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Experimental Investigation and Hardness Analysis of Chromoly Steel Multipass Welds Using GMAW

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Abstract**—**This work presents the result of investigations aimed at determining the hardness of the welded Chromoly (A 4130) steel plate of 2” thickness. Multi pass welding for the thick sections was carried out and analyzed for the Chromoly alloy steel plates. The study of hardness at the weld metal reveals that there is the presence of different micro structure products which yields diverse properties. The welding carried out using GMAW with ER70s-2 electrode. Single V groove design was selected for the butt joint configuration. The presence of hydrogen has been suppressed by selecting low hydrogen electrode. Preheating of the plate prior to welding reduces the cooling rate which also affects the weld metal microstructure. The shielding gas composition used in this analysis is 80% Ar-20% CO_2. The experimental analysis gives the detailed study of the hardness of the material.

Keywords**—**Chromoly, Gas Metal Arc Weld (GMAW), Hardness, Multi pass weld, Shielding gas composition.

I. Introduction

THE metal is welded using Gas metal arc welding process with solid or flux core welding wires. With different shielding gas composition then there will be change in the material properties, characteristics and microstructure of the given metal [1]. The characteristics of gas metal arc welding (GMAW) process are high productivity, applicability for a wide range of base metal thickness in all positions of welding [2]. In this process due to the requirement of higher deposition rate and better wetting we replaced the traditional solid wire by the flux-cored or metal core wire due to its advantage [3], [4]. To protect the weld pool and molten droplet transferred across the arc, we use shielding gas for the process. In addition, it should promote a stable arc, desired mode of metal transfer and weld bead characteristics. Traditionally, CO_2 is used as a shielding gas due to its reduced price, but its usage has been limited because of the problem of spatter, oxidation losses and poor all-position performance [2]. On the other hand Argon alone is unsuitable for welding chromoly as it cannot obtain the desire arc stability and desired weld bead characteristics [3]. Therefore argon mixed with CO_2 is being preferred as a shielding gas for arc stability, mode of metal transfer, weld bead etc.

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During welding the shielding gas interacts with the weld pool and the addition of CO_2 in argon causes oxidation, which results in loses of alloy constituents and produce inclusions in the weld [5]. In general the presence of inclusions is detrimental to weld properties. However under given set of conditions certain *oxide* inclusions promote the formation of an acicular ferrite face which improves toughness [6], [7]. On the other hand the presence of a very high volume fraction of inclusions may initiate premature ductile fracture [8].

Thus the quality, efficiency and overall operating acceptance of the GMAW process are strongly dependent on the shielding gas composition. Although both sold and flux core wires are widely used, there are few published investigations of the influence of shielding gas composition on the weld metal microstructure and mechanical properties of chromoly [9], [10]. This investigation aims to study the effect of mechanical properties of the material after multipass welding is done by GMAW.

II. Experimental Procedures

A. Test Panel

The size of the test panel is 12” long, 6” width, 2” thickness. The panel was fabricated from chromoly steel. Two sets of test panel of the same size and morphology were made, as shown in Fig. 1, and were welded in multi layers, as shown in Fig. 2.

Fig. 1 GMAW Feeder

B. Machine Setup

GMAW machine consist of power source, wire feeder, gas cylinder and automatic feeding table. First the electrode wire is installed in the wire feeder and it should pass into the torch without affecting spring in it. Then connect the shielding gas in the machine it will flow through the torch. Apply the feed rate, voltage and pinch as per requirement of the experiment. Then proceed for welding process.

Fig. 2 Work Piece in Mid Phase

TABLE I
WELDING PARAMETERS

Pass no	Current (A)	Voltage (V)	Travel Speed (cpm)
1	180	42	192
2	192	42	192
3	194	41	192
4	208	38	192
5	212	39	192
6	202	39	192
7	189	40.1	190
8	188	40.2	190
9	187	40	190
10	194	40	190
11	180	40.1	190
12	180	40.5	190
13	160	41.3	190
14	169	42	190
15	196	39.8	170
16	225	38.3	130
17	230	38.4	130
18	232	38.7	130
19	247	38.8	100
20	250	38.7	100

C. Welding

Our work piece is placed on a plate which is kept on the automatic feeder plate and the torch is fixed on the holder at the distance of 25mm from the place going to be welded. The work clamp in the machine which gives ground connection should hold the work piece in the part. The torch should be hold in right position to minimize the spattering. The electrode should be held in straight position for straight weld bead form in the v groove.

D. Shielding Gas

The effect of shielding gas in the welding is also analyzed during the process. The inappropriate choosing of welding gas for the material will cause spatter and slag formation in the welding process will happen. When using 50% argon and 50% carbon-di-oxide it will produce more spattering due to the gas and metal properties. For this metal we choose 85% Argon and 15% CO_2 to reduce the spattering, increase the weld penetration suitable for thicker plates. By keeping nominal pressure required for experiment is kept for good results.

E. Hardness Testing

To check the hardness of the weld we have done the testing in Rockwell hardness method to identify the weld quality of the material. After we had finished the welding, the work piece was placed for Rockwell hardness in that point where we can check the hardness of the material. By selecting five major points in the hardness test we got the result by analyzing the five points around the major ones to minimize the error in the readings. The hardness values are shown in the table.

TABLE II
WELDING SPECIFICATIONS

Welding Process	GMAW
Welding Position	“v groove”
Filler Metal Specification	ER70s-2
Shielding Gas	85%Ar – 15% CO_2
Electrode extension	25-30
Polarity	DCRP
Preheating/Interpose Temperature	150º C

TABLE III
CHEMICAL COMPOSITION OF BASE METAL 4130

Element	Content %
Iron, Fe	97.03-98.22
Chromium, Cr	0.80-1.10
Manganese, Mn	0.40-0.80
Carbon, C	0.280-0.330
Molybdenum, MO	0.15-0.25
Sulphur, S	0.040
Phosphorous, P	0.035
Silicon, Si	0.15-0.30

TABLE IV
CHEMICAL COMPOSITION OF ER70S-2:

Element	Content %
Silicon, Si	0.45-0.7
Manganese, Mn	0.9-1.4
Titanium, Ti	0.05-0.15
Aluminum, Al	0.05-0.15
Phosphorus, P	0.025
Carbon, C	0.150
Sulphur, S	0.035
Zirconium,Zr	0.02-0.12

Fig. 3 GMAW Welding Apparatus

TABLE V
RESULT OF ROCKWELL HARDNESS TEST

POINTS	Observed Rockwell Hardness Values					Average
A	56.0	61.0	54.0	52.0	52.0	57.80 HRA
B	68	70	57	61	66	64.40 HRA
C	54	51	58	54	52	53.80 HRA
D	61	57	52	55	54	55.80 HRA
E	65	61	67	55	62	62.00 HRA

III. RESULT AND DISCUSSION

The hardness result shows the strength of the metal in the heat affected zone and in the welded area. The hardness value change on the base metal is due to the multipass welding in the v groove. Due to multipass welding each time when the pass was formed the previous weld pass and the metal will change in the internal structure due to this the hardness value will change in the metal in various places. To improve mechanical properties of the material we have done a multipass welding on them. We have taken hardness value for four points in the same axis on the top of the material and the point in the bottom center of the v groove presented in the material. First the left side of the base metal had the hardness of 64.40 HRA where the hardness in the other side of the material was 62.20 HRA. Comparing the hardness values of the base metal averagely it has a same value around 63 HRA. The Hardness value in the v groove of the metal was tested in three different points in the material. Due to the multipass welding it shows different hardness values in the area of welding on the v groove. In this area, when the welding process take place due to multipass purpose each time the welding take place the existing welding will be suffer to heating and deformation will take place in some area where the surface base metal which the pass has been performed will be affected by the heat, it is called as heat affected zone in the material. First the hardness value in the bottom of the welded metal can be considered by testing hardness in the place it shows about 57.80 HRA by considering average of five places around the point in this some point has shown the value of hardness up to 61 HRA. The second point which is located top left side of the welded material has the hardness value about 53.80 HRA where the value has been taken as an average around the point have been chosen. In this average point we have the highest value about 58 HRA. Another point situated in the top right side in the v groove in this point the hardness value has shown about 55.80 HRA by taking average of five points around it in that the highest value of hardness obtained is about 61 HRA. By analyzing all the hardness value in the welded points the highest was attained in the base metal where the lowest value was obtained in the v groove surface but the hardness didn't not differ as much from the base metal. It is varying about only by 18%. But in some parts of the v groove metal the values attained as same as the base metal. In this multipass welding we have to fill the v groove of the metal by 20 passes of welding during that time we maintained inererpass temperature around 150 degrees Celsius. After that by varying the feed rate we have done the welding on the v groove. By varying feed rate and interpass temperature we can eliminate or decrease the porous formation and slag formation on the weld on the v groove.

Fig. 4 Welding Process

IV. CONCLUSION

In the rectangular work piece we had taken the "v" groove for welding in the area and check the hardness and durability of weld. We filled the "v" groove area in the metal by multiple pass welding. During the multipass welding, after each weld the previous weld will be deformed and joint with the ast weld performed with the metal strongly so we can expect more hardness in the v groove surface and solid structure without forming any slag or porous formation. By testing the hardness of the base metal and welded v groove surface in the metal the hardness value of the base metal is around 64 HRA where the v groove surface has around 52 HRA so we can say the hardness value around the metal is averagely around 56 HRA. So we can use the metal with weld in the high tension and strain areas.

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