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A Study of Microstructure and Hardness in AISI 50110 (EN 31) Welded Joints Using Gas Metal Arc (GMAW) Welding

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Abstract

In this research paper, we focus on the study of MIG (GMAW) welding process for study of micro structure and effect of heat on hardness of base metal, weld bead and HAZ by welding of EN 31. In this present research paper an electrode of 308 having diameter 1.2 mm was used with direct current electrode positive polarity. CO_2 was employed for shielding purposes. The shape of the fusion zone depends upon a number of parameters such as gas flow rate, voltage, travel speed and wire feed rat. The dimensions of EN 31 are given as 320X160X10mm. Double – V butt joint was applied with 90°, two variables are decided current and voltage. In heat affected zone (HAZ) the value of hardness was found highest but the harness at weld-ment was found minimum. In order to understand the micro structural changes occurring in the weld zone is investigated through the optical microscopy. The hardness measurements were taken across the weld zone and HAZ.

Keywords: *GMAW, AISI 50110, EN 31, Microstructure, Hardness.*

1. Introduction

From 3000 or more years welding was done by hammering hot or cold metals to times was more of a casting of filler metal into joints than true soldering as we know today. This type of soldering is done with charcoal & blow pipe in 1330 B.C. In Bronze Age Small gold circular boxes were made by pressure welding lap joints together. During the Iron Age the Egyptians and people in the eastern Mediterranean area learned to weld pieces of iron together. Many tools were found which were made approximately 1000 B.C. During the middle Ages, the art of blacksmithing was developed and many items of iron were produced which were welded by hammering.

In 1881 carbon arc welding was discovered by Auguste De Mèritens. The process was carried out in a box with a fixed electrode. In 1885 carbon arc welding was discovered by N. Benardos & S. Olszewski. Carbon arc welding uses an arc between a carbon electrode and the weld pool. The process is used with/without shielding or application of pressure. In 1900 oxyacetylene welding was discovered by Charles Picard. An oxy-fuel gas welding process uses acetylene as the fuel gas without the application of pressure.

In 1903 E. Thomsan introduced first resistance butt welding machine. In 1907 shielded metal arc welding was discovered by Oscar Kjellberg. Shielded metal arc welding uses an arc between a covered electrode and the weld pool. The process is used with shielding from the deposition of the electrode covering without the application of pressure, and with filler metal from the electrode. In 1940 Gas Tungsten Arc Welding was discovered by Russel Meredith. Gas Tungsten arc welding uses an arc between a tungsten electrode (non consumable) and the weld pool. The process is used with shielding gas and without the application of pressure. Laser was introduced in 1964.

In 1948, GMAW was developed by Battelle Memorial Institute. It used a smaller diameter electrode and a constant voltage power source developed by H. E. Kennedy. It gave high deposition rate, but the high cost of inert gases limited its use to non-ferrous materials and prevented cost savings. In

1953, the use of carbon dioxide as a welding atmosphere was developed, and it quickly gained popularity in GMAW, since it made welding steel more economical. In 1958 and 1959, the short-arc variation of GMAW was released, which increased welding of thin materials possible while relying on smaller electrode wires and more advanced power supplies. It quickly became the most popular GMAW variation. The spray-arc transfer variation was developed in the early 1960s, when people added small amounts of oxygen to inert gases. More recently, pulsed current has been applied, giving rise to a new method called the pulsed spray-arc variation. GMAW is now one of the most popular welding methods, especially in industrial environments. It is used extensively by the sheet metal industry and by the automobile industry. [1]

2. MIG Welding (GMAW)

Gas–metal arc welding (GMAW) is a process that melts and joins metals by heating them with an arc established between a continuously fed wire electrodes. Shielding of the arc and the molten weld pool is done by using inert gases such as argon, carbon dioxide and helium, and this is why GMAW is also called the metal–inert gas (MIG) welding process. Both ferrous and non-ferrous metals can be welded easily; also it can weld large quantity of metals in short period of time without any need of skilled worker. A big advantage of this welding is that by a single machine large variety of metals can be weld; the only changes are done in the electrode wire and shielding gas. The equipment involve in the welding are power source, wire fed unit, welding gun, shielding gas, and a water cooling system if required. This method is different from TIG welding because in TIG welding a non-consumable wire is used but in MIG welding consumable wire is used. The wire is feed from the reel automatically and is run by a variable speed electric motor which is determined by the arc voltage, with an increase of voltage wire feed rate increases. This process is more efficient than TIG welding. In semiautomatic welding the welder guides the gun and adjusts process parameter.

3. Literature Survey

Many researchers have been done on different materials for obtaining maximum yield strength and tensile strength. In this research we will find out the maximum tensile strength and yield strength of SS202 (Stain less steel), by MIG welding.

A research work has been done by Ajit [8] on AISI 1040 medium carbon steel joints for finding its yield strength with the help of GMAW. The longitudinal yield strength is greater than the transverse yield strength. Response surface methodology (RSM) has been applied to study the MIG welding process parameters to attain the maximum yield strength of the joint.

Gautam kocher [9] perform welding on IS 2062 and E250 mild steel plates using CO 2 as shielding gas. Welding speed was selected as process variable while arc voltage, welding current, wire feed rate distance between the nozzle and the plates are fixed. The penetration area and wetting angle increases with increase in welds speed at constant wire speed rate and constant arc voltage and welding current and finally reaches to their maximum value and then both parameters again start increase with increase in the weld speed in the single pass weld.

An research was done on, effect of different parameters on welding penetration, micro structural and hardness measurement in mild steel by using robotic GMAW. Izzatul Aini Ibrahim [10] found that by increasing the welding current the depth of penetration increases, penetration also effected by welding speed and arc voltage. The grain boundaries of microstructure changes from bigger size to smallest size when the variables welding parameters changes.

A research was done on Magnesium and Aluminum alloy plates in lap form using the MIG process with zinc foil as the interlayer material. The zinc foil acted as a barrier layer that restrained reactions between the aluminum and magnesium atoms, and a crack-free lap joint of dissimilar materials was obtained. H.T. Zhang [11] found that the tensile strength of the lap joint was 64 MPa, and a fracture occurred at the interface between the fusion zone and the un-melted Magnesium and Aluminum alloy.

To study the effect of welding pulsed current on fatigue behaviour a research work has been done on Aluminum alloy AA7075. Filler material used for joining the plate was AA 5356 [AL–5Mg] grade aluminum alloy. V. Balasubramanian [12] found that pulsed current welding improves the fatigue resistance of the welded joints.

A study has been done on multiple quality characteristics optimization of metal inert gas (MIG) arc welding aluminum foam plates. The micro-hardness and the bending strength of the weld ments characteristics were investigated. The significant parameters selected were filler material, current, welding speed, gas flow rate, work-piece gap, arcing angle, groove angle, and electrode extension length. From the experimental results the three factors that have the greatest effect were current, speed, work-piece gap. Shih Jing-Shiang [13] found that the bending strength was 4.3260 Kgf and the hardness 1.4995 Kgf.

T. Senthil [14] studied the effect of pulsed current tungsten inert gas welding parameters on the tensile properties of AA 6061 aluminium alloy. From the experiments, it was found that increase in peak current and frequency result in increase of tensile strength. However, base current and pulse on time was having inversely proportional relationship with the tensile strength, if the base current was raised, then the tensile strength was decreased.

By taking 304L stainless steel a research has been done on the effect of hydrogen in argon as a shielding gas in MIG welding. Kaya Develi [15] found that the maximum tensile strength 610N/mm² comes out when the current value kept 240 amp and the shielding media consist of 1.5% H2–Ar, the best toughness comes out on 240amp and shielding media having 0.5 %H2 - Ar. It was found that increasing hydrogen content in argon as a shielding medium increased the penetration profile depth and width, size of the grains became larger with increasing heat input because of increasing hydrogen addition into the shielding media.

By using TIG and MIG welding a research has been done by LI Rui-fen [16] on Galvanized steel sheets using copper as a filler material. From the experiments, it was found that the joint zone hardness was higher than that of the base material or copper filler from the micro hardness tests of TIG brazing specimens, and the fracture spot was at the base materials zone from the tensile tests of MIG brazing specimens. The high joint strength obtained in this study was due to the formation and dispersal of inter-metallic compound Fe5Si3 (Cu) in the joint zone.

4. Problem Definition

As carbon steel has a wider application in the different types of industries and used in manufacturing of copious amount of spare parts, assemblies and machineries. So we choose EN 31 (IS-103 Cr1) as our base material.

Table 1 Base Metal Specifications

BS:970 EN:SPECN	IS	AISI/SAE
EN-31	103 Cr1	50110

Table 2 Chemical Composition of Base Metal

Chemical composition of base material EN31	
Element	**Percentage %**
Iron Fe	96.980
Carbon C	0.950
Silicon Si	0.176
Manganese Mn	0.456
Sulphur S	0.048
Phosphorus P	0.035
Nickel Ni	0.043
Chromium Cr	1.000
Molybdenum Mo	0.029
Aluminum Al	<0.010
Copper Cu	0.259
Titanium	<0.005
Niobium	<0.010
Cobalt	<0.010
Boron	<0.001
Lead	<0.010
Vanadium	<0.010
Zirconium	<0.006

According different norms and standards, the base material has identical names. The carbon content of EN31 material can vary from 0.90 % to 1.20 % where as Manganese 0.30 % to 0.75 %, Silicon 0.15 % to 0.35 %, Chromium 1.00% to 1.60%, Sulphur content is limited to 0.04% maximum and Phosphorus up to maximum limit of 0.04 %. The remaining percentage of the composition is iron (Fe). In order to obtain a strong bonded joint the properties of the base metal and the welding wire must comply with each other. The type of material of welding wire total depends upon the material that is required to be welded.

EN 31 is use in Ball and Roller Bearings, Spinning tools, Beading Rolls, Punches and Dies. By its character this type of steel has high resisting nature against wear and can be used for components which are subjected to severe abrasion, wear or high surface loading.

5. Objectives

(i) To identify the significant process parameters for base material EN 31.
(ii) To study the hardness and microstructure of the base materials, heat affected zone (HAZ) and weldment.
(iii) To study the effect of variable welding parameters on response.
(iv) Optimizing the process parameters for maximum response value.
(v) Verification of result.
(vi) To study the chemical composition of welded joint.
(vii) To study the effect of various welding parameters on these properties

6. Experimental Setup

6.1 Start up Procedure

Stainless steel is used in all type of industries for example in automobile, utensils, refrigeration air conditioning and others public sector units. In this research, plates of AISI 50110 (EN31) having dimensions 310mm length, 160mm width, 10mm thickness has been used as a work piece material. EN31 is continuously used in automobile industries, aircraft industries, pipes and pipes fitting so far no research has been done on joining SS202 by using GMAW process.

6.2 Selection of Welding Process

By MIG welding any type of metal can be welded and for stainless steel mostly MIG and TIG welding are used but we adopted MIG welding. The optimization of process parameter is one of the research areas in welding. Due to high range of process parameters MIG welding is chosen most material processing. The welding current in depend on the wire feed rate and welding speed. By increasing the welding speed the deposition rate can be reduced.

6.3 Selection of Parameters

There are many parameters which affect the response in output. These parameters are as follows:

A. Arc voltage
B. Welding current
C. Welding speed
D. Gas flow rate
E. Electrode diameter
F. Nozzle to work out distance
G. Wire feed rate
H. Electrode stick out
I. Welding position
J. Electrode to work angle

7. Results and Conclusion

The plate of AISI 50110 (EN31) High carbon steel was welded and the specimens for testing the tensile strength, yield strength, hardness were prepared. The samples were of rectangular bar type having 19.36 mm width 9.1 mm thickness and 10 mm gauge length and the area was 176.18 mm2. The weld quality depends upon many factors such as welding speed, arc voltage, welding current ,welding speed and most important on the quality of the welder. These factors can affect the penetration of the weld and weld bead. The pictures of test specimens after performing the tests are shown in Figure 1 below:

Fig. 1 Test specimens after various mechanical testing

Different type of testing such as hardness, microstructure, chemical testing are done on prepared test samples.

7.1 Micro Test (Microstructure)

The microstructure of the welded joint thus obtained from joining of two similar plates of EN31 steel were studied at a magnification scale of 400X. The microstructure of the base metal shows uniform structure pattern of δ - ferrite in austenite matrix. The grain shape of the base material was in the pentagonal shape as shown in Figure 3

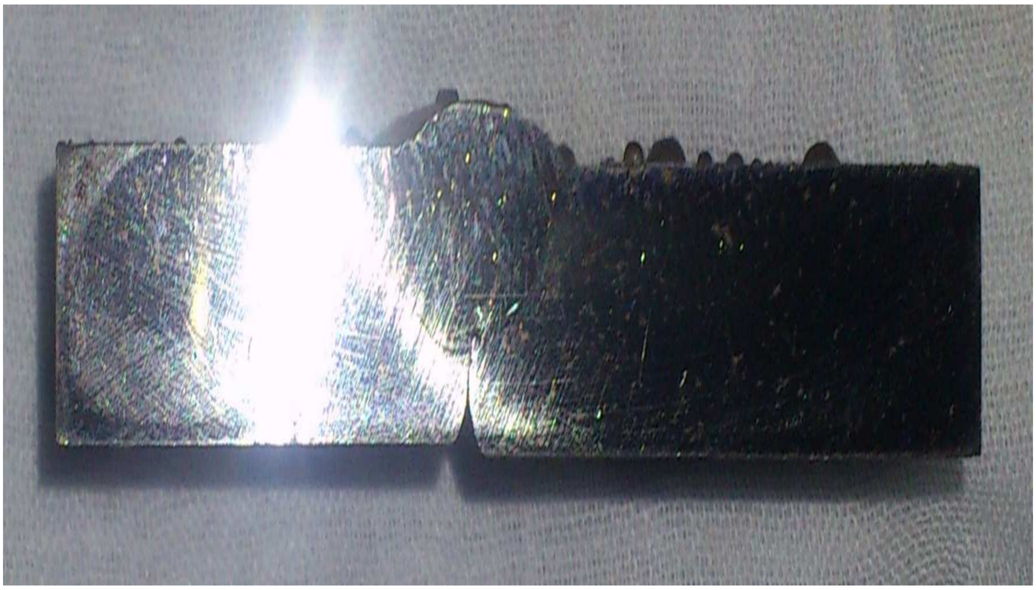

Fig. 2 Test specimen prepared for Microstructure test

And the microstructure of heat affected zone shows partially elongated δ - ferrite grains in austenite matrix. The microstructure of the test specimen at optimal combination of process variables arc voltage and welding current of HAZ is shown in Figure 4

Due to fine grains size in heat affected zone the hardness is highest there. For transverse testing, the test specimens were cut at an angle of 90 weld bead of the joint at center. And test specimen also have base metal on the both ends. The test specimen was broken away from the weld joint of base material end, but not from the middle of joint.

The microstructure of the weld metal shows no uniform structure pattern of δ - ferrite in austenite matrix as shown in Figure 5

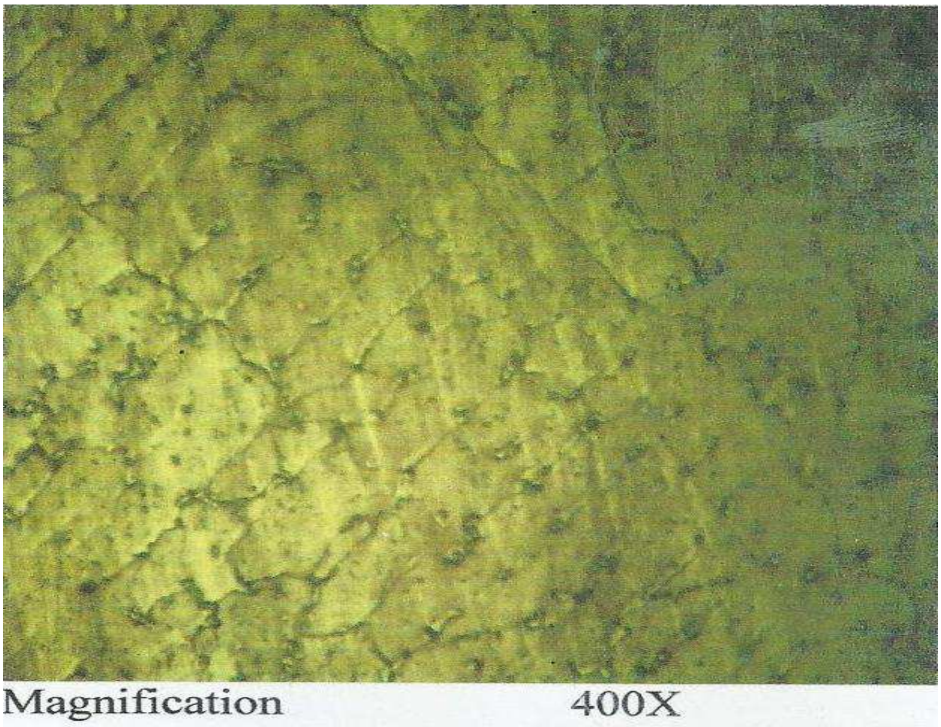

Fig. 3 Microstructure of base material (Report no. 1308020285)

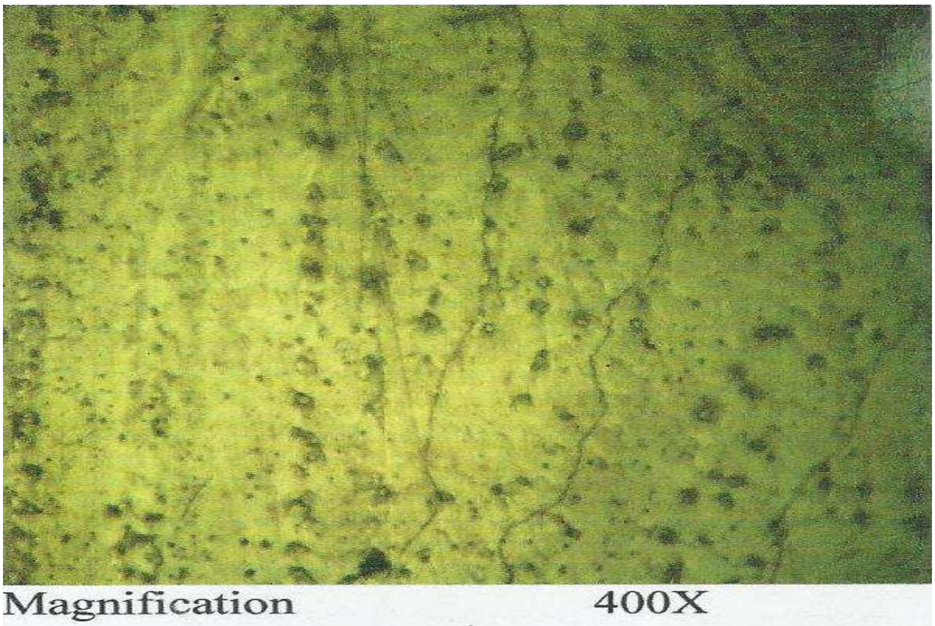

Fig. 4 Microstructure of heat effected zone (Report no. 1308020288)

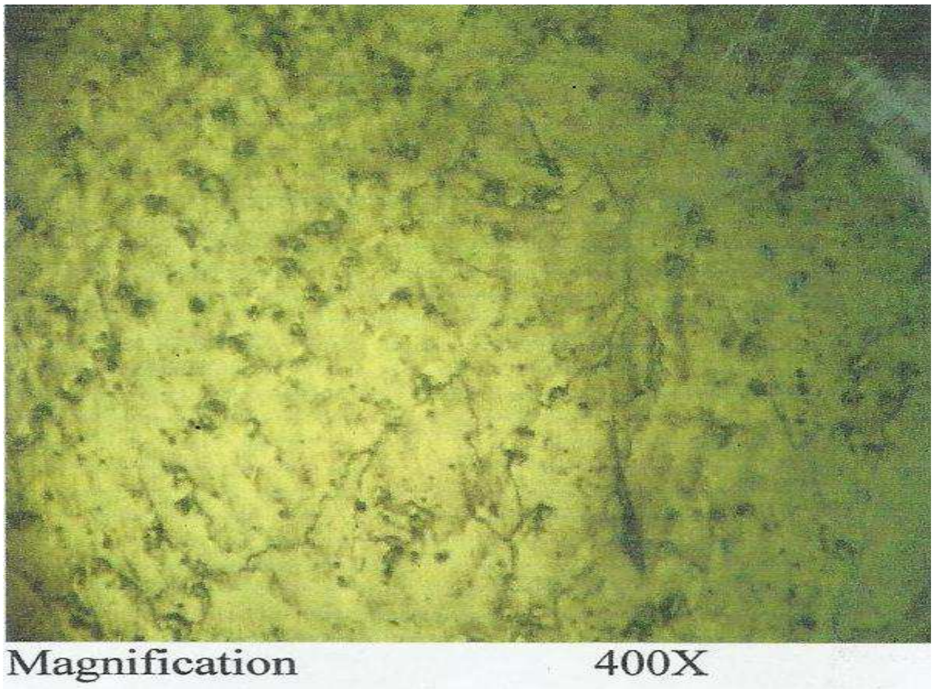

Fig. 5 Microstructure of weld bead (Report no. 1308020287)

7.2 Hardness

The test samples from all the 10 run were subjected to Vickers Hardness testing machine for hardness testing. The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf.

Fig. 6 Test specimen prepared for Hardness test

Table 3 Design Matrix of Hardness for RSM

Run No.	Factor 1	Factor 1	Response 1		
	A Arc Voltage (V)	B Welding Current (A)	Vicker Hardness A-scale (HV 10)		
			P.M.	H.A.Z.	Weld
1	28.7	225	314	391	238
2	31.0	225	281	471	244
3	28.7	255	269	491	239
4	33.3	225	282	481	235
5	31.0	225	281	471	244
6	31.0	255	271	528	236
7	33.3	255	280	493	244
8	33.3	195	262	470	233
9	28.7	195	282	526	254
10	31.0	195	273	467	250

The full load is normally applied for 10 to 15 seconds. Six readings of hardness were taken at three phases of samples: parent metal, heat affected zone and weldment. Then the final reading was the mean value of the hardness at each phase shown in Table 3. The scale of hardness was A-Scale and hence designated by HV 10.

8. Final words and Future work

The similar weld joint of EN31 material was developed effectively with MIG welding with selected range of input variable parameters. So, MIG welding procedure is effective welding procedure for obtaining good grain strength, in EN31 steel. Further it was found that out of selected variable process parameters: arc voltage and welding current, arc voltage was the parameter which affects the hardness of EN31 weld joints at most.

In future work, we can take remaining constant variable like wire feed rate, gas flow rate, electrode stick out welding position, welding speed etc. as process variable parameters and can study and evaluate their effect on tensile strength of the EN31. We can also study and optimizes the tensile strength in future work.

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