tensile strength is defined as the ability of a material to resist a force that tends to pull it apart. Tensile strength, maximum load that a material can support without fracture when being stretched, divided by the original cross-sectional area of the material. We use Universal Testing Machine (UTM) to find the tensile strength of a weld joint.

1.17. Universal Testing Machine

It is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standards and compression tests on materials, components and structures.

Fig 14. Universal Testing Machine

1.18. Leeb Hardness Tester

The Leeb hardness test is a non-destructive method for assessing metal hardness swiftly. It employs a rebound principle, where an impact body strikes the material's surface and rebounds. A handheld device with a probe, spring, and sensor measures the rebound velocity. Calibration curves correlate rebound velocity to hardness values. It's widely used in manufacturing, construction, and maintenance industries. Calibration with known hardness samples ensures accuracy. Despite its convenience, factors like surface condition can influence results. The Leeb hardness test contributes to efficient quality control practices.

Fig 15. Leeb Hardness Tester

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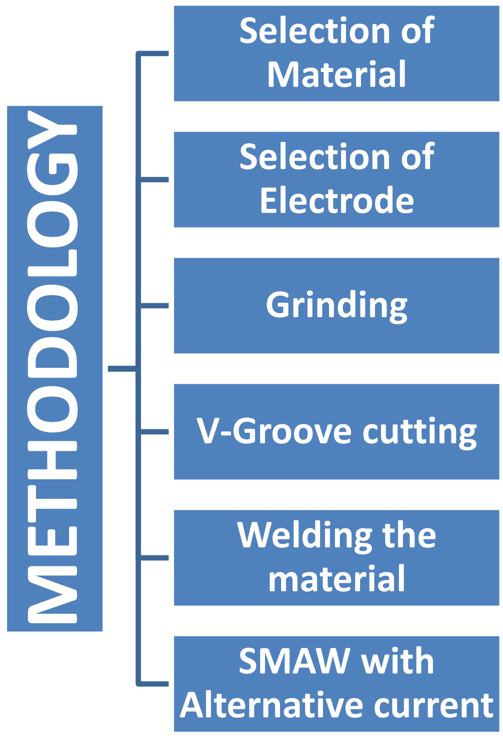
METHADOLOGY



CONCLUSION

From observation table and result analysis following major conclusion are obtained in the investigation into the effect of welding current on the tensile properties of SMAW welded mild steel joints underscores the critical importance of welding parameter optimization for achieving superior weld quality and structural integrity. By systematically varying welding currents, this study has revealed significant correlations between current levels and key tensile properties such as ultimate tensile strength, yield strength, and elongation. The findings highlight the potential for enhancing weld performance through targeted adjustments in welding parameters, leading to improved reliability, cost-effectiveness, and innovation within the welding industry. This deeper understanding of the relationship between welding current and tensile properties paves the way for more informed decision-making in welding process optimization, quality assurance, and structural design, ultimately contributing to the advancement of welding technology and the creation of stronger, more durable welded joints in mild steel applications.

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