TO STUDY THE EFFECT OF PROCESS VARIABLE ON THE PROPERTY OF 2.25 Cr-1 Mo STEEL IN GAS METAL ARC WELDING

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ABSTRACT

In large steel fabrication industries such as shipbuilding, power plants and petro-chemicals, Gas Metal Arc Welding (GMAW) is the one of the most common technique for joining metals. Its various characteristics like high productivity, improved mechanical properties, easy of automation and overall lower cost of production makes it first choice for many fabrication processes.

This paper focuses on the GMAW of 2.25 Cr-1Mo high temperature creep resistance steel, which is used in power plants, petrochemicals and in nuclear industries. In this work, we able to find the effect of welding parameters such as heat input and shielding gas on the properties of weld metal. The main objectives are to evaluate the hardness and tensile strength of weld metal.

In this experimental study, two welding parameters are used and they are:

a) Heat input (high heat input & low heat input)

b) Shielding gas (Argon - Carbon-dioxide - Oxygen and Argon - Carbon-dioxide).

The experimental results and their analysis clearly indicate that there is a possibility of sound welding with good combination of heat input and shielding gas. By controlling weaving, lower heat input can be achieve which causes increase in impact value of weld joint by three times and further reduces the chances of temper-embrittlement.

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 low heat input using Ar-CO2as shielding gas as comparison with high heat input and Ar-CO2-O2 blend of shielding gas.

KEYWORDS

Gas metal arc welding, heat input, shielding gas, temper-embrittlement, microstructure, inclusion and gas absorption.

GAS METAL ARC WELDING:-

The gas metal arc welding (GMAW) process uses a solid wire electrode that is continuously fed into the weld pool. The wire electrode is consumed and becomes the filler metal. GMAW equipment is relatively low in cost. Also, this process gives high deposition rate in lbs/hr (kg/hr) than the shielded metal arc or gas tungsten arc welding processes. The low initial cost, the ability to weld continuously, and the ability to deposit weld metal faster, make GMAW an attractive choice for welding. GMAW can be used to produce high-quality welds on all commercially important metals such as aluminum, magnesium, stainless steels, carbon and alloy steels, copper, and others. GMAW may also be done easily in all welding positions..

SHIELDING GASES:-

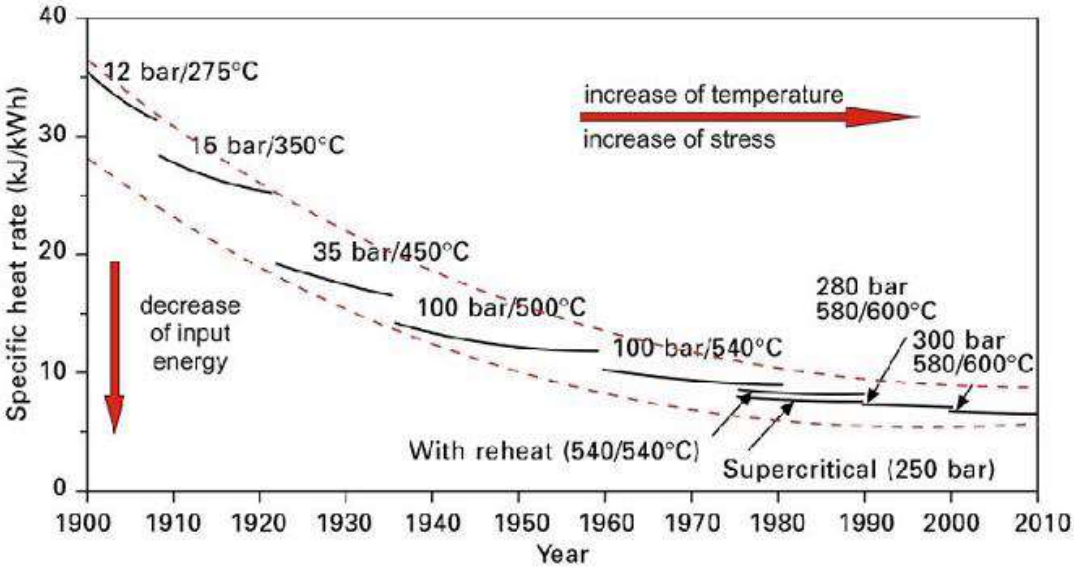
During any arc welding process, oxygen and other atmospheric gases can react with the molten metal, causing defects that weaken the weld. The primary function of a shielding gas is to protect the molten weld metal from atmospheric contamination and the resulting imperfections. In addition to its shielding function, each gas or gas blend has unique physical properties that can have a major effect on welding speed, penetration, mechanical properties, weld appearance and shape, fume generation, and arc stability. A change in the shielding gas composition is usually considered an “essential variable” in most qualified welding procedures. Shielding gases are inert or semi-inert gases that are commonly used in several welding processes, most notably gas metal arc welding. Their purpose is to protect the weld area from atmospheric gases, such as oxygen, nitrogen, and water vapour. Depending on the materials being welded, these atmospheric gases can reduce the quality of the weld or make the welding process more difficult to use.

BASE METAL (2.25Cr-1Mo STEEL) :-

2.25Cr-1Mo steel is known as creep resistant steels because they do not sag even at high temperatures (550^0C-580^0C). These steel are key to the construction of steam generator components of liquid metal cooled fast breeder reactors and fossil fired power plants, chemical and petrochemical plants a long time. These steel are used for turbine casing, elevated temperature header and piping as well as super heater and re-heater tubes in various power generating units. The selection of these structural material at elevated temperature is primarily based on a good combination of mechanical properties, high oxidation resistance,

high creep resistance, high weld ability, high corrosion resistance, high thermal conductivity, low thermal expansion of coefficient, hydrogen embrittlement, temper embrittlement and good resistance to stress corrosion cracking in steam and sodium environment systems compared to other steels.

During the last decade, great progress has been made in developing creep-resistant steels of high strength and corrosion resistance at ever increasing temperature. Although in the past, the driving force for the developments has been primarily to achieve higher efficiencies, the focus has been shifted more recently to the reduction of emission of CO2, dioxins, and other environmental hazardous gases by increasing the pressure and temperature. Since roughly 1900, the heat rate of thermal power plants has been reduced step-by-step increase in the steam parameters from 275^0C/12 bars to 620 ^{0}C/300 bars.



Stages of development of material for higher temperature application

EXPERIMENTAL DETAILS AND PROCEDURE

INTRODUCTION:-

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 takeninto consideration) be characterized as the ratio of the arc power supplied to the electrodeto the arc travel speed, as shown in the following equation:

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

Where,

I - is welding current;

V- is welding arc voltage;

v- is the arc welding speed,

Q- is the heat input

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. With higher weaving single layer is sufficient for one pass but this decrease the traveling hence increase in heat input. Total thickness is filled by six passes of weld layer as shown in Fig 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. and another high heat input mixed double blend 90% Ar+8%CO2(HHI-M2B) as shown in Fig. and Table 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

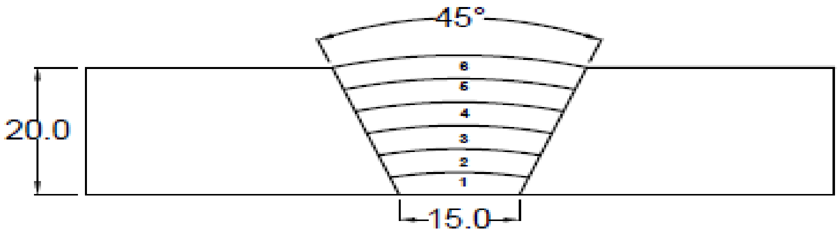
Shielding Gas = Ar+8%CO2+2%O2/Ar+10%CO2

High heat input welding parameters

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

Average traveling speed = 72 mm/min

Average heat input rate = 8.2 KJ/mm



High heat input weld joint

HHI-M3B weld joint

HHI-M2B weld joint

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. Table 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%CO2+2%O2 (LHI-M3B) as shown in Fig.4.5 and another with mixed double blend (LHI-M2B), Ar+8%CO2 as shown in Fig.

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

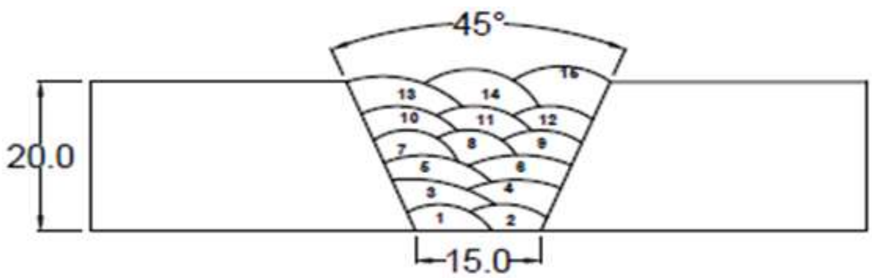
Shielding Gas = 90% Ar+8%CO2+2%O2 /Ar+10%CO2

Low heat input welding parameters

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

Average traveling Speed =270 mm/min

Average heat Input rate = 1.6 kJ/mm



Low heat input weld joint

LHI-M3B weld joint LHI-M2B weld joint

POST WELD HEAT TREATMENT (PWHT):-

High level residual stresses can occur in weldments due to restraint by the parent metal during weld solidification. The stresses may be as high as the yield strength of material itself. PWHT is required to reduce the residual stresses formed during welding. PWHT restores the macro structure of the steel. In high pressure applications, constructors have to strictly follow PWHT requirements to avoid component failures.According to ASTM standard, 2.25Cr- 1Mo steel falls under the category of A370 group. Heat-treatment is done according to specified cycle (ASME Vol. IV). PWHT is performed in automatic induction furnace of dimension 500×500×800 with highest temperature 1000 ± 5^{0}C.

Loading Temperature	: 250^{0}C
Rate of heating	: 60 ^{0}C
Soaking Temperature	: 690±10 ^{0}C
Soaking Period	:1 hrs/25mm
Rate of cooling	: 40 ^{0}C
Unloading Temperature	: 400^{0}C

VARIOUS TESTING:-

After preparing the various specimen for varying parameters, next step is to do various testing. Specimen for various test were cut from these welded plates.

HARDNESS TESTING:-

Hardness has been variously defined as resistance to local penetration, scratching, machining, wear or abrasion, and yielding.

The multiplicity of definitions, and corresponding multiplicity of hardness measuring instruments, together with the lack of a fundamental definition, indicates that hardness may not be a fundamental property of a material, but rather a composite one including yield strength, work hardening, true tensile strength, modulus of elasticity, and others. The followings are the most common hardness test methods used:

1. Rockwell hardness test
2. Brinell hardness test
3. Vickers hardness test

In this study hardness is tested by Vickers Hardness tester.

VICKERS HARDNESS TESTER:-

The Vickers hardness is a hardness measurement based on the net increase in depth of impression as load is applied. The hardness is measured in HV. In the current study, MITUTOYO HM -200 series USA made, tester, scale range 10 HV – 1000 HV has been used. Higher the HV number, harder the material

.In the Vickers method of hardness testing, the depth of penetration of an indenter under certain arbitrary test conditions is determined. The Vickers test has two distinct force ranges, micro (10g to 1000g) and macro (1kg to 100kg), to cover all testing requirements. In this study, 500g load is applied on indenter. A micro Vickers hardness tester is shown in Fig.

Vickers Hardness Tester

SPECIMEN PREPARATION FOR HARDNESS TEST:-

Specimens for hardness test have been drawn out from weld metal. There are four specimens, one from each joint. For hardness test, the surface should be smooth without any roughness. After initial surface preparation, the surface is finished by emery paper.Emery paper of 300 grade has been used first which is followed by grade 600, 800 and 1200 respectively. Then finial finishing process is carried out on buffing machine. The prepared specimens are tested by placing them on the table of hardness tester. After initial setting of load and range of hardness number the machine is switch on for indenter penetration. The machine used here is automatic and it gives direct reading. Fig. shows specimen for hardness test.

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Specimen for hardness test

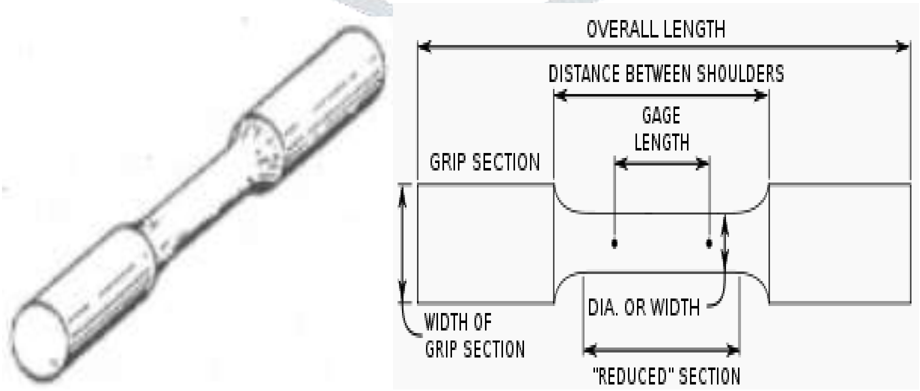
TENSILE TEST:-

Tension test is widely used to provide basic design information on the strength of materials and is an acceptance test for the specification of materials.

The parameters obtained during the tension test are ultimate tensile strength (UTS), yield strength(YL), percent elongation (EL) and the reduction in area (RA%).In this test, a specimen, is prepared as per specification for gripping into the jaws of the testing machine. The specimen used is approximately uniform over a gage length (the length within which elongation measurements are done).

TENSILE TEST SPECIMEN:-

There are four round specimens as shown in Fig., drawn out from each welded joint. The tensile specimens are drawn longitudinally from weld joint, so that only welded material is tested, to avoided effect of HAZ and base metal.



Specimen for tensile test

The specimens are prepared on lathe machine as per specifications of American Society of Testing of Materials (ASTM -A370 vol.-7). As pulling proceeds, the change in the gage length of the specimen, is measured from either the change in actuator position (stroke or overall change in length) or by a sensor attached to the specimen (called an extensometer). In this study extensometer has been used. Fig. 4.14 illustrates the specimen preparation on lathe machine and test performed on universal testing machine.

Specimens are prepared with following dimensions:

Diameter = 12.5 mm,	Distance between shoulders = 80 mm
Gage Length = 50 mm	Diameter of grip section = 20mm

Specimen preparation for tensile test

Preparation of tensile sample on lathe machine

Tensile specimen

Testing on UTM

 Specimen during necking	 Breaking of specimen

RESULTS AND DISCUSSION

INTRODUCTION:-

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.

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

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. Table and Fig illustrate the variation of hardness with variation in welding parameters.

Effect of welding parameters on hardness

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

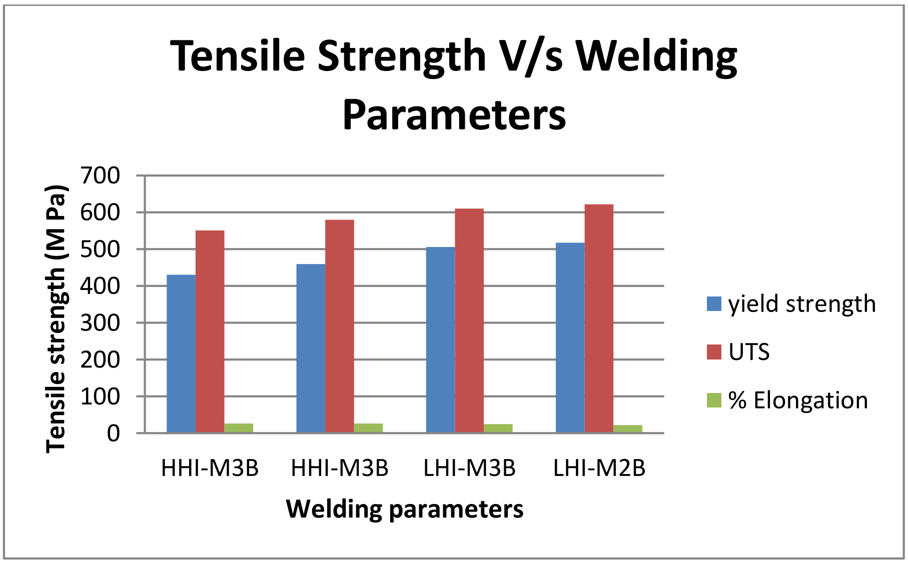
Highest hardness is observed when joint is welded with high heat input (HHI). However, this is noticeable that 7.8 kj/mm, high heat input has two values of hardness 207HV and 216 HV for Ar-CO2-O2 (M3B) and Ar-CO2(M2B)blends respectively as shown in Table 5.1. Following the same trend, low heat input (LHI), 1.6 kj/mm, has 172HV and 180HV hardness for Ar-CO2- O2and Ar-CO2blends respectively. The conclusion can be drawn from the graph shown in Fig. that, high heat input using Ar-CO2blend as shielding gas results highest hardness value followed by Ar-CO2-O2blend keeping heat input constant. Low heat input using Ar-CO2-O2blend shows lowest hardness while with this input and double blend is on third place in descending order.

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 and Fig. Show the variation of tensile strength with welding parameters.

Effect of welding parameters on tensile strength

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



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.

CONCLUSIONS: -

This study helps in determining the changes in mechanical properties 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 properties. However, grater effect of shielding gas is analyze which again affect the mechanical properties. A comparison is established between achieved properties at different selected parameters.

The following conclusions are derived from the current study:

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.

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.