Effect of Heat Input and Shielding Gas on Hardness, Tensile and Impact Strength of 2.25 Cr-1Mo Steel Weld Metals in GMAW

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Abstract
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.

Keyword
GMAW, Shielding Gas, Heat Input, Mechanical Properties.

I. Introduction

A. Gas Metal Arc welding and Weld Variables: The weld consumables used for GMAW process are the welding wire and shielding gas. The welding wire used in the study is an alloyed wire. The shielding gas is necessary to protect the electrode molten drop and weld pool from atmospheric contamination. The arc stability, metal transfer phenomenon and bead formation are strongly influenced by the composition and flow rate of shielding gases. The composition of shielding gas mixture used in carrying gas metal arc welding of steel significantly affect the mode of weld metal transfer and weld metal properties, specially the toughness [1-5]. The metal transfer mode refers to the process of transferring material of the welding wire in the form of liquid droplets to the work piece. Depending on weld parameters used, metal transfer mode can be; globular, spray or short-circuiting. At low welding current, globular transfer mode occurs, while spray mode appears at higher welding current. The shape of the weld bead would be influenced by the metal transfer mode. The shape of weld bead would influence the weld metal cooling which would alter the weld metal transformation i.e. final weld metal micro-structure. On the other hand, depending upon the shielding gas mixture composition the oxygen equivalent of the shielding gas would be determined indicating the effect of oxygen on weld metal micro-structure [6]. Inert gas such as argon is widely used. As argon is relatively expensive, carbon dioxide and oxygen are generally mixed with argon used in Gas metal Arc Welding. By reducing the surface –tension, the mixture gives good wetting characteristics. However, with the carbon dioxide shielding gas, arc and metal transfer can be unstable and spatter increase. The operational variable affecting the mode of metal transfer are the welding current, composition of shielding gas active element coating on the electrode, polarity and welding material. Among these variable welding current is the most common variable. Mixture of argon and carbon dioxide has been used as shielding gas for GMAW of structural steel. Addition of oxygen/or carbon dioxide to the shielding gas gives a significant source of oxygen absorption for the molten weld metal. The shielding gas oxygen activity influences the amount, size and composition of oxide inclusions formed in weld metal [7]. Heat input is a function of current, voltage and travelling speed. Increase in current and voltage results increase in heat input. Heat input put a sound impact on properties of weld metals [8]. The primary goal of this study is to develop an understanding of variations in heat input, shielding gases and its effect on gas absorption by the weld plate. Shielding gas and welding parameters have to be chosen in such a way as to produce sound and defect free welding economically, keeping productivity in mind.

II. Material and Experimental Procedure

2.25 Cr-1mo steel of 19 mm thick plate is used as base metal on which V-groove of 45 deg is made. The groove is filled by Gas Metal Arc Welding. The chemical composition of Base metal is given in Table 1. The plate was cut in to two pieces of 125 × 200 mm and groove has been made. Weld assembly is made as shown in fig. 1.

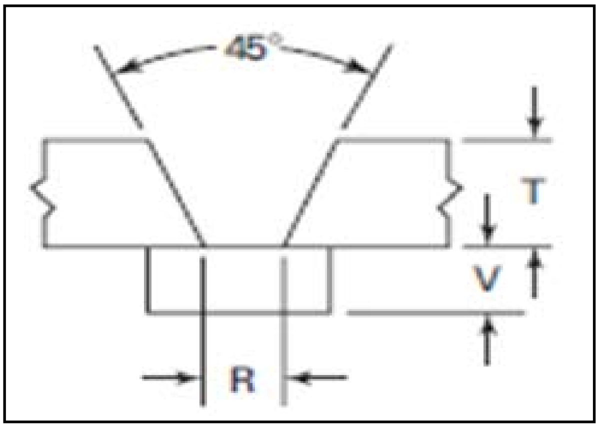


Fig. 1:

Thickness of Base Plate (T)	=	19mm
Thickness of Back up Plate (V)	=	15mm
Root opening (R)	=	13mm

The electrode used in this experiment is ER 90 S BL 3 with a diameter 1.6 mm. Chemical composition of wire is shown in Table 2

Table 1: Chemical composition of base metal

C	Mn	Si	P	S	Cr	Mo	Al
0.145	0.547	0.40	0.018	0.007	2.388	0.958	0.016

Table 2; Chemical composition for electrode wire

C	Si	Mn	P	S	Cr	Mo	Al
0.09	0.13	0.72	0.005	0.001	2.38	0.99	0.007

The cover gas activity was varied by addition of oxygen or carbon dioxide to argon. Two mixtures are used 90%Ar-10%CO_2 and 90%Ar- 8CO_2-2% O_2.The electrode extension length between the contact tube and the tip of the electrode was held constant at 15 mm. All gas flow rates during welding were fixed at 16-18 lpm. The high heat input welding operation is performed in six layers of welding with high weaving. The different heat input rate used in study 1.65, 8.2 KJ/ mm. This different heat input obtained by changing the welding current and voltage. By lowering down current and voltage low heat input can be achieved. Controlling weaving during welding, results variation in travelling speed.

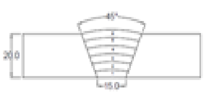
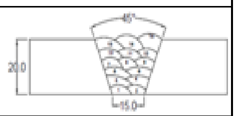
A. Specimen for Test

Heat input is function of current, voltage and traveling speed. With higher weaving single layer is sufficient for one pass but this decrease the traveling speed hence increase in heat input. Total thickness is filled by six passes of weld layer. For higher heat input, whole thickness of plate has been filled with fifteen number passes. Four plates were welded two with high heat input and two with low heat input. Two different shielding gas mixture were used, mixed triple bland, Ar+8%CO_2+2%O^2 and mixed double blend Ar+8%CO_2.

Welding parameters for high heat input are given below:

Shielding Gas (Ar+8%CO_2+2%O_2 /Ar+10%CO_2) and gas Flow rate (17 ltr /min) are same for high and low heat input. Also same polarity (DCEP) has been used for both of the cases.

Table 3: Welding parameters for high & low heat input

Welding parameters	High heat input	Low heat input
Voltage	28.2-30.8V	25.2-26.8V
Current	298-345 A	250-290 A
Weaving	Yes	No
Traveling Speed	72 mm/min	270 mm/min
Heat Input rate	8.2 KJ/mm	1.65 KJ/mm
Figure		

Following heat –treatment process has been followed by welding.

B. Post Welding Heat Treatment (PWHT)

Loading Temperature : 250°C
Rate of heating : 50°C
Soaking Temperature : 690±10°C
Soaking Period : 1 hr/25mm
Rate of cooling : 40°C
Unloading Temperature : 400°C

III Results and Discussion Hardness testing

For hardness test specimen is cut out base from the weld plate and filing is provided to the specimen. After filing the specimens are carried out under from the finishing from the hammer paper and from the buffing process on the buffing machine (Fig. 2). The hardness was measured by micro Vickers hardness tester (Fig. 3). Table 3 illustrates effect of welding variables on hardness.

Fig. 2: Hardness Test Specimen

Fig. 3: Vickers Hardness Tester

Table 4: Effect of welding variables on Hardness

Sr. No.	Welding Speed(mm/min)	Heat input (KJ/mm)	Welding Process	Hardness in Vickers(HV)
1.	82.5	7.8	HHI-M3B	172
2.	82.0	7.8	HHI-M2B	180
3.	271.4	1.6	LHI-M3B	212
4	270.0	1.62	LHI-M2B	216

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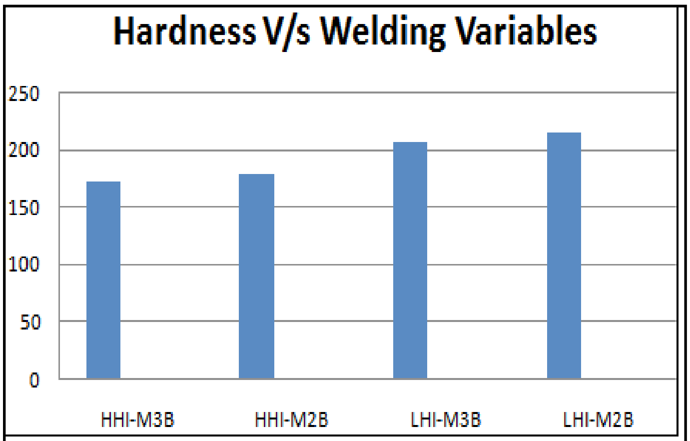


Fig. 5; Graph B/W hardness and welding Variable

A. Tensile Test

Tensile test was carried out as per ASTM standard (φ12.5 x 50) on UTM. Three parameters were selected to define tensile strength, Yield strength, ultimate tensile strength and % elongation.

Table-4: Effect of weld variables on Tensile Strength

Sr. No.	Welding Speed (mm/min)	Heat input (KJ/mm)	Welding Process	Tensile Strength(MPa)		
				Yield strength	UTS	% Elongation
1.	82.5	7.8	HHI-M3B	431	550	25.8
2.	82.0	7.8	HHI-M2B	460	580	26.0
3.	271.4	1.6	LHI-M3B	506	610	25.4
4	270.0	1.62	LHI-M2B	517	621	22.4

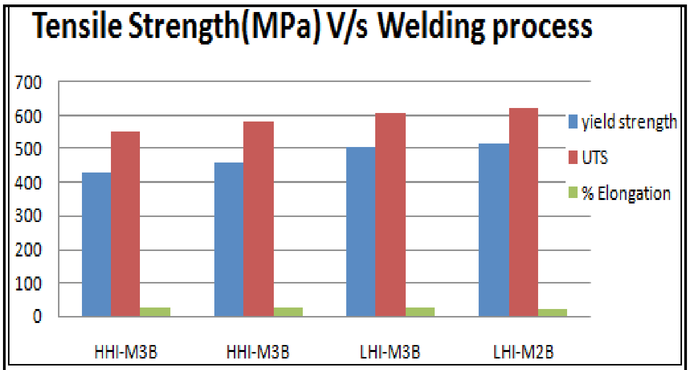


Fig. 6; Graph B/W Tensile strength and welding variables

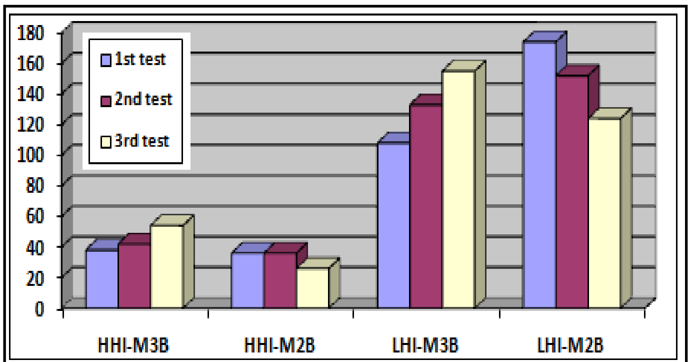
B. Impact Strength

Impact strength is the ability to withstand shock load or impact load. It is measurement of toughness of the metal. Impact energy is measured in joules per cm2. It is measured by charpy testing machine. Specimens are taken out from transverse to weld metal and V- notch has been cut right angle to the weld direction. Three specimens were considered in one set during the test and there were four set of impact specimen taken out from each test plate. Vertical milling machine and surface grinder was used for making standard size of specimen. V-notch has been cut by broaching machine with special cutter. Before performance of test notch geometry has been checked by profile projector.

Dimensions of impact sample : 10x10x55 mm, 2 mm V notch

Table -4: Effect of weld parameters on Impact energy

Sr. No.	Welding Speed (mm/min)	Heat input (KJ/mm)	Welding Variables	Impact Energy (Joules)
				25^0C (RT)
1.	82.5	7.8	HHI-M3B	38,42,54
2.	82.0	7.8	HHI-M2B	36,36,26
3.	271.4	1.6	LHI-M3B	108,133, 155
4	270.0	1.62	LHI-M2B	174,152, 124



Graph B/W weld parameters and Impact energy

IV. Conclusion

This paper helps in determining the effect of welding variables such as heat input and shielding gas on mechanical properties in gas metal arc welding process. During this research we find hardness of weld metal decrease with heat input. Higher heat input causes tempering of weld metal which lower down hardness of the weld metal. A low heat input results increase in hardness. There is not any considerable effect of amount of oxygen present in mixture of shielding gas on hardness. The effects of these parameters are same on tensile strength with decrease in amount of heat input tensile strength increases and no significant effect of shielding gas. Impact strength of weldmetal is very much affected by heat input. There is three time increment in impact strength when welded with low heat input rate. Shielding gas Ar + CO2 + O2 helps in formation of inclusion that decreases the impact value. However there is not any sudden or drastic change is felt here, values changes marginal only.

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