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Effect of heat input on tensile strength and micro structure of butt weld joint using mig welding

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ABSTRACT

Present work investigates the effect of heat input (controlled by welding current, weldingvoltage and welding speed) on tensile strength, micro-hardness and microstructure weldments produced by shielded metal arc welding (SMAW). From the experimental results it was found that the increase in heat input affects the micro-constituents of base metal, and heat affected zone (HAZ). Tensile strength decreases with increase in heat input and from scanning electron microscopy of tensile test fractured surfaces exhibited ductile & brittle failure. From micro hardness data values it was observed that hardness of material increases with increase in heat input in weld pool and decreases in HAZ zone. Optical microscopy shows that smaller dendrite sizes and lesser inter-dendritic spacing were observed in the fusion zone at low heat input. And long dendrite sizes and large inter-dendritic spacing were observed in the fusion zone of the joint welded at high heat input. Further it was observed from the optical micrographs that the extent of grain coarsening in the HAZ increases with increase in heat input.The welding heat input has a great influence on the weldments properties. This paper describes the influence of welding heat input on the weld metal toughness of high-carbon steel surface welded joint.

***Keywords*: Austenitic stainless steel, Heat affected zone, Micro-hardness, Shielded metal arc welding, Ductile facture, Ultimate tensile strength.**

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I. INTRODUCTION

Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the pieces to be joined (the workpieces) are melted at the joining interface and usually a filler material is added to form a pool of molten material (the weld pool) that solidifies to become a strong joint. In contrast, Soldering and Brazing do not involve melting the workpiece but rather a lower-melting-point material is melted between the workpieces to bond them together.

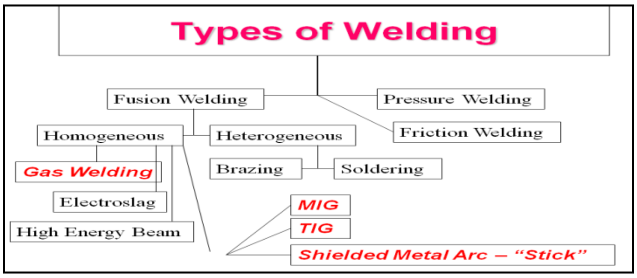

Figure 1. Types of Welding

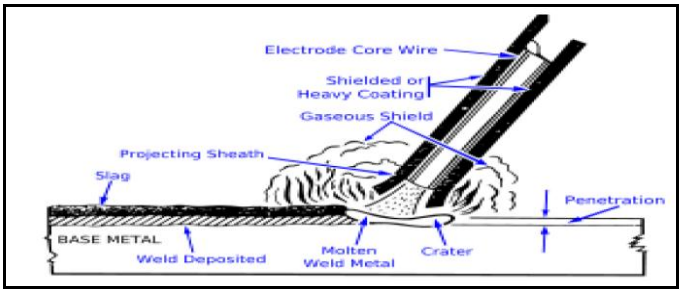

Figure 2. MIG Welding

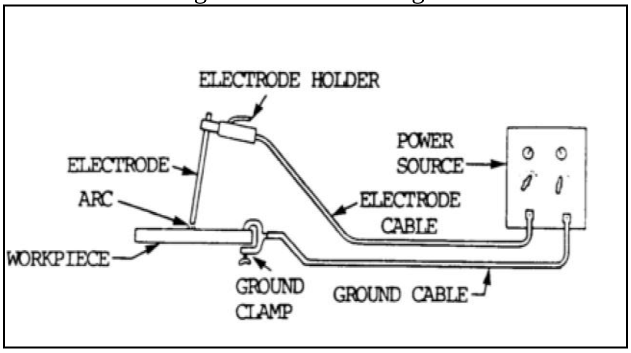

Figure 3. MIG Welding

The table shows the *Basic weld symbol* for the different types of welds.

TABLE 1. BASIC WELDING SYMBOL

Type of weld							
Bead	Fillet	Plug or slot	Groove				
			Square	V	Bevel	U	J

II. LITERATURE SURVEY

JatinderGill,JagdevSingh [1] in his work "The effect of welding speed and heat input rate on stress concentration factor of butt welded joint of IS 2062 E 250 A steel plates by gas metal arc welding (GMAW) were studied. For this series of experiments were carried out at fixed wire feed rate, welding current , arc voltage ,distance between gas nozzle and plate, gas pressure and the vertical angle of welding.Thus Different samples were obtained by employing arc voltage of 20V, welding current of 110A, wire speed of 5.918m/min and welding speeds of 94.83, 109.90, 120.00, 131.25, 140, 150 and 169.76 mm/min.

OliveraPopović, Radica Prokić-Cvetković [2] in his workThe welding heat input has a great influence on the weldments properties. This paper describes the influence of welding heat input on the weld metal toughness of high-carbon steel surface welded joint.The steel is surfaced with self-shielded wire, with three different heat inputs (6.5; 10.5 and 16 kJ/cm).Total impact energy, as well as crack initiation and crack propagation energies, are estimate at three testing temperatures. It has been established that with heat input increase toughness decreases and that heat input of 7 kJ/cm is optimal for weld metal toughness of investigated steel.

Hari Om and Sunil Pandey [3] in his work "Submerged arc welding (SAW) is a fusion joining process, known for its high deposition capabilities. This process is useful in joining thick section components used in various industries. Besides joining, SAW can also be used for surfacing applications. Heat Affected Zone (HAZ) produced within the base metal as a result of tremendous heat of arc is of big concern as it affects the performance of welded/surfaced structure in service due to metallurgical changes in the affected region. This work was carried out to investigate the effect of polarity and other SAW parameters on HAZ size and dilution and to establish their correlations. Influence of heat input on dilution and heat affected zone was then carried out.

Apurv Choubey,Vijaykumar S. Jatti [4] his workPresent research work investigates the effect of heat input (controlled by welding current, welding voltage and welding speed) on tensile strength, micro-hardness and microstructure of austenitic 202 grade stainless steel weldments produced by shielded metal arc welding (SMAW). The base aterial used in the present investigation was Cr-Mn SS and 308L SS solid electrode was used as the filler material. From the experimental results it was found that the increase in heat input affects the micro-constituents of base metal,and heat affected zone (HAZ). Tensile strength decreases with increase in heat input and from scanning lectron microscopy of tensile test fractured surfaces exhibited ductile & brittle failure. From micro hardness data values it was observed that hardness of material increases with increase in heat input in weld pool and decreases in HAZ zone. Optical microscopy shows that smaller dendrite sizes and lesser inter-dendritic spacing were observed in the fusion zone at low heat input. And long dendrite sizes and large inter-dendritic spacing were observed in the fusion zone of the joint welded at high heat input. Further it was observed from the optical micrographs that the extent of grain coarsening in the HAZ increases with increase in heat input..

Ajay N.Boob, Prof.G. K.Gattani [5] "Heat flow in welding is mainly due to heat input by welding source in a limited zone and it subsequent flow into body of work piece by conduction. A limited amount of heat loss is by a way of convection and radiation. Local Heating and cooling of metal shrinkage on olidification and structural change on solidification cause temperature distribution. In the present work, authors have investigated the width of HAZ with various process parameters like heat input & welding speed. In manual metal arc welding (MMAW), selecting ppropriate values for process variables is essential in order to control heat-affected zone (HAZ)dimensions and get the required bead size and quality.

NiranjanPawaria,SureshKataria, Amit Goyal, Seeone Sharma [6] V-grooved butt joint of 2.25 Cr-1Mo steel was welded with a copper coated solid wire by Gas metal arc welding process.Two different gas mixtures were used, 90% Argon, 8% Carbon dioxide,2% oxygen and 90% Argon 10% Carbon dioxide. The heat-input varied by varying current and Voltage. It can be further varied by weaving across transverse direction of weld groove.Mechanical properties like hardness, tensile strength and impact strength of were tested. Four plates has been welded, two with high heat input and another two with low heat input using different mixture of shielding gas. All the test specimens are drawn out from welded plate and tested as per ASTM standard. Hardness is tested on micro - Vickers hardness tester on 500gf. Three parameters yield strength; ultimate tensile strength and percentage elongation are selected as indicator of tensile strength and tested on UTM using offset method for curve generation. Impact test is carried out at room temperature, three specimen having V-notch at perpendicular to the welding direction has been broken on charpy impact test machine, for reliability of the test. Minimum reading form the three has been considered for impact energy of the test. It is observed that test carried at low heat input shows batter result as compared to high heat input in hardness, tensile and impact properties. Weld with 90% Argon 10% Carbon dioxide does not put significant impact on hardness and tensile strength but there is considerable difference in impact strength. Combine low heat input and 90% Argon 10% Carbon dioxide mixed blend increase impact energy three times as compared to high heat input and 90% Argon, 8% Carbon dioxide, 2% oxygen shielding gas blend.

III REVIEW OF LITERATURE SURVEY

In the present situation, number of paper published so far have been surveyed, reviewed and analyzed. A substantial amount of work has been conducted on v-groove butt weld joint for their strength and geometry in the past. Also a substantial amount of work has been conducted on variations of groove angle in v groove butt weld joint for strength and distortion. Also lots of work done in failure detection and crack and fatigue analysis. From the literature survey it is clear that there is vast scope for effect of heat input on strength of v groove butt weld joint. Because welding heat input is an important parameter in metal joining processes. So the study of effect of heat input on tensile strength and micro structure of butt weld joint is very important in fabrication field.

A. Research Gap Identification

i. Problem Definition;

In India also in world there is the number of process industries. In which number of different joint weld, by using different type, different type parameters, and different welding geometries on different materials or same materials. After some life time there will be failure of weld joint. There are number of reasons for failure. By doing study it is found that in process and shipping industries the welding plays an important role. If the strength is not proper then there is possibilities of early failure of joint .In metal joining process there are so many parameters such as residual stresses, distortion, Welding speed, groove angle etc on which the strength of weld joint depends. Gas Metal Arc Welding (GMAW), by definition, is an arc welding process which produces the coalescence of metals by heating them with an arc between a continuously fed filler metal electrode and the work. The process uses shielding from an externally supplied gas to protect the molten weld pool. The application of GMAW generally requires DC+ (reverse) polarity to the electrode. In non-standard terminology, GMAW is commonly known as MIG (Metal Inert Gas) welding and it is less commonly known as MAG (Metal Active Gas) welding. In either case, the GMAW process lends itself to weld a wide range of both solid carbon steel and tubular metal-cored electrodes. The alloy material range for GMAW includes: carbon steel, stainless steel, aluminum, magnesium, copper, nickel, silicon bronze and tubular metal-cored surfacing alloys. The GMAW process lends itself to semiautomatic robotic automation and hard automation welding applications.

This project deals with investigation of effect of welding speed, type of inert gas used for shielding. This project deals with the investigation of effect of welding heat input on tensile, bend impact strength at different heat input rate of the weld joint.

ii. Objective of project ;

The purpose of this work is to study the V-groove butt weld joint at heat input used in the plate welding. To increase the strength of weld. Following are the objectives of the project work,

1) To study the effect of heat input in V-groove butt weld joint to find the max tensile strength ,on plate welding.

2) To suggest the best suitable heat input and best hardness in v-groove angle.For particular application.

IV PROJECT METHODOLOGY

A.Metal Joining Process

i. MIG Welding Process; MIG (Metal Inert Gas) welding, also known as MAG (Metal Active Gas) and in the USA as GMAW (Gas Metal Arc Welding), is a welding process that is now widely used for welding a variety of materials, ferrous and non ferrous. The essential feature of the process is the small diameter electrode wire, which is fed continuously into the arc from a coil. As a result this process can produce quick and neat welds over a wide range of joints.

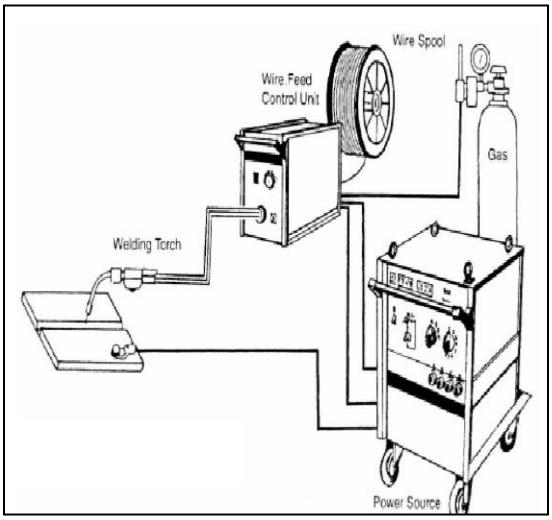

Figure 4.MIG Welding Machine

Power Source-MIG welding is carried out on DC electrode (welding wire) positive polarity (DCEP). However DCEN is used (for higher burn off rate) with certain selfshielding and gas shield cored wires.

The Wire-feed Unit The wire-feed unit, or sub-assembly where this is mounted in the power source cabinet (known as a composite MIG), provides the controlled supply of welding wire to the point to be welded. According to the welding wire size and Arc voltage provided by the power source, a constant rate of wire speed is required, in MIG welding the power source provides Arc voltage control and the wire feed unit provides welding wire speed control, (in MIG this equates to welding current).

The MIG Torch This provides the method of delivery from the wire feed unit to the point at which welding is required.The MIG torch can be air cooled or water cooled and most modern air cooled torches have a single cable in which the welding wire slides through a Liner. Gas flows around the outside of this Liner and around the tube the Liner sits in is the power braid and trigger wires. The outer insulation provides a flexible cover.

Shielding Gas This is a complicated area with many various mixtures available, but the primary purpose of the shielding gas in the MIG process is to protect the molten weld metal and heat affected zone from oxidation and other contamination by the atmosphere.

Aluminium – Argon
Magnesium – Helium
Copper Alloys - Argon - Helium Mix
Steel - CO_2 not commonly used *
today, Ar-CO2 mix is preferred

B.WELDING PARAMETERS AND THEIR EFFECTS

Weld quality, and weld deposition rate both are influenced by various welding parameters and joint geometry. These parameters are the process variables as given below :

i. Welding current
ii. Arc Voltage
iii. Welding speed.
iv. Electrode Feed rate
v. Electrode extension (stick-out)
vi. Electrode diameter
vii. Joint geometry.

Each of the above parameters affects, to varying extent, the following:

i. Deposition rate
ii. Weld-bead shape
iii. Depth of penetration
iv. Cooling rate
v. Weld induced distortion.

Hence, a proper understanding of the effects of welding parameters (or process vari-ables is important to obtain a sound welded joint with adequate metal deposition rate and minimum distortion. General effect of these variables will be discussed in the following paragraphs.

i)Welding Current

Melting rate is directly proportional to the energy (current and voltage) used for a given elec-trode and polarity used in DC welding. Part of this energy Q is used to melt the base metal (q_b), part goes to melt electrode and flux (q_f) rest is dissipated as conduction (q_{ep} + q_{ce}), convection (q_v) and radiation (q_r)

$$Q = q_b + q_f + (q_{cp} + q_{ce}) + q_v + q_r$$

,

$$Q = IV.\ J/S$$
$$= I^2\ Ra\ J/S$$

where Q = electrical energy consumed
I = welding current
V = arc voltage
Ra = arc resistance

Welding current is most important variable affecting melting rate, the deposition rate, the depth of penetration and the amount of base metal melted.

If the current (for a given welding speed) is too high, it will result in:

- excessive penetration (thinner plates will melt through)Excessive melting of electrode excessive reinforcement
- More heat input to plates being joined increased distortions
- If the welding current is too low, it will result in: inadequate penetration lack of fusion

Current could be DC or AC. DC provides steady arc and smooth metal transfer, good wetting action, uniform weld bead size, specially suited to thin section welding, give better quality welds in vertical and overhead welding positions.

ii)Arc Voltage;

Arc voltage is the voltage between the job and the electrode during welding. For a given elec-trode it depends upon the arc length. Open circuit voltage on the other hand is the voltage generated by the power source when no welding is done.Open circuit voltage varies between 50–100 V whereas arc-voltages are between 17 V to 40 V. When the arc is struck, the open circuit voltage drops to arc voltage and welding load comes on power supply.The arc voltage depends on arc length and type of electrode.As arc length increases, arc resistance increases, (resulting in higher voltage drop (i.e., arc-voltage increases and arc current decreases. This decrease in current depends upon the slope of volt-ampere curve explained earlier.Arc length is the distance between the molten electrode tip to the surface of molten weld pool. Proper arc length is important in obtaining a sound joint. As the metal droplet transfers through the arc there is a variation in instantaneous arc voltage. Welding will be quite smooth if the arc voltage variation and hence the arc length is maintained consistant. As a general rule arc length should not be more than the electrode diameter.

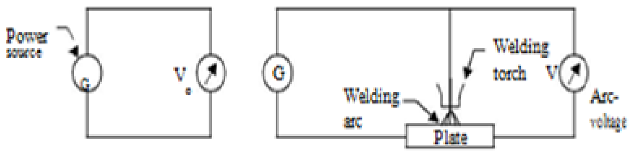

Figure 6. Weld Bead

Short arc: causes short circuits during metal transfer

Long arc—lacks direction and intensity, gives heavy spatter, low deposition rate and formation of undercuts. Though arc length needs to be controlled in order to obtain a quality welding, it is much easier to monitor and control arc voltage.

Weld-bead appearance depends on arc-voltage. Increase in arc-voltage tends to cause porosity, spatter flatten the weld bead and increase weld width. Reduction in arc-voltage leads to : narrower weld-bead, higher crown, deeper penetration. Trials are, therefore, made to obtain optimum arc voltage.

iii)Welding Speed;

Welding speed is the linear rate at which the arc moves with respect to plate along the weld joint. Welding speed generally conforms to a given combination of welding current and arc voltage.

If welding speed is more than required

- Heat input to the joint decreases.
- Less filler metal is deposited than requires, less weld reinforcement height
- Undercut, arc blow, porosity and uneven bead shape may result.

If welding speed is slow

- Filler metal deposition rate increases, more weld reinforcement
- Heat input rate increases
- Weld width increases and reinforcement height also increases more convexity.
- Penetration decreases beyond a certain decrease in speed.
- A large weld pool, rough bead and possible slag inclusion.

With all variables held constant, weld penetration depth attains a maximum at a cer-tain intermediate welding speed. At excessively low welding speeds the arc strikes a large molten pool, the penetrating force gets cushioned by the molten pool. With excessively high welding speeds, there is substantial drop in thermal energy per unit length of welded joint resulting in undercutting along the edges of the weld bead because of insufficient backflow of filler metal to fill the path melted by the arc. Welding speed is to be adjusted within limits to control weld size and depth of penetration.

iv)Electrode Feed Speed;

Electrode feed rate determines the amount of metal deposited per unit length or per unit time. In most welding machines the welding current adjusts itself with electrode feed speed to main-tain proper arc length.

v)Electrode Extension;

Electrode extension, also known as length of stick out, is the distance between the end of the contact tube and the end of the electrode as shown in Fig. 3.25. An increase in electrode extension results in an increase in electrical resistance.This causes resistance heating of electrode extended length, resulting in additional heat generation and increase of electrode melting rate. But the energy so consumed reduces the power delivered to the arc. This reduces arc voltage and thus decreases bead width and penetration depth.

To maintain proper head geometry alongwith a desired penetration and higher melting rate (i.e., large electrode extension), the machine voltage setting must be increased to main-tain proper arc length. At current densities above 125 A/mm^2, electrode extension becomes important. An increase of upto 50% in deposition rate can be achieved by using long electrode extensions without increasing welding current. This increase in deposition rate is accompa-nied with decrease in penetration.

Thus when deep penetration is desired long electrode extension is not desirable. On the other hand, for thinner plates, to avoid the possibility of melting through, a longer electrode extension becomes beneficial. It is also important to note that the increase in arc extension make it more difficult to maintain correct position of electrode tip with respect weld centreline.

vi)Electrode Diameter;

Electrode affects bead configuration, affecting penetration and deposition rate. At any given current, a smaller diameter electrode will give higher current density causing a higher deposition rate compared to large diameter electrode. A larger diameter electrode, how-ever requires a higher minimum current to achieve the same metal transfer characteristics. Thus larger electrode will produce higher deposition rate at higher current. If a desired feed rate is higher than the feed-moter can deliver changing to larger size electrode will permit desired deposition rate and vice versa. In case of poor fit-up or thick plates welding larger electrode size is better to bridge large root openings then smaller ones.

V.EXPERIMENTAL SET UP

Heat input: Welding speed is the linear rate at which the arc moves with respect to plate along the weld joint. Welding speed generally conforms to a given combination of welding current and are voltage. If welding speed is more than required

1. Heat input to the joint decreases.
2. Less filler metal is deposited than requires , less weld reinforcement

If welding speed is slow

1. Heat input rate increases.
2. Weld width increases and reinforcement height also increases more convexity

A. What is Heat Input?

In arc welding, energy is transferred from the welding electrode to the base metal by an electric arc. When the welder starts the arc, both the base metal and the filler metal are melted to create the weld. This melting is possible because a sufficient amount of power (energy transferred per unit time) and energy density is supplied to the electrode.Heat input is a relative measure of the energy transferred per unit length of weld. It is an important characteristic because, like preheat and interpass temperature, it influences the cooling rate, which may affect the mechanical properties and metallurgical structure of the weld and the HAZ . Heat input is typically calculated as the ratio of the power (i.e., voltage x current) to the velocity of the heat source (i.e., the arc) as follows

$$\text{HEAT INPUT RATE} = \frac{V \times I \times 60}{v} \quad \text{J/mm}$$

V=arc voltage in volts
I=welding current in ampere,
v =speed of welding in mm/min.

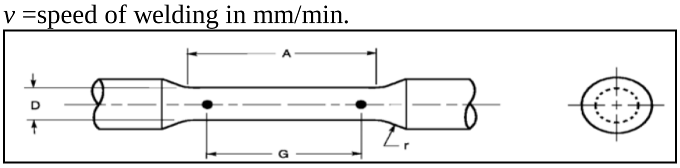

Figure 8 Weld specimen

B. Work Piece Material Used

The present study is carried out with low carbon steel of grade EN-3A. The chemical composition of base metal EN-3A and wire En-3A are shown in Table 1 and Table 2 respectively.

Table 2CHEMICAL COMPOSITION OF THE BASE METAL, EN-

3A

Element	Weight %	Element	Weight %
C	0.16	S	0.020
Mn	0.76	P	0.026
	0.22	Si	

TABLE 3CHEMICAL COMPOSITION OF THE WIRE, EN-3A

Element	Weight %	Element	Weight %
C	0.15	S	0.021
Mn	0.78	P	0.029
	0.23	Si	

TABLE 4RECOMMENDED WELDING CONDITIONS

Parameter	Unit	Minimum Value	Maximu Value
Current	Ampere	0	400
Voltage	Volt	0	54
Welding speed	m/min	0.11	1.10

TABLE 5.EXPERIMENTAL DATA

Parameter	Unit	Level 1	Level 2	Level 3	Level 4	Level 5
Current	Ampere	140	150	160	170	180
Voltage	Volt	24	25	26	27	28
Welding speed	m/min	0.165	0.179	0.193	0.206	0.220

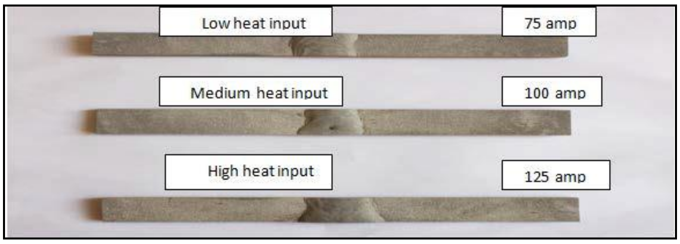

Figure 9 Weld Specimen After welding

TABLE 6 EXPERIMENTAL DATA

Experiment No.	Current (A)	Voltage(V)	Welding speed (m/min)
1	140	24	0.165
2	140	25	0.179
3	140	26	0.193
4	140	27	0.206
5	140	28	0.220
6	150	24	0.179
7	150	25	0.193
8	150	26	0.206
9	150	27	0.220
10	150	28	0.165
11	160	24	0.193
12	160	25	0.206
13	160	26	0.220
14	160	27	0.165
15	160	28	0.179
16	170	24	0.206
17	170	25	0.220
18	170	26	0.165
19	170	27	0.179
20	170	28	0.193
21	180	24	0.220
22	180	25	0.165
23	180	26	0.179
24	180	27	0.193
25	180	28	0.206

TABLE 7EFFECT OF ARC VOLTAGE ON MECHANICAL PROPERTIES OF WELD METAL

Arc voltage (V)	Hardness (HB)	Yield strength (MPa)	UTS (MPa)
20	188	271	390
22	186	263	388
24	182	260	383
26	179	251	382
28	173	249	378

TABLE 8EFFECT OF WELDING CURRENT ON MECHANICAL PROPERTIES OF WELD METAL

Welding current (A)	Hardness (HB)	Yield strength (MPa)	UTS (MPa)
115	178	267	387
125	177	263	384
135	174	257	382
145	171	254	376
155	169	253	373

TABLE 9 EFFECT OF WELDING SPEED ON MECHANICAL PROPERTIES OF WELD METAL

Welding speed (cm/min)	Hardness (HB)	Yield strength (MPa)	UTS (MPa)
40	167	248	372
45	171	257	375
50	180	264	385
55	182	271	390
60	187	277	398

VI CONCLUSION

Present work describes about the effect of heat input on micro structure and various other properties of welding process and remedies to carry out Butt weld joint effectively in MIG welding for imparting adequate strength.

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I sincerely thank to my project guide **Prof. H.K. Mishra (ME Co-ordinator)** for guidance in carrying out this paper. who has been constantly a source of encouragement for this paper work. I wish to avail myself of this opportunity, express a sense of gratitude and love to my friends and my beloved parents for their manual support, strength, and help for everything.

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