Experimental Investigation of Gas Metal Arc Welding (GMAW) on 2.25 CR-1MO Steel

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Abstract— Welding is a procedure of changeless joining two materials (normally metals) through confined mixture coming about because of an appropriate blend of temperature, weight and metallurgical conditions. Contingent on the mix of temperature and weight from a high temperature with no weight to a high weight with low temperature, a wide scope of welding forms has been created. There are numerous kinds of welding including Metal Arc, Submerged Arc, Resistance Butt, Flash, Spot, Seam and Projection. While there are numerous techniques for joining metals, welding is a standout amongst the most helpful and fast strategies 1available. The gas metal circular segment welding (GMAW) process utilizes a strong wire terminal that is ceaselessly bolstered into the weld pool. The wire anode is devoured and turns into the filler metal. GMAW hardware is moderately low in expense. The low starting cost, the capacity to weld constantly, and the capacity to store weld metal quicker, settle on GMAW an alluring decision for welding. This chapter reveals every aspect of GMAW. It comprises all components of GMAW such as welding machine, shielding gases, filler/electrode wire and welding joint assembly of welding plates. V grooved butt joint will be filled with 1.6 mm electrode wire (ER 90 BL-3) using ESAB AUTO K 400 welding machine. Specimen for various tests such as hardness, tensile, micro-structure, inclusion and gas absorption will be drawn from the butt welded joint as per specification.
Key words: GMAW, PPM, IGBT

I. Introduction

Gas Metal Arc Welding (GMAW) is characterized as "an electric curve welding process that produces combination of metals by warming them with a circular segment between a constant filler metal anode and the work piece." Shielding is acquired totally from a remotely provided gas.

The gas metal circular segment welding (GMAW) process utilizes a strong wire terminal that is ceaselessly bolstered into the weld pool. The wire anode is devoured and turns into the filler metal. GMAW hardware is moderately low in expense. Likewise, this procedure gives high statement rate in lbs/hr (kg/hr) than the protected metal bend or gas tungsten circular segment welding forms. The low starting cost, the capacity to weld constantly, and the capacity to store weld metal quicker, settle on GMAW an alluring decision for welding. GMAW can be utilized to create amazing welds on all economically vital metals, for example, aluminum, magnesium, treated steels, carbon and compound steels, copper, and others. GMAW may likewise be done effectively in all welding positions.

For higher generation rate shower exchange method of metal exchange has been utilized in gas metal circular segment welding. Splash method of metal exchange will happen when the current and voltage settings are expanded over those required for globular exchange. At the point when splash exchange happens, fine beads of metal frame. These beads travel at a high rate of speed straightforwardly through the circular segment stream to the weld pool. The progress current changes with the anode width, its sythesis, and the measure of terminal expansion. For 1.6 mm distance across wire welding current has been taken 250-350A. It diminishes as the anode broadens more distant from the contact tube. Before splash exchange can happen, a present setting over the progress current dimension must be made on the welding machine. Until the change current is surpassed, the metal exchanges as expansive globules. Over the progress current dimension, the squeeze drive ends up sufficiently incredible to press the metal off the tip of the cathode as fine beads. Splash exchange happens just when in any event 90% argon is utilized as the protecting gas. Regular protecting gas blends for carbon and low-compound steels are: 98% Ar + 2% O_2, 95% Ar + 5% O_2, 95% Ar + 5% CO_2, and 90% Ar + 10% CO_2.

A. Base Metal (2.25CR-1MO Steel) Uses and Properties

2.25Cr-1Mo steel is known as wet blanket safe steels since they don't list even at high temperatures (550 ^{0}C - 580 ^{0}C). These steel are critical to the development of steam generator parts of fluid metal cooled quick raiser reactors and fossil terminated power plants, substance and petrochemical plants quite a while. These steel are utilized for turbine packaging, lifted temperature header and channeling just as super warmer and re-radiator tubes in different power producing units. The choice of these basic material at lifted temperature is basically founded on a decent mix of mechanical properties, high oxidation obstruction, high killjoy opposition, high weld capacity, high consumption obstruction, high warm conductivity, low warm development of coefficient, hydrogen embrittlement, temper embrittlement and great protection from stress erosion splitting in steam and sodium condition frameworks contrasted with different steels.

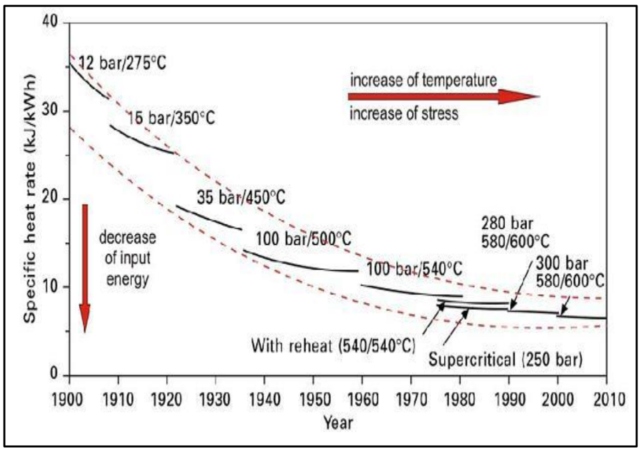


Fig. 1: Stages of development of material for higher temperature application

Amid the most recent decade, extraordinary advancement has been made in creating creep-safe steels of high quality and consumption opposition at consistently expanding temperature. In spite of the fact that previously, the main impetus for the improvements has been essentially to accomplish higher efficiencies, the center has been moved all the more as of late to the decrease of outflow of CO_2, dioxins, and other ecological dangerous gases by expanding the weight and temperature. Since approximately 1900, the warmth rate of warm power plants has been diminished well-ordered increment in the steam parameters from 275 0C/12 bars to 620 0C/300 bars.

B. Properties of 2.25CR-1MO Steel

Properties of steel decide its utility. Some of steel properties include:

1) Tensile Strength

Elasticity is property that alludes to the measure of extending a material to check the amount it can withstand. It is estimated by isolating the cross segment of the steel by pressure applied on the zone. It has an elasticity of 90,000 pounds of power for each square inch. Steel has an exceptional property where its compressive quality is practically comparable to its elasticity. It infers, that this combination reacts indistinguishable route to a devastating power from to an extending power.

2) Hardness

The property of steel decides the opposition of the compound to disfigurement, entrance, scratching, machining, yielding and scraped spot. This indenter is additionally exposed to an extreme load. At that point, when the test is finished, the space measure is determined and on premise of this technique, hardness is determined. The hardness of base metal in Vickers at 500gf is 205 HV.

3) Strength

Strength is a property of an alloyed metal to twist plastically and engrossing vitality simultaneously. This property is contrarily corresponding to rate of stacking and straightforwardly relative to the temperature change. For example, steel with moderate dimensions of carbon, exposed to anxiety at high temperature is similarly harder than steel containing low. Strength of this steel at room temperature is 117 J/cm^3.

4) Gas Metal Arc Welding Machine

The welding machine is produced with cutting edge inverter based innovation. With power part Insulated Gate Bipolar Transistor (IGBT) and Precision Placement Machine (PPM) innovation, the inverter changes over DC voltage, which is amended from info AC voltage to high recurrence AC voltage, as a result, the voltage is changed and corrected. In this way, the outcome is littler estimated of the primary transformer and lighter in load of the inverter welder, which rates the exhibitions of welding by 30%. The high recurrence swaying, which empowers the yield of high recurrence DC, is utilized in the curve beginning framework. The highlights of this machine are as following: stable of current solid, totally convenient, productive and low clamor created while the welding current task is performed. It has a more profound and more grounded welding infiltration ability, just as a higher obligation cycle than different results of comparative nature that are accessible in the market. It is reasonable for welding carbon steel, amalgam steel and delicate steel with different wires.

Specifications	Range
Mains Voltage, Frequency (V, Hz)	3 × 415, 50
Rated input power capacity KW	16
Setting range current (A)	16 – 400
Setting range Voltage (V)	8 – 400
Open circuit Voltage(V)	55 (max)
Rated duty cycle %	400/60
Efficiency %	85
Power factor	0.649
Dimension (L x W x H)	675 × 350 × 690
Weight KG	122

Table 1: Technical specifications of GMAW machine

Fig. 2: Welding machine (GMAW, ESAB AUTO K 400)

II. EXPERIMENTAL DETAILS AND PROCEDURE

Warmth input is a standout amongst critical process parameters in controlling weld reaction. It very well may be alluded to as an electrical vitality provided by the welding bend to the weldment. By and by, be that as it may, warm info can around (i.e., if the circular segment productivity isn't mulled over) be portrayed as the proportion of the bend control provided to the cathode to curve travel speed, as appeared in the accompanying condition:

$$Q = I \times V \times 60 / v$$

where,
I - is welding current;
V- is welding arc voltage;
v - is the arc welding speed,
Q - is the heat input

A. Specimen for High Heat Input

Heat input is function of current, voltage and traveling speed. GMAW process is constant voltage source. During this research we select higher value of current and voltage and lower value of traveling speed so that higher rate of heat input could attainted. Two plates were welded with same parameters but different shielding gas mixture, one with high heat input mixed triple blend 90% Ar + 8% CO_2 + 2% O_2 (HHI-M3B) as shown in Fig.3 and another high heat input mixed double blend 90% Ar+8% CO_2 (HHI-M2B) as shown in Fig. 4. Table 2 illustrates values of travel speed, current, voltage and heat input used.

The base metal and its root gap have taken as per specifications ASME (2010 Section II, part C). Voltage and current has set according to diameter of wire, material to be weld and thickness. Moreover, literature helps to select the range of voltage and current. Next to this, shielding gas flow rate depends upon diameter of electrode wire which is 1.6 mm and for this 17-20 liter/min is specified as per American Welding Society (AWS) Section II, part C, SFA-5.28/SFA 5.28M.

Welding parameters are given below:
Gas Flow rate = 17 ltr/min
Base Plate: = 20 (T) × 250 (L) ×150 (W) mm
Voltage = 28.2-30.8V
Root Gap (R) =15 mm
Current = 298-345 A
Type of welding = Multilayer
Polarity = Direct current electrode positive (DCEP)
Weaving = Yes
Shielding Gas = Ar + 8% CO_2 + 2% O_2 /Ar + 10% CO_2

Layer No.	Voltage (V)	Current (A)	Traveling Speed (mm/min)	Inter pass temp.		Heat-input/layer
				Starting	End	
01	28.2-29.8	298-310	78.0	175	300	6.55
02	28.4-29.8	302-328	86.4	175	300	6.30
03	28.4-29.8	310-340	77.0	180	350	7.25
04	28.8-30.8	320-346	64.8	170	400	8.28
05	28.7-29.8	312-344	65.4	175	450	8.20
06	29.4-30.2	319-345	61.7	200	480	9.23

Table 2: High heat input welding parameters

Average traveling speed = 72 mm/min
Average heat input rate = 8.2 KJ/mm

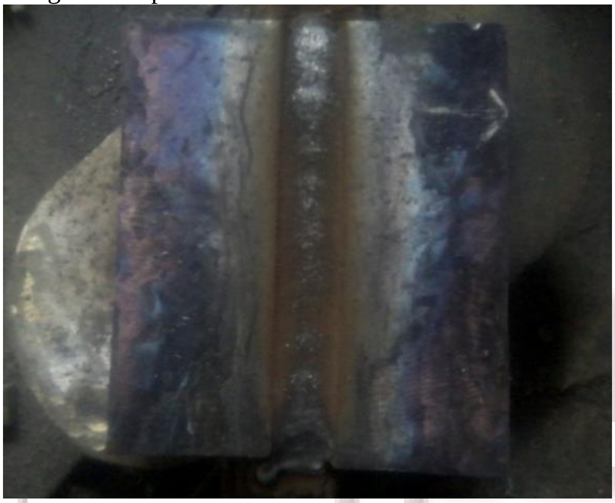


Fig. 3: HHI-M3B weld joint

Fig. 4: HHI-M2B weld joint

B. Specimen for Low Heat Input

Welding speed represents the distance of the torch traveled along the weld line per unit of time. In this study, high traveling speed or welding speed is achieved by controlled weaving. The thickness of weld plate is been filled by fifteen weld layers as shown in Fig. 5. Table 3 illustrates different values of all the parameters. Two joints are made with low heat input with different shielding gas. One with low heat triple blend, Ar + 8% CO_2+2% O_2 (LHI-M3B) as shown in Fig.4.5 and another with mixed double blend (LHI-M2B), Ar + 8% CO_2 as shown in Fig. 7.

Layer No.	Voltage (V)	Current (A)	Traveling Speed (mm/min)	Inter pass temp.		Heat input
				Starting	End	
01	25.2-26.2	260-284	231	185	260	1.86
02	25.2-26.2	260-284	240	175	308	1.72
03	25.2-26.2	260-284	230	180	290	1.84
04	25.2-26.2	260-284	230	170	335	1.83
05	25.2-26.2	260-284	223	175	326	1.85
06	25.2-26.2	260-284	277	200	347	1.83
07	25.2-26.2	260-284	377	270	360	1.19
08	25.2-26.2	260-284	247	245	346	2.02
09	25.2-26.2	260-284	353	270	310	1.18
10	25.2-26.2	260-284	218	245	313	1.83
11	25.2-26.2	260-284	333	240	346	1.22
12	25.2-26.2	260-284	250	253	317	1.67
13	25.2-26.2	260-284	241	247	317	1.74
14	25.2-26.2	260-284	181	270	375	2.29
15	25.2-26.2	260-284	330	260	340	1.62

Table 3: Low heat input welding parameters

Various welding parameters for low heat input are given below:

Gas Flow rate = 17 ltr/min
Base Plate = 20(T) x250(L) x 150(W) mm\
Voltage = 25.2 - 26.8V
Root Gap(R) = 15 mm
Current = 250 - 290 A
Type of welding = Multilayer
Weaving = No
Shielding Gas = 90% Ar + 8% CO_2+ 2% O_2 /Ar + 10% CO_2
Average traveling Speed = 270 mm/min
Average heat Input rate = 1.6 kJ/mm

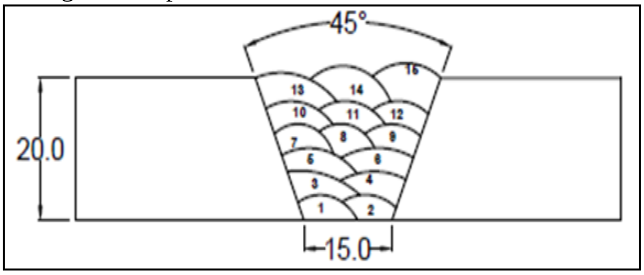


Fig. 5: Low heat input weld joint

Fig. 6: LHI-M3B weld joint

Fig. 7: LHI-M2B

III. EXPERIMENTS AND RESULTS

On the basis of experiments it can be determine that there is remarkable effect of the various process parameters on the mechanical properties welding joint of 2.25Cr-1Mo steel. During these experiments effect of two selected variables has been checked on properties such as hardness, tensile strength, microstructure, Inclusion, Gas absorption and temper-embrittlement.

The process parameters:-

1) Heat Input
2) Shielding Gas

In this study, the effects of above mentioned parameters on the following properties of the 2.25 Cr-1Mo weld metal steel has been analyzed.

1) Hardness
2) Tensile Strength
3) Microstructure
4) Inclusion

A. Effect on Hardness

For examine the effect of heat input and shielding gas on hardness, we consider two different values of heat input, high heat input(HHI) and low heat input (LHI) and two different mixture of shielding gases, mixed triple blend (M3B) Argon+8 % CO_2+ O_2, and mixed double blend(M2B) Argon+8 % CO_2. Four specimens are prepared and tested on Vickers hardness tester using 500g load as discussed in chapter 4. Table 4 and Fig 5.1 illustrate the variation of hardness with variation in welding parameters. Highest hardness is observed when joint is welded with high heat input (HHI). However, this is noticeable that 7.8 kj/mm, high heat input has two values of hardness 207HV and 216 HV for Ar-CO_2-O_2 (M3B) and Ar-CO_2 (M2B) blends respectively as shown in Table 4. Following the same trend, low heat input (LHI), 1.6 kj/mm, has 172HV and 180HV hardness for Ar-CO_2- O_2 and Ar-CO_2 blends respectively. The conclusion can be drawn from the graph shown in Fig.8, that, high heat input using Ar-CO2 blend as shielding gas results highest hardness value followed by Ar-CO_2-O_2 blend keeping heat input constant. Low heat input using Ar-CO_2-O_2 blend shows lowest hardness while with this input and double blend is on third place in descending order.

Sr. No.	Welding Speed(mm/min)	Heat input (kj/mm)	Welding Parameters	Hardness in Vickers(HV)
1.	82.5	7.8	HHI-M3B	207
2.	82.0	7.8	HHI-M2B	216
3.	271.4	1.6	LHI-M3B	172
4.	270.0	1.62	LHI-M2B	180

Table 4: Effect of welding parameters on hardness

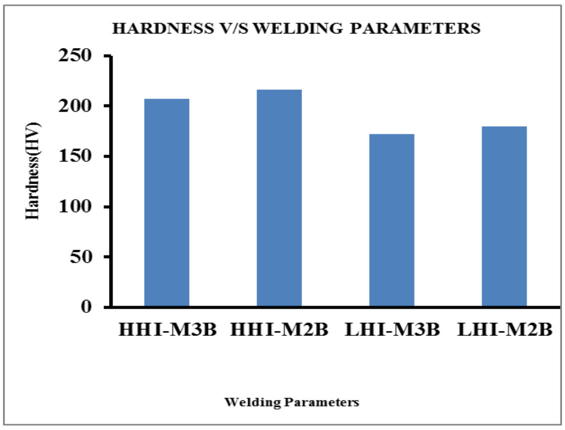


Fig. 8: Graph between hardness and welding parameters

B. Effect on Tensile Strength

Four specimens are drawn from each joint has been tested on universal testing machine. Yield strength (Y.S), ultimate tensile strength (U.T.S) and %elongation (EL) is indicator of tensile strength. Table 5 and Fig.9 show the variation of tensile strength with welding parameters.

Sr. No.	Welding Speed (mm/min)	Heat input (kj/mm)	Welding Parameters	Tensile Strength (M Pa)		
				YS	UTS	% EL
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

Table 5: Effect of welding parameters on tensile strength

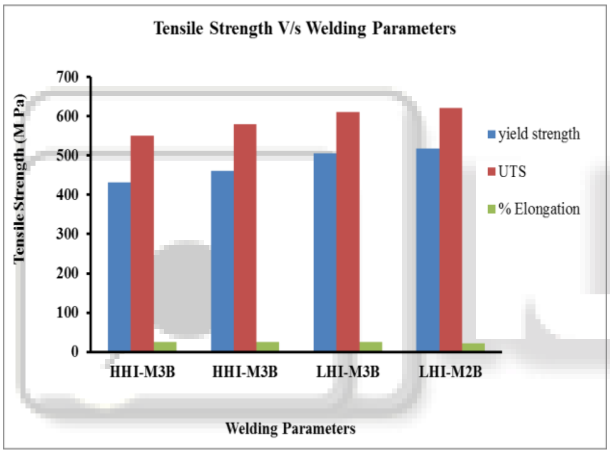
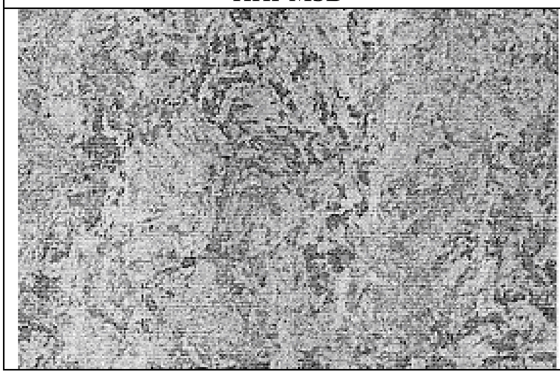
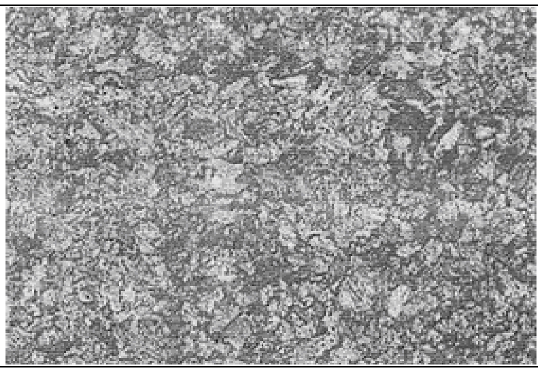


Fig. 9: Graph between tensile strength and welding parameters

Highest value of UTS and YS is achieved when specimen with LHI-M2B is tested, 517 and 621 M Pa respectively. However, percentage elongation (EL) is low (22.4%) as compared to M3B (25.4%) keeping heat input constant (1.6kj/mm). In later case value of UTS and YS value is 506 and 610 M Pa respectively. Lowest value of tensile strength from is achieved when HHI-M3B specimen is tested. HHI-M2B has given highest value of EL but could reach 580 M Pa UTS and 460 M Pa Y.S. 5.5

C. Effect on Microstructure

Four specimens have been tested with optical microscope as discussed in chapter 4. All specimens should be etched in nital and washed in alcohol before going for examination. The surface image is captured at 100x magnification. A close view of the micro- images help to understand the difference between the structures of different specimens. Fig10 shows the microstructure of specimens. High heat input specimens have tempered coarse bainite structure. However, microstructure of HHI-M3B specimen is coarser than HHI-M2B. Both structures are in tempered form due to high heat input. In spite of low heat input LHI-M3B specimen showed coarse bainite structure. Reason for this is related with shielding gas. Using Ar- CO_2-O_2 as a shielding gas, results in coarser micro-structure than Ar- CO_2 blend.

HHI-M3B	HHI-M2B
	

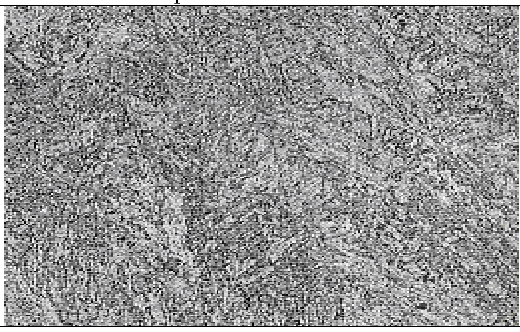
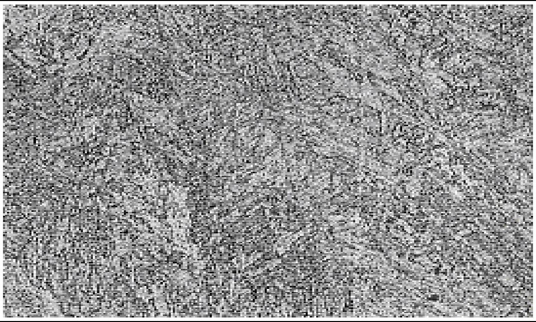
Tempered Coarse Bainite	Tempered Coarse Bainite
	
LHI-M3B Coarsed Bainite	LHI-M2B Fine Bainite
MAG. 100X	

Fig. 10: Microstructure of weld metals

D. Effect on Inclusion Formation

Prepared specimens have been examined on optical microscope for presence of inclusion in weldments. Table 6 illustrates the inclusion rating with respect to welding parameters. It is clear from the Table 6 that variation in welding parameters does not put much effect on formation of sulfide, alumina and silicate. They are only found only in thin form. Evidence of oxide is found in all four specimens. However, HHI-M3B specimen contains highest amount of oxide, 1.0 mm thin type and 0.5 mm thick type.

Sr. No	Welding speed (mm/min)	Heat input (kj/mm)	Welding Parameters	Inclusion							
				Type A (Sulfide)		Type B (Alumina)		Type C (Silicate)		Type D (oxide)	
				Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
1.	82.5	7.8	HHI-M3B	0.5	0	0.5	0	0.5	0	1.0	0.5
2.	82.0	7.8	HHI-M2B	0.5	0	0.5	0	0.5	0	1.0	0
3.	271.4	1.6	LHI-M3B	0.5	0	0.5	0	0.5	0	1.0	0
4	270.0	1.62	LHI-M2B	0.5	0	0.5	0	0.5	0	0.5	0

Table 6: Effect of welding parameters on inclusion rating

IV. CONCLUSIONS

This study helps in determining the changes in mechanical properties, microstructure, temper embrittlement, inclusion and gas absorption with respect to welding parameters such as heat input and shielding gas in GMAW process. It is matter of consideration that 2.25 Cr-1Mo steel which is used for high temperature application, is very sensitive to change in these properties. The results indicate that heat input, set direct impact on mechanical, micro-structural and temper-embrittlement properties. However, grater effect of shielding gas is analyzed on inclusion formation and gas absorption, which again affect the mechanical and micro-structural properties. A comparison is established between achieved properties at different selected parameters.

The following conclusions are derived from the current study:

1) The value of hardness increases with increase in heat input. The welding temperature goes very high in this case and when welding stops, the joint felt quenching effect. This results in high hardness. On the other hand, shielding gas has not much effect on hardness.
2) Tensile strength is much affected by heat input. High heat input results decline in yield strength (YS) and ultimate tensile strength (UTS) values. With low heat input high value of YS and UTS is achieved. Moreover, Ar-CO_2 blend shielding gas promotes higher tensile value.
3) The microstructure of weld joints is pure bainite, there, is not any intermixing with other structures. Bainite turn out to be coarser as heat increases. Ar-CO_2-O_2 blend promotes oxide formation that further makes structure coarse. Also high heat input cause tempering during welding. Fine bainite came out when heat input is kept low.
4) Inclusion formation is not much effect by heat input. It is affected by shielding gas only. Sulfide, alumina and silicate are found in thin form only. Tendency of oxide formation is higher when welding with triple mixer blend (Ar-CO_2-O_2) of shielding gas.

To sum up, as heat input increases, hardness increases and tensile strength increases also impact strength fall drastically. Also, microstructure gets coarser but not much effect on inclusion is analyzed. On the other hand, welding with low heat input, results in high tensile strength, high impact value and fine bainite microstructure

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