To Study the Effect of Process Variable on Properties of 2.25cr-1mo Steel in GMAW

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Abstract-In large steel fabrication industries such as shipbuilding, power plant and petrochemical, Gas metal arc welding (GMAW) is the one of the most common method for joining of metals. It's various characteristics like high productivity, high mechanical properties, easy of automation, overall lower cost of production makes it first choice for many fabrication processes. This dissertation focuses on Gas Metal Arc Welding on 2.25 Cr-1Mo high temperature creep resistance steel used for power plant, petrochemical and nuclear industries. In this investigation we will able to find the effect of welding parameters such as heat input & shielding gas on properties of weld metal. The main objectives are to evaluate the mechanical properties (hardness, tensile strength and impact strength), microstructure, inclusion, gas absorption and temper-embrittlement of weld metal. By controlling weaving, lower heat input can be achieve which causes increase in impact value by three times and further reduces the chances of temper-embrittlement. In this work, microstructure of welded pieces was observed using optical metallurgical microscope (AXIO). It is visually observed that in the case of high heat input weld, coarse tempered bainitic structure is achieved. Therefore the work carried out clearly indicates that there is a considerable. improvement in the quality of weld of 2.25 Cr-1Mo steel components when they are welded with lower heat input by control weaving as comparison with higher heat input. This is true with reference to improvement in mechanical, microstructure, temper-embrittlement etc.
Keywords– Gas metal arc welding, heat input, temper-embrittlement.
Abbreviations-
SWIL- Star Wire India Limited, Ballabhgarh, Haryana.

I. INTRODUCTION

Originally, the economics importance of welding was realized mainly for repairing and salvaging of all kinds of worn and damaged metal equipments and parts. The economics and improvements brought about by the more recent techniques of the cutting and the welding processes have placed them as an outstanding tool for manufacturing, construction and maintenance purposes. Welding is the only solution in cases where equipments is to be constructed of steel plates, the thickness of which is greater than joined by means of riveting and caulking. Due to its wide application and demand of productivity make gas metal arc welding seems very good alternative. There are many variables in welding which put sound impact on properties of weld metal. 2.25Cr-1Mo steel used for critical applications such as power plant and nuclear pressure vessel. To achieve those properties all parameters of welding should be well defined. The problem of change in properties during welding leads to dimensional inaccuracies and misalignments of structural members, pressure vessels which can result in corrective tasks or rework on the work piece or a big accident. This motivates me to find the effect of welding parameters such as heat & Shielding gas On properties of weld metal.

Present focus has following objectives.

1. To study the effect of heat input on mechanical, micro structural and temper – embrittlement properties of weld metal of 2.25 Cr-1Mo steel.

2. To study effect of heat input on inclusion rating and gas absorption properties.

3.To study the effect of shielding gas (presence of oxygen in mixed blend) on mechanical, microstructural and temper- embrittlement properties.

4. To study effect of shielding gas on inclusion rating and gas absorption properties.

II. LITERATURE REVIEW

In recent years, GMAW has been widely developed for mostly alloy steel and high creep resistance steel. Most of the work on GMAW has been dedicated to the study of the flow of material, the effect of welding parameters on the microstructure, mechanical properties, fatigue properties, Creep properties, Hydrogen and Temper-embrittlement.The effect of heat-treatment i.e. pre-heating temperature, Inter pass temperature, Post welding heat-treatment temperature (PWHT) has also been studied.

W. Provost [1] Investigate the effects of a stress relief heat treatment on the toughness of pressure vessel quality steels. This paper gives the results of the third phase of a research programmed on the influence of post weld heat treatments on the toughness of welded joints in pressure vessel quality steels. Special attention is paid to the minimum plate thickness for which a post weld heat treatment should be recommended. In addition to the qualification tests, several large-scale tests were carried out on test plates of various thicknesses. The results indicate that, although the present code requirements are satisfactory for C-Mn steel, they should be completely altered for an Nb- microalloyed steel, welded with a high heat input.

T.A Lechtenber, **J.R. Foulds [2] i**nvestigate the effect of preheat on the microstructure, hardness and toughness of HT-9 weldments. The welding preheat temperature is shown to significantly affect the dynamic fracture behavior of a 12CR- 1Mo steel (HT-9) weld metal. A decreased preheat, effecting a faster weld metal cooling rate, results in an increased upper shelf energy and lower ductile-brittle transition temperature with no charge in weld metal. SEM examinations indicate a decreased dendrite spacing and lower interdendritic segregation with a faster cooling rate. It Is evident that the varying interdendritic ferrite content and morphology and the dendrite spacing, both controlled by the cooling rate, play a significant role on the weld metal dynamic fracture behavior. The results suggest the lowest preheat compatible with good welding practice be used for maximum benefits to weld metal fracture mechanics.

J.N Clark [3] Investigate about the weld repair of low alloy creep resistant steel castings without preheat and post-weld heat treatment.He present report on fracture toughness data for untempered CrMoV weld metal, deposited by CrMoV electrodes, so that the risk of fast fracture can be assessed. Additional data on creep ductility of the weld metal are presented and discussed with reference to the longer-term integrity of repairs.

D.G. Crawford, T.N. Baker [4] Investigate about Microstructure and toughness of low carbon steel weld metal .As part of an investigation into the microstructure and properties of low carbon microalloyed steel weld metal, the influence of changes in the optically resolvable microstructure on Charpy impact transition temperatures were examined. An analysis of the experimental data was carried out, based on the premise that minor phases were the primary sites for brittle crack initiation, and that successful propagation or otherwise of such cracks was a function of the surrounding gross microstructure. The resulting correlation between microstructure and toughness provided a means of rationalizing the influence of a range of compositional and other variables on toughness, through their effects on the microstructure.

III. Experimental Description and Result Analysis

1. Setup Description- Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. There are four primary methods of metal transfer in GMAW, called globular, short-circuiting, spray, and pulsed-spray. Spray mode appears at high current and voltage and used for high productivity.

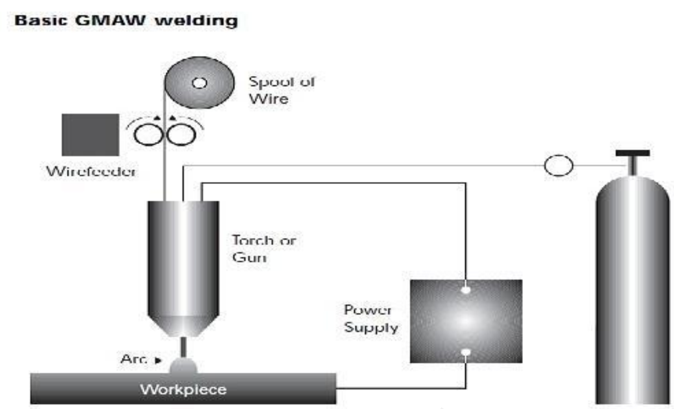

Fig.1 Experiment setup for GMAW

Technical Specifications of GMAW Machine-
Table1.1

Mains Voltage, Frequency (V, Hz)	3x415,50
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)	675x350x690
Weight KG	122

Chemical composition of welding wire
Table 1.2

C	Si	Mn	P	S	Cr	Mo	Ni
0.085	0.073	0.535	0.0069	0.0022	2.13	0.93	.045
Al	Cu	Sn	Ti	V	W	B	Co
0.002	0.145	0.001	0.001	0.011	0.004	0.0001	0.004
Nb	Pb	Sb	As				
0.002	0.001	0.001	0.001				

Shielding gas protects the weld pool from environment and reduce the chances of oxidation. A proper flow (17- 20 Lit/min) is very much needed for sound weld quality. In this investigation there were use 90% Argon + 8% Carbon dioxide + 2% oxygen shielding gas.

PREPARATION OF WELDING ASSEMBLY - A test piece of 50 X 200 X 250 mm, Groove angle 450 is prepared from a large plate of 2.25 Cr-1Mo.The plate is hardened (9400C) and tempered (7100C).see fig.(4.3) Now at various process parameters welding of these pieces are done. The specimen for various Testing has cut from these pieces.

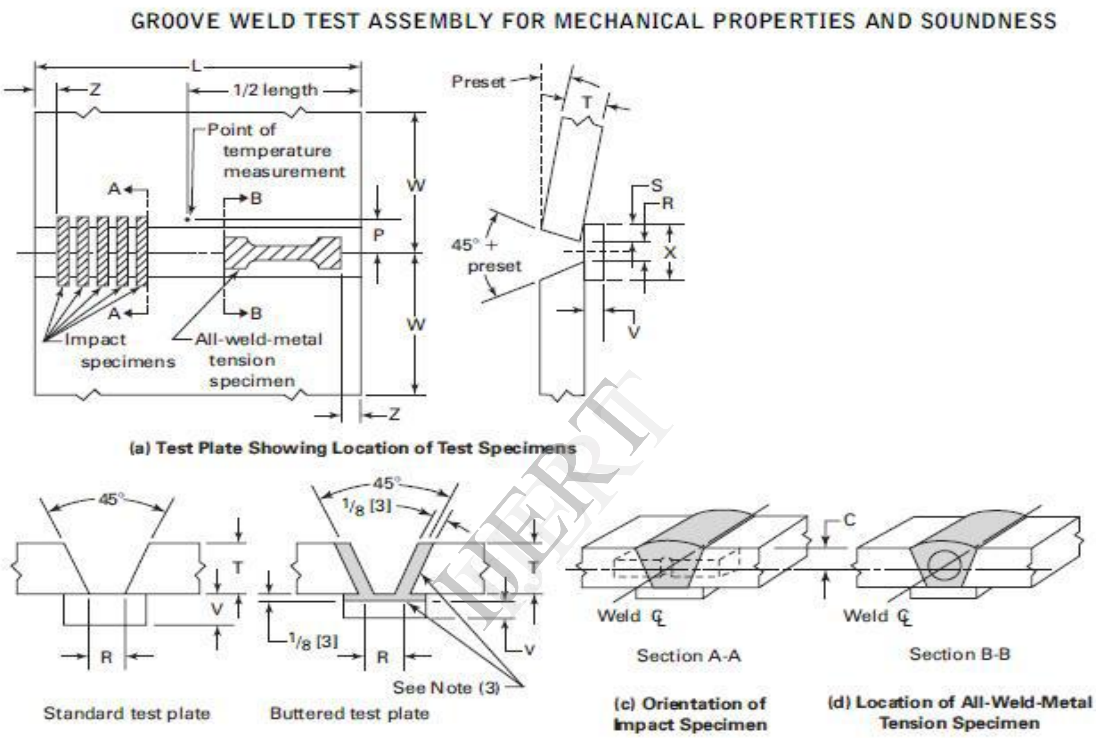

Fig.2 Welding Assembly

Test pieces for welding were cut from a large plate and V groove of has been made. Groove has been filled by welding using above stated weld consumable with different heat input (controlling weaving) and with two different shielding gases. Specimen for various test has been cut out from the welded plate

2. Data Collection from experiment- Heat input is one of the most important process parameters in controlling weld response. It can be referred to as an electrical energy supplied by the welding arc to the weldment. In practice, however, heat input can approximately (i.e., if the arc efficiency is not taken into consideration) be characterized as the ratio of the arc
power supplied to the electrode to the arc travel speed, as shown in the following equation:

$$\boldsymbol{Q = (I * V * 60)/V}$$

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

A. SPECIMEN FOR HIGER HEAT INPUT - Welding parameters is given below.

Gas Flow rate = 17 ltr/min
Voltage = 28.2-30.8V
Current = 298-345
Type of welding = Multilayer
Polarity = DCEP
Shielding Gas = Ar+8%CO2+2%O2
Heat Input rate = 8.2 KJ/mm

Base Plate: 20(T) x250(L) x 150(W) mm
Root Gap(R): 15 mm
A Weld at starting before plate: 12.5 mm
Weld at end after plate: 12.5 mm
Total Weld Length: 275mm
Traveling Speed = 72 mm/min
Weaving = Yes

Welding variables for high heat input (HHI)

Table-1

Layer no.	Voltage(V)	Current(A)	Traveling Speed (mm/min)	Inter pass temp. Starting	End	Heat Input/Layer
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.o	180	350	7.25
04	28.8-30.8	320-340	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

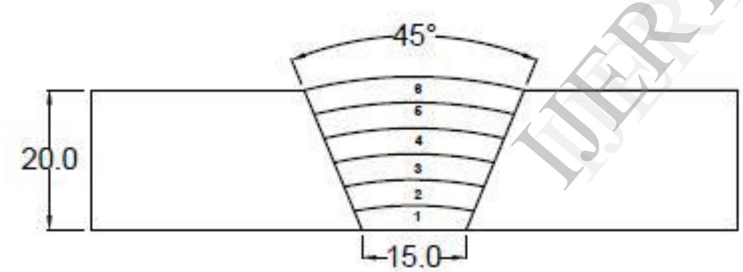

Fig. 3 Welded Plate with high heat input (Weaving) HHI

SPECIMEN FOR LOW HEAT INPUT

Various welding variables for low heat input are given below:
Gas Flow rate =17 ltr./min
Voltage = 25.2-26.8V
Current = 250-290 A
Type of welding = Multilayer
Polarity = DCEP Total
Shielding Gas = Ar+8%CO2+2%O2
Avg. Heat Input rate = 1.6 KJ/mm

Base Plate: 20(T) x250(L) x 150(W) mm
Root Gap(R): 15 mm
Weld at starting before plate: 12.5 mm
Weld at end after plate: 12.5 mm
Weld Length: 275mm
Traveling Speed =270 mm/min
Weaving =No

Welding Variables for Low heat input (No Weaving) LHI

Table.3

Layer No.	Voltage (V)	Current(A)	Traveling Speed (mm/min)	Inter pass temp. Starting	End	Heat Input/layer
01	25.2-26.2	264-284	231	185	260	1.86
02	25.2-26.2	264-284	240	175	308	1.72
03	25.2-26.2	264-284	230	180	290	1.84
04	25.2-26.2	264-284	230	170	335	1.83
05	25.2-26.2	264-284	223	175	326	1.85
06	25.2-26.2	264-284	277	200	347	1.83
07	25.2-26.2	264-284	377	270	360	1.19
08	25.2-26.2	264-284	247	245	346	2.02
09	25.2-26.2	264-284	353	270	310	1.18
10	25.2-26.2	264-284	218	245	313	1.83
11	25.2-26.2	264-284	333	240	346	1.22
12	25.2-26.2	264-284	250	253	317	1.67
13	25.2-26.2	264-284	241	247	319	1.74
14	25.2-26.2	264-284	181	270	375	2.29
15	25.2-26.2	264-284	330	260	340	1.62

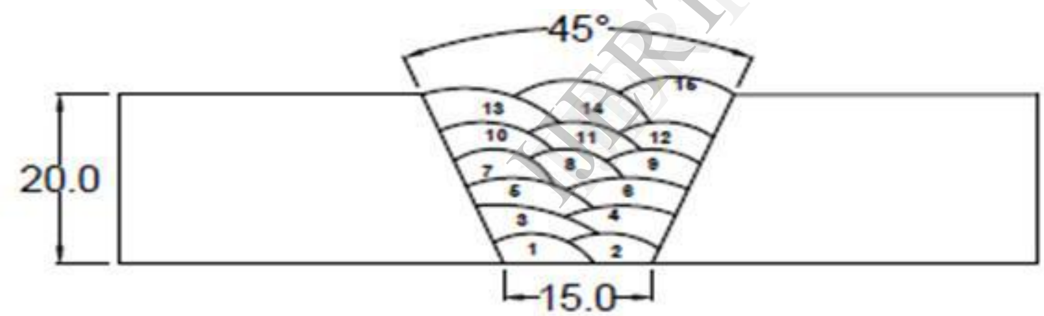

Fig. 4 Welded plate with Low heat input (without weaving) LHI

***3.* Results** - In this investigation I consider the effect of the above mentioned parameters on the following properties of the 2.25 Cr-1Mo weld metal steel.

1. Hardness 2. Tensile Strength 3. Inclusion
4. Gas absorption 5. Temper-embrittlementthe

Effect of heat input and shielding gas on various properties, we consider two different values of heat input (HHI) high heat input, and low heat input (LHI) and two different mixture of shielding gas mixed triple blend (M3B) Argon+8 % CO2+ O2, and mixed double blend(M2B) Argon+8 % CO2 and study their effect on hardness. The following table and graph shows the variation of harness with Welding variables.

A. Hardness-

Table-3.1 Effect of process variable on Hardness

Sr.No.	Welding Speed (mm/min)	Heat input (KJ/min)	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	207
4.	270.0	1.62	LHI-M2B	216

B. Tensile Strength-

Table-3.2 Effect of Process Variable on tensile strength

Sr.No	Welding Speed (mm/min)	Heat Input (KJ/mm)	Welding Process	Tensile Strength(MPa)		
				Yield strength (MPa)	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

C. Gas absorption

Table-3.3 Effect of Process Variable on Gas absorption in weld metal

Sr.No	Welding Speed (mm/min)	Heat input (KJ/mm)	Welding Process	Gases Absorbed (PPM)		
				Oxygen	Nitrogen	Hydrogen
1.	82.5	7.8	HHI-M3B	923	98	0.8
2.	82.0	7.8	HHI-M2B	484	87	1.2
3.	271.4	1.6	LHI-M3B	687	77	0.6
4.	270.0	1.62	LHI-M2B	466	66	0.6

D. Inclusion Rating

Table-3.4 Effect of Process Variable on Inclusion rating

Sr.No.	Welding Speed	Heat Input	Welding process	Inclusion (ASTM E-45)							
				Type A		Type B		Type C		Type D	
				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

E. Temper – embrittlement

Table -3.5 Effect of Process Variable on temper-embrittlement

Sr. No.	Welding Speed (Mm/min.)	Heat Input (KJ/min.)	Welding variables	Impact Energy (Joules)			
				25^0 C(RT)	0^0C	20^0C	40^0C
1.	82.5	7.8	HHI-M3B	38,42,54	08,10,08	10,08,08	04,04,06
2.	82.0	7.8	HHI-M2B	36,36,26	12,10,08	10,08,10	04,06,08
3.	271.4	1.6	LHI-M3B	120,133,155	20,22,26	12,14,16	08,08,06
4.	270.0	1.62	LHI-M2B	74,152,124	20,20,28	12,16,16	08,10.06

V. Conclusion

This research helps in determining the changes in mechanical, microstructural; temper embrittlement, inclusion formation and gas absorption properties with respect to welding variables such as heat input and shielding gas in gas metal arc welding process. During this research the change in hardness, impact strength, tensile strength and microstructure, Inclusion rating, gas absorbed and temper-embrittlement at various process parameters is investigated. A comparison is established between achieved properties and variables. There is a considerable impact of shielding gas on inclusion formation and gas absorption. Variation in heat input cause change in mechanical, microstructural and temper-embrittlement properties. The original properties and the values of these properties are different for base metal. This means that during welding there is always some changes in the properties of material. In past shielding gas and heat input are two parameters which we did not consider much during welding. But these parameters really affect the welding quality which can be seen from above discussion.

The following conclusions are derived from above research.

1. There is decrease in hardness and small decrement in tensile strength and also a drastic decrement in impact properties as heat input increases. Presence of oxygen in mixture of shielding gas doesn't put any remarkable effect on these properties.
2. Microstructure gets coarser at higher heat input which further cause decrement in impact energy. Welding with lower heat input results in fine bainitic structure. Due to high effect of heat input on microstructure the effect of Shielding gas is not clearly understood.
3. There is increase in inclusion rating as mixed triple bland shielding gas(when oxygen is present in mixture) has been used, specially oxide formation. Inclusion rating is low when welded with lower heat input. Higher heat input cause marginal increment in thick type inclusion.
4. Higher heat input increases chances of gas absorption.
5. Higher heat input cause temper-embrittlement. In service life material face temper-embrittlement after a long period of time. But due to high heat input temper-embrittlement takes place during welding itself, which lower down its impact energy at room temperature as well as at lower temperature such as – 40C.

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