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The Optimization of various parameters of shielded metal arc welding (SMAW) for a cast iron

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Abstract

The shielded metal arc welding (SMAW) process is one of the most widely used metal joining processes in various commercial sectors. Water transport, ship-building technology, automobile, aerospace industries, construction works, petrochemicals industries, etc., create pressure in the industrial sector. Due to those concerns, enterprises want the welding process to be feasible, economical, and sustainable. The SMAW process has various types of inputs and output parameters. The sustainability concerns associated with the SMAW process include electric current, the electric voltage needed, material consumption, slag form, fume emission, and hazard work condition sheet affected zone associated with the health of human and occupational safety. There is a need to characterize the feasibility and economic aspect of the SMAW process. Various numbers of the available literature and paper focus on only the Taguchi technique to optimize the elements of the welding process; however, these papers have economic and feasible aspects that are rarely addressed. The study presented in this paper is SMAW processes concerning economic, viable, and optimal triple bottom line. Finally, this study concluded recommends achieving economic and feasible SMAW weld processes.

Keywords—SMAW, Optimization, Cast Iron, Voltage Current, Heat, Materials

1. INTRODUCTION

SMAW also called manual arc welding (MMA), flux shielded arc welding, or informally stick welding, is a manual curve welding process that utilizes a consumable terminal covered with a transition to lay the weld(Dawson et al., 1986). An electric flow, substituting direct flow from a welding power, is used to frame an electric circular segment b/w the electrode and workpiece to be joined. The workpiece and the electrode get melted and form a pool of molten metal after a specific time interval from a joint. The electrode's flux coating disintegrates and gets vaporized, making a shielding gas and providing a layer of slag, which defends the weld area from contamination. In light of the adaptability of the cycle and the straightforwardness of its gear and activity, SMAW is the world's first and most well-known welding process(Franz et al., 1996). It helps other welding processes in the support and fixes industry. Although motion-core circular segment welding is filling in fame, SMAW is utilized widely in developing weighty iron structures and modern manufacture. The cycle generally uses the weld of irons and prepares; however, aluminum, nickel, and copper compounds can likewise be welded with strategy(Chen et al., 2017; Yu et al., 2018).

1.1 SMAW process and equipment

SMAW uses heat energy that arc supports to melt the top of the consumable shielded electrode and parent works. Both the electrode and piece will be fused with the help of a circuit. Wires from the source are attached to the works and holder. During welding, the process starts by forming an arc b/w the workpiece and the tip of the electrode. The surface of the workpiece and tip of the electrode is fused. Metal forms to electrode transfer from the arc into a weld pool at the end. The filler is deposited during the welding process. Arc of SMAW nuggets very high temperature might be a range of 50000C.

1.2 Equipment:

The equipment essential for SMAW is less complex than the former arc weld process. Manually welding equipment includes a power source, electrode holder, wires, connectors, wire brush, chipping hammer, and electrodes (Pouranvari, 2010).

The paraphernalia for the SMAW is

- (POWER) A constant source of current.
- Electrode clamp holder.
- Welding (wire) cable.
- Ground clamps.
- Clamp to connect the workpiece to the source.
- Hammer and wire brushes.

a) Power source/supply

SMAW generally needs a constant current range of 50 to 300 Amps and a low voltage range of 10 to 50 volts. The possibility of the current could be up to 600 Amps also. The input power supply is 220 volts or above to achieve the required voltage value. A rectifier is also installed whenever DC sources are required. Accessories that control the power supply generally step-down. AC transformers using multiple coils, DC rectifier, inverter, and DC Generator(Anon, 1973).

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The polarity in this welding process depends on what kind of electrode is used and what kind of weld quality desirable **DCEN** result that generates an excess amount of heat to the electrode, and high melting rate, and reduces the weldments' depth. While **DCEP** does workpiece are negative make higher penetration the weld. AC source lead that heats distributed uniformly creates the balance b/w melting and penetration of the weld(Osborn, 1977).

b. Electrode holder

The electrode holder clamps the electrode and ensures the wire connection between the electrode and the source terminal. It is spring-loaded and, when pushed through, the welder to on and off. It is shielded, and the welder might feel comfort in the continuing process. It is accessible in several sizes, and the dimensions are rated on behalf of the current handle capacity(Cembrero et al., 2004).

c. Electric cables

Cables connect between electrode and workpiece to the terminal. An earthing line is also for the protection of the welder and others. The outer layer of wire should be allowed to sustain current, wear, dust, oils, and water, and the radius of the cable should vary. It has enormous value as the current and duty cycle(Buchanan et al., 2007).

d. Welding shield

Shielded Metal Arc Welding is the cycle that melts and joins the metal by melting them through an arc between a protected metal anode and the parent metal. The terminal exterior covering, known as motion, supported creating the curve and gave the gas that slag cover to shield the joint from tainting. The electrode center provides a more significant part of the joint filler metals; when the electrode is progressed alongside the workpiece at the accurate speed, the metal supplies in a uniform layer known as a bead. Depending upon the electrode presence utilized, the welding power source (AC) /(DC) depends on the electrode presence. The welding attributes were commonly acquired using DC power sources (Noboru et al., 1978; Osborn, 1977).

The SMAW procedure involves adequate electric flow to dissolve the anode equally, a legitimate measure of the parent metal, and a sound hole among the tip of a terminal and parent metal or liquid weld pool. This type of necessity is fundamentally used for the mixture. The sizes and sorts of terminals for protected metal circular segment welding characterize the curve power requirements (inside the general scope 16 volt to 40 Volt inside the broad scope range of 20 to 550 A. The current might be rotating or direct, yet the power source should have the option to control the present level to answer the perplexing factors of the welding (Anon, 1973; El-Banna, 1999; Pouranvari, 2010).

1.3 Experimental procedure and SMAW input parameter.

SMAW is the famous welding process used in industries to join ferrous and nonferrous metals. In this process, random change in current value and voltage value Dependable procurement of these varieties during accurate welding and its resulting examination can be precious to different boundaries of the bend welding process. Presently, an advanced curve control arrangement reasonably changes welding boundaries by the least time delay and sets correct welding boundaries within the actual cycle (El-Shennawy & Omar, 2010).

Subsequently, concentrating on the specific way of behaving of these cutting-edge power sources utilized for welding is fundamental to procure every one of the possible moment varieties occurring while at the same time welding is underway. In the current review, the impact of fluctuating information is considered. To assess the effects of current varieties in the SMAW cycle, information was obtained at various existing qualities 70A-120A. Statistics securing was finished on six welding power sources to concentrate on the way of welding sources' behavior. In those cases, information was obtained at an inspecting pace of 1 lac examples/s for a span of 20 s utilizing a universally applicable DSO while welds are in the works. Welds were arranged using the same weld anode as a similar welder utilizing indistinguishable boundaries (Chamim et al., 2017).
We are further utilizing these investigations. Evaluating the sources considering the SOM method coordinated well with reviewing showed up, given the presence of the weld globule. The result shows that the strategy introduced here could be used to evaluate the different boundaries of welding sources.

1.4 Electrode detail:

An electrode wire is coated and made from a material comparable to welded metal; assortments of elements determine the right electrode for every project. MIG welding terminal is a constantly taken care of wire alluded to as MIG wire. An electrode that welds the cast iron. It could be welded with a covered steel terminal, yet this strategy ought to be utilized as a crisis measure, as it were. While using a steel terminal, the constriction of steel metal and carbon got from solid metal through the weld; also, the hardness of weld brought about by quick cool off should be thought of. Steel recoils more than cast iron when surrendered from a liquid to a strong. When a considerable amount of filler is applied to the joint, the works iron might break back to the line, except if prevented advances are taken (Fujii et al., 2007).

To remove these troubles, the pre-arranged joint should weld by keeping the weld metal for a short string, 0.75 to 1.0 inches long. Those are made irregularly and, now and again, by the backstop and skipped method. To keep away from hard, the circular segment should be struck in the electrode, not the outer layer of the parent metal.

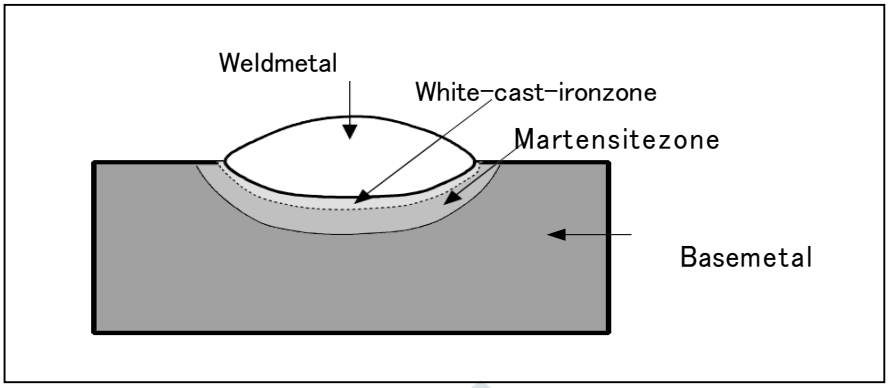

Fig 1.1 Microstructural representation of the heat-affected zone of a cast-iron weldment cross-section(Takahashi et al., 2020)

The electrodes used should have a 1/8 in. (3.2 mm) diameter to be a critical diameter to avoid unnecessary welding heat. Welding was performed with changed terminals. Less Weaving, each weld deposit is thoroughly cleaned.

1.5 Common problems in weldability

Common problems affecting their weldability when joint cast iron materials,
(1) Extra carbon contented,
(2) A smaller amount of flexibility of the workpiece.
(3) Highly contented with different elements like phosphorus, sulfur, and oxygen,
(4) Cast defects
(5) Impregnated oil.

Weldability by cast Iron Type

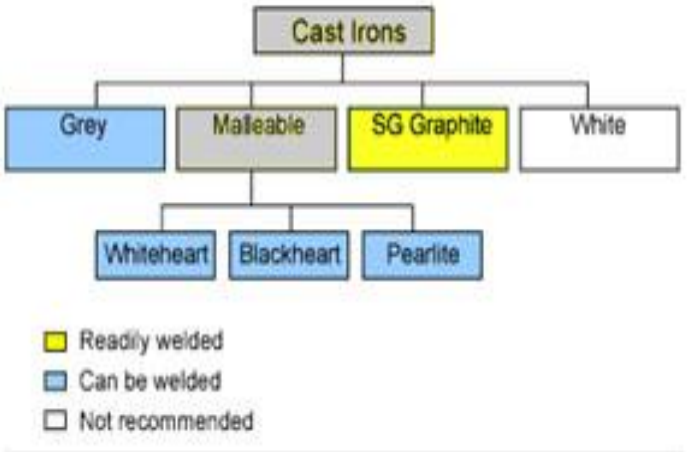

Fig 1.2 shows the weldability of various cast iron

1.6 Characteristics of cast iron

Cast Iron	Tensile Strength (MPa)	Compressive Strength (MPa)	Hardness (HB)	Elongation (%)	Toughness (j)
White	200 – 410	N/A	321 – 500	Very low	Very low
Malleable	276 – 724	1350 – 3600 (pearlite & martensitic)	110 – 156 (ferrite) 149 – 321 (pearlite & martensitic)	1 – 10	4 – 12 j @ 20°C
Grey	152 – 431	572 – 1293	156 – 302	<0.6	Very low
Ductile	345 – 827	359 – 920	143 – 302	2 – 20	16 – 27 @ 20°C

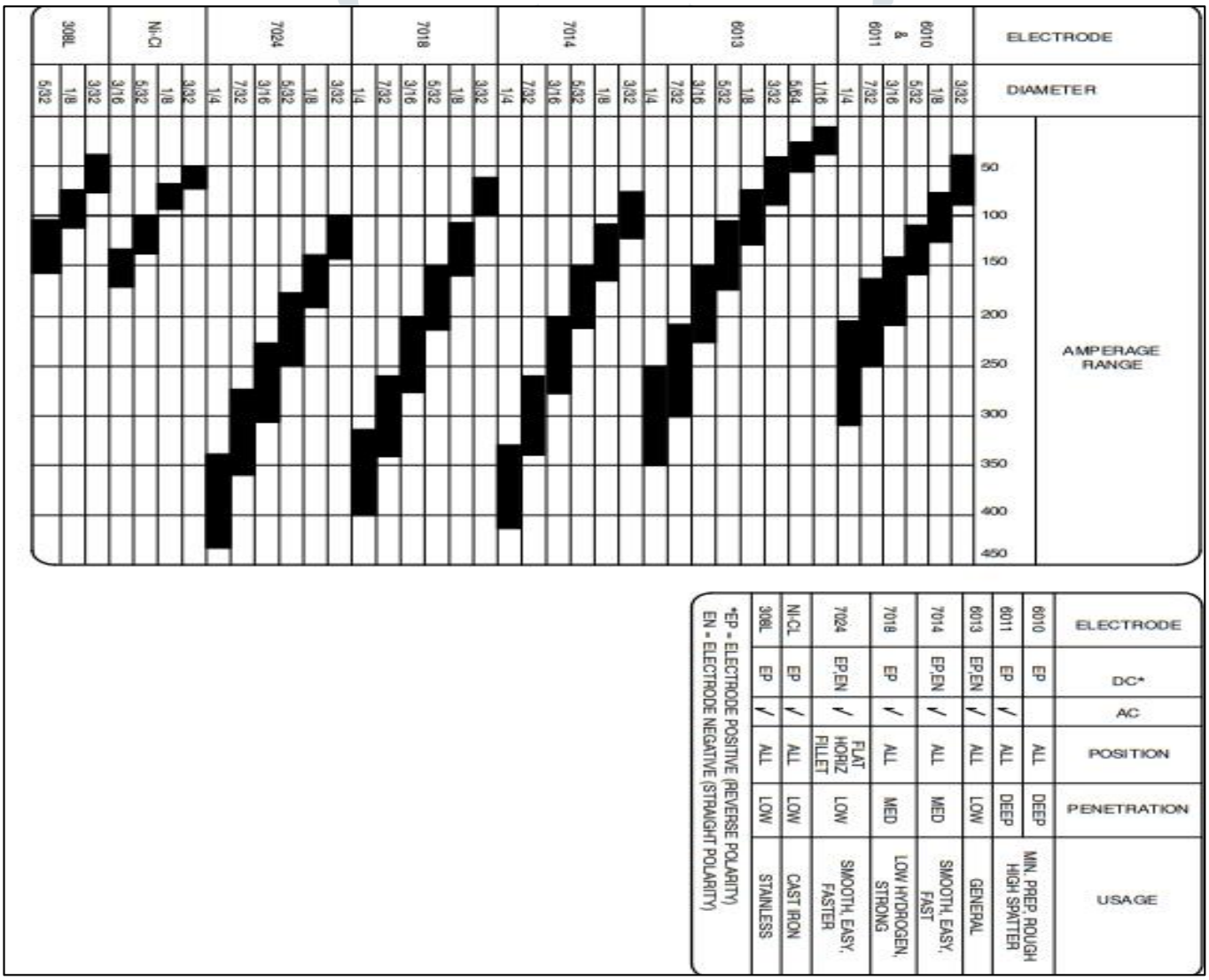

Fig 1.3 The chart shows the electrode specification for different metal types.

2. Experimental procedure

Materials Hot-rolled plate of low-carbon steel was attained in place of a local metal market in Lagos, Nigeria. 12 mm thick samples of the steel plate were cut and arranged for fusing. E6013electrode through gauge dimensions 10 and 12 were chosen for the SMAW procedure.
A cast iron is an alloy of several elements containing iron, silicon, and carbon, where carbon usually has a 1.7 - 4.5 % range. The whole weldability of cast iron is small, but it depends on type, intricacy, width, cast intricacy, and the necessity for machineability (Suharto et al., 2019).

2.1 Conditions that Affect Weld Bead Shape

- Electrode angle
- Travel speed
- Arc length

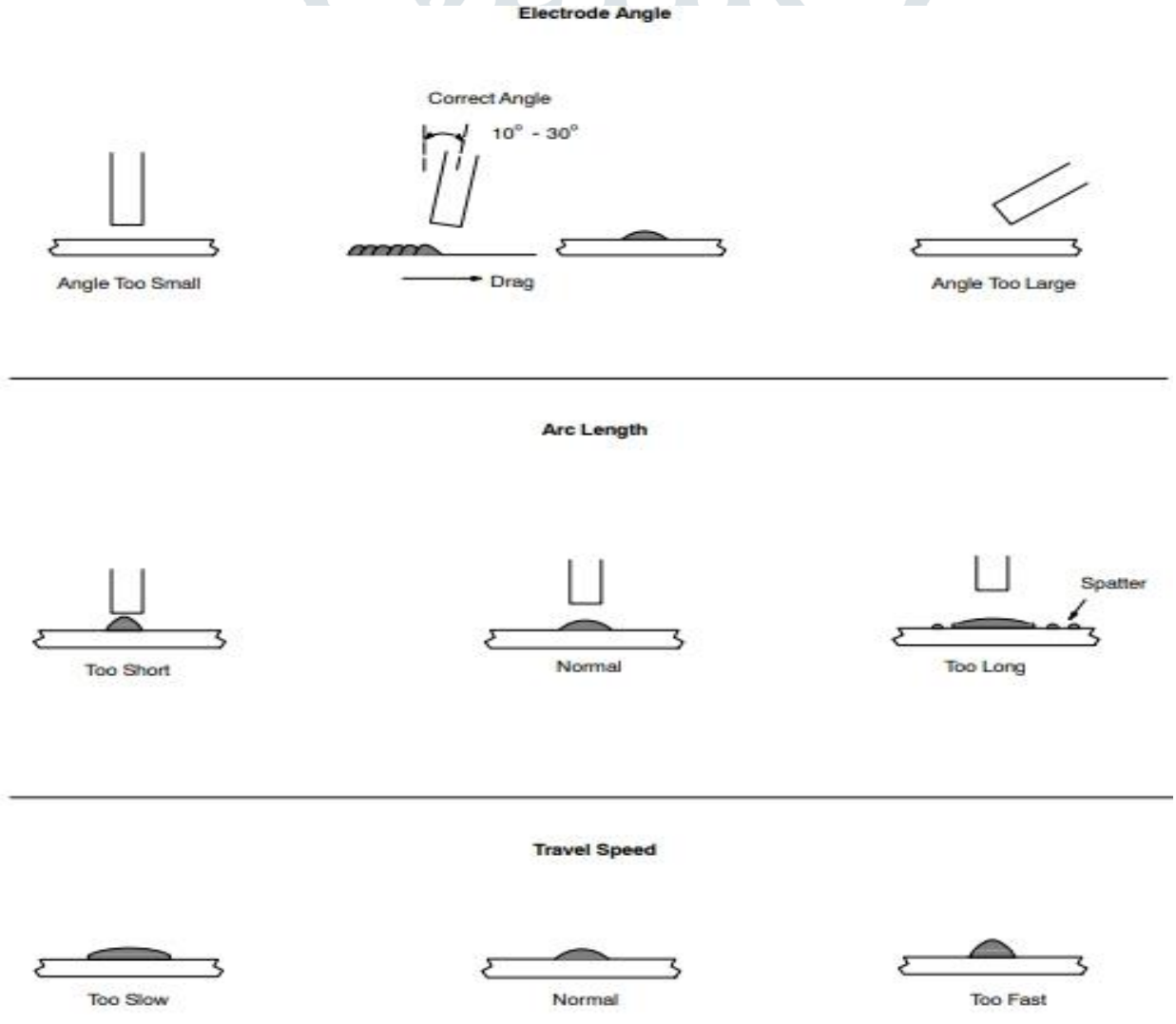

Fig 2.1 Show the Conditions that Affect Weld Bead

Shape

2.2 Cast Iron Welding Tips

Due to the container of high carbon, it is challenging to weld cast iron. These effects in great cracking difficulties also thermal expansion problems. Cast irons have in the region of 2 to 4% C. SMAW welding might be used to restore the moldings by different types of welds material that are based on machine comfort: i.e.

- nickel 55 used for softer join
- nickel 99 used for softer join
- HTS-528 used for Brazing Rod

Nickel is a non-iron alloy that doesn't have any carbon. Preheat any workpiece to escape crack. It is preheating control with a temple stick. Heat and earlier weld overhaul could be fundamentals for monitoring the cooling rate after welding(Takahashi et al., 2021). These are convenient when restoring intricate shapes, meaning that materials' different width responds differently to heat. Cleaning the joints or fused, including oil and soil. So, we use crushing or scrubbing thinners for cleaning. Afterward cleaning action, we see the maintenance porosity is a problem. So, we increase the work piece's permeability to fix their porosity problems. There are projecting flaws for fixes; for example, blow openings or breaks, all damaged regions should be removed by cold etching, gouging, or crushing. On the off chance that air-carbon circular segment, hotness impacted zone will conform to the gouged region(Poonnayom & Kimapong, 2018). Before soaking, the projecting should be preheated to 300°C to lessen the gamble. The depression should likewise be daintily ground to eliminate solidified material before saving the maintenance since graphite in this district might break down during gouging, expanding its aversion to breaking during ensuing welding. While eliminating breaks or straight deformities, the closures of the gap ought to be dulled by penetrating before gouging to forestall further spread during the groundwork for the fix. The natural finishes of the break, which might be exceptionally fine, ought to be situated by color infiltration or attractive molecule strategies before penetrating (Yu et al., 2018).

Fig 2.2 Cast Iron Welding Repair Preheating

2.3 Benefits of Cast Iron

Cast iron benefits as good welds metal:

- better castability
- melting point lower
- Low cast
- It can be shaped easily by (sand) casting

Properties of cast iron such as:

1. Damping capacity
2. Ductility
3. Thermal conductivity
4. Strength
5. Hardness

2.4 Cast Iron Welding Processes

Welding utilized the rescue cast iron castings; the fixed cast have fizzled to assist and join the model with one another or steel part in assembling operations. The toweling system and filler metal choice rely upon the kind of weld property wanted to help everyday life. For instance, various fillers can be used while utilizing the safeguarded metal curve welding process. The fillers would meaningfully affect the different matches of the weld contrasted with the workpiece material.

Variety match could be a deciding element, explicitly in the rescue or fix of the cast, where a distinction of variety wouldn't be OK. Regardless of which of the weld processes is chosen, some preliminary advances should be made. It is essential to decide the specific kind of solid metal to weld, whether it is a dark solid metal or pliable or pliable. On the off chance that actual data isn't known, it is ideal for accepting that it is dark solid metal with zero flexibility.

As a general rule, it isn't prescribed to weld fix dark iron castings are likely to warming and cooling in typical assistance, mainly while warming and cooling shift above the scope of temperatures surpassing (205°C)cast iron is utilized filler rod, weld metal and works metal might have various constants of development and compression.

Fix these kinds of manufacturers could be made, yet dependability and administration life such fixes can't be anticipated with precision.

2.5 Cast Iron Welding Preparation

For setting up a project for weld, it's essential to eliminate surface matter to neat and clean the projecting space of the weld. That implies removing paint, oil, and other unfamiliar things beginning the welds zone. It is alluring to the heat region to eliminate the gas from the weld zone for a short time. The skin with a high silicon surface could be removed from the contiguous weld region. The edges of the joint ought to be chipped at the frame at a 60° angle

Channels involved; a V depression from 60-90° point should be utilized. The V should expand roughly 1/8 in. (3.2 mm) from the lower part of the break. A tiny opening should be bored at all finish of the gap to prevent it from spreading. Total entrance welds should generally be utilized since crack or imperfection is not eliminated rapidly returns under conditions.

Preheating is alluring to the welding of iron by any welding process. It very well diminished while utilizing incredibly pliable filler metal. Preheating would lessen the warm inclination b/w the weld and the iron rest. The preheating temperature ought to connect with the welding system, the filler metal sort, the mass, and the intricacy of the projecting. Preheating should be possible by any of the typical techniques. Light warming is regularly utilized for moderately small casts weighing 13.6 kg or less. The more significant part might be the heater preheated. Now and again, transitory heaters are worked around the region instead of taking part in a heater.

Like this, the part could be kept up with a large underpass temperature in an impermanent heater throughout welding. Preheating should be general since it assists with working on the material's

malleability and will spread shrinkage worries about an enormous region to avoid fundamental anxieties at any point.
Preheating will, in general, assist with softening the region nearby the weld; it helps with degas projecting, and like this, it diminishes the chance of pores of the stored metal and speeds up.
Slowly cool or post warming the further develops machine capacity to the hotness impacted zones in cast iron adjoining the weld. The post cool ought to be just about as delayed as expected. This should be possible by covering the projection by protecting materials to retain the air. Arc Welding Cast Iron

The SMAW procedure can weld cast iron, low carbon steel, etc. Four types of fillers metal may be used as below:

- Cast iron cover electrode
- Cover with copper base alloy electrode
- Body with nickel base alloy electrode
- Mild steel cover with electrodes

There were two types of copper-base electrodes, as mentioned below:

- copper as well as alloy
- copper as well as aluminum alloy

2.6 Brazing and Braze type welding of Cast Iron

Brazing is also used to join one metal to other metals and their alloys. The joint plan should be chosen for brazing, so pleasing fascination makes the filler metal stream intently fitting parts. The torch strategy is typically utilized. Also, the arc of carbon, twin carbon circular segment, the tungsten curve, and the plasma curve can be generally used as heat sources. During brazing, also use filler material sand these materials frequently used, zinc copper alloys. Braze joining is also used to weld cast iron. In braze welding, the filler is not used as capillary action, and that joining process is known as bronze welding; during this joining process, filler melt beyond460°C. Braze welding would not arrange for a pigment match. Since there is practically zero material mixing, that zone neighboring the weld in the parent metal isn't considerably solidified. The weld and joining section is machinable after the weld is finished.
By and large, a 93°Cpreheat is adequate for all applications. The cooling rate isn't fundamental, and a pressure alleviation heat treatment isn't generally needed. This sort of welding is regularly utilized for fixing welding of auto parts, and farming executes components and, surprisingly, auto motor squares and heads. It must be used when the shortfall of a variety match isn't questionable. Welding Techniques Studding Cracks where extensive welding is, in some cases, stable by sprinkling. In these interactions, the gap is eliminated by crushing a V channel. Openings are penetrated and then selected at a point on every single side of the notch. Studs are in the wrong way into these openings to a length equivalent to the width of a stud, with upper closures prominent nearly6.4 mm over the iron surface.

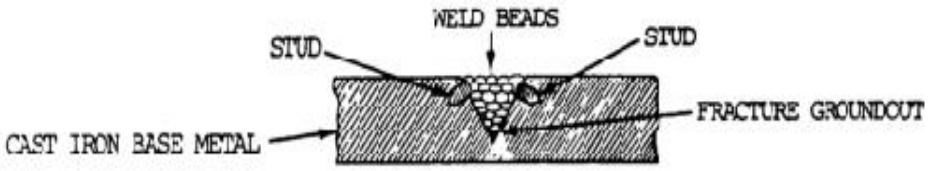

Fig 2.3 Methods of Cast Iron Repair

3. Result and discussion

Consistent voltage power sources are rarely advisable to use in a welding process as a steady feed electrode. The framework settles the curve for regular changes in the torch angle. The

current is an almost fixed rate. The National Electrical Manufacturers Association characterizes a straight voltage source, i.e., a consistent flow AC and DC transformer rectifier in its distribution Electric Arc.

The below Figure shows a commonplace volt-ampere yield relation for a steady voltage source.

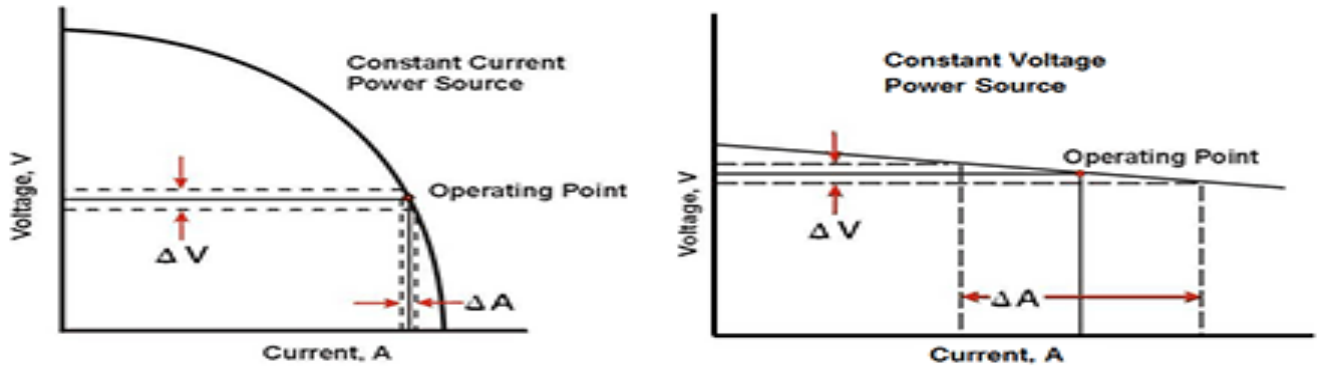

Fig 3.1 the fig shows the constant current power and constant voltage power sources

Due to high impedance, a minor decline was shown in the slope. Concerning point Y on a slant, in correspondence to 200 amp of current on the X-axis, any variation in voltage on the rise has a corresponding change in the current. The volt-ampere characteristic was suitable for constant electrode feed welding processes, including GMAW, SAW, and FCAW. A famous process is known that small changes in the arc length (voltage) cause a considerable difference in the current for these welding processes.

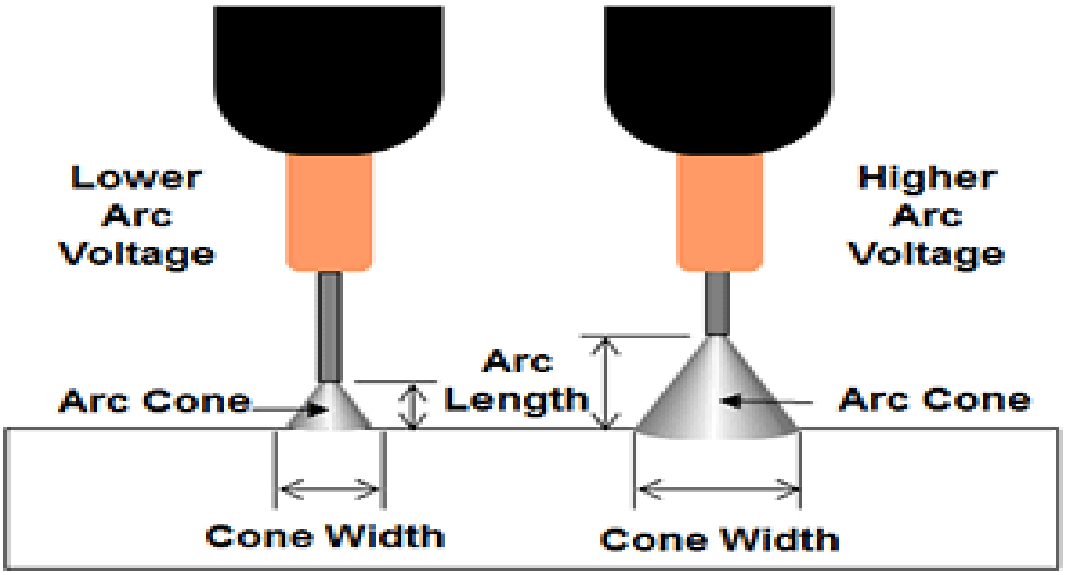

Fig 3.2 shows the correct view of the cone of weld

3.1 Constant current power sources

The GTAW always used constant-current sources, and the arc voltage gives a clear and cut indication of arc length at a given current. To correct the error, these systems directly get the arc voltage compared to the actual value reference and control torch height. An arc voltage value varies with the current, shielding gas, workpiece composition, polarity, and electrode vertex angle; the system reference must be fixed for a definite buy. The below graph shows the constant current and the constant voltage characteristics curve at the various voltage and current. Always arc length width of welds and voltage of welding plays a crucial role during the welding process, and figure 3.1

shows how these parameters affect various weld strength and hardness, etc. The thickness of workspaces over the different welding states is shown below the chart. Here, in this graph figure 3.3, we used to show that our workpieces on various current, voltage and welding travel speed and after putting on different values of current and voltage in chart try to find the optimum value of these parameters on which is going to show most fruitful result implemented using conventional analog or microprocessor control.

Table 1:- ***practical work condition results obtained from workshops***

Weld no.	**Voltage range setting(volt)**	**Current range setting(ampere)**	**Welding travel speed (mm/sec)**
1	30	100	5.19
2	45	150	4.53
3	60	200	5.93
4	75	250	7.16
5	90	300	10.52
6	30	100	2.66
7	45	150	1.94
8	60	200	2.98
9	75	250	2.04

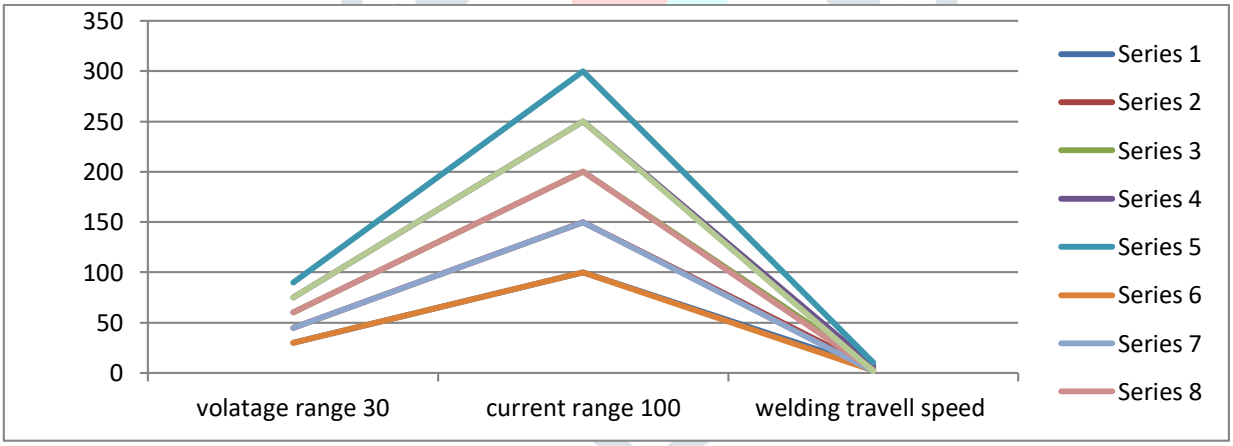

Fig 3.3 This graph shows the Optimization of various current and voltage ranges.

Here are some other parameters on which the weld quality of cast iron depends below, i.e., bevel angle, the actual welding time, etc.

Table 2: - ***various weld sizes resulting in the state of welding***

Workpiece thickness(S)	**Welding current(I)**	**State of welding <=**
S<=3	0<I<60 60<I<90 90<I<350	The electrode will stick to the material Ideal welding Melting and distortion will gradually occur in the material
3<S<=8	0<I<=60 60<I<=80 80<I<=110 110<I<350	The electrode will tick to material Insufficient penetration Ideal welding Melting and distortion will gradually occur in the material
8<S<20	0<I<=60 60<I<=90 90<I<=130 130<I<350	The electrode will tick to material Insufficient penetration Ideal welding Melting and distortion will gradually occur in the material
S>20	0<I<=80 80<I<=120 120<I<=150 150<I<=350	The electrode will tick to material Insufficient penetration Ideal welding Melting and distortion will gradually occur in the material

Table 3: - ***various bevel grooves angle resulting in the state of welding***

Sample no.	No of runs	Welding current, I(A)	Arc voltage E(V)	The actual time of welding, t(s)	Travel Speed S(mm/min)	Heat input, H (kJ/mm) per run
Bevel angle 30	4	70	240	85	94.74	10.64
		122	240	62	145.16	12.1
		120	240	74	121.62	14.21
		120	240	80	112.5	15.36
Bevel angle 45	4	70	240	135	66.67	15.12
		100	240	73	123.29	11.68
		105	240	84	107.14	14.11
		113	240	70	128.57	12.66
Bevel angle 60	4	70	240	131	68.7	14.67
		100	240	70	128.57	11.2
		108	240	91	98.9	15.72
		110	240	73	123.29	16
Bevel angle 90	4	70	240	137	65.69	15.34
		85	240	60	150	8.16
		110	240	60	150	10.56
		110	240	65	139.46	11.44

4. Conclusion

The in-house weld of cast iron needs thorough research in four key steps to know **how to weld cast iron**.

- Identification of the alloy
- Thorough cleaning of the part
- Selection of preheat temperature
- Selection of welding technique

1. Identify the type of cast iron

A family of five-c alloys with 2-4% carbon makes them intricate cast iron metal. It is less flexible and malleable and doesn't stretch or deform when heated. Instead, they crack and make the process of welding enormously problematic.

There are numerous types, and we show the

1 weldability of cast iron.

- **Gray cast iron** – difficult to weld
- **White cast iron** – do not weld almost
- **Malleable cast iron** – properties get changed, and it is useless
- **Ductile cast iron** – significantly less weldable and slow, It is always preferable to advise the user manual, manufacturer's opinion

2. Cleaning the cast weld exteriors

As in utmost welding, the cleaner the surface, the joining is better. Clean the surfaces from paint, lubricant, oil, and outer material. Better to apply heat cautiously and slowly to the weld area for a short moment to remove the entrapped gases.

3. Preheating or cold joint

We need to accept one because, unlike other metals, cast iron is brittle and has a minimal ability to deform when bending, contracting, and expanding.

4. Selecting welding techniques and consumables

You have strong-minded that gray cast iron is to weld; now, it is time to select the **iron welding measures**. The **best method to weld cast iron** is with every welding process, provided you choose the accurate filler material and technique. We base the choice of joining process on personal preference, but a few factors remain to consider before the conclusion.

5. ACKNOWLEDGMENT

The author would like to acknowledge their parents and professor for their guidance.

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