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STUDIES ON THE EFFECTS OF OXIDATION AND ITS REPRESSION IN MAG WELDING PROCESS

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ABSTRACT

This article highlights repression of oxidation tendency of CO_2 in MAG welding. The results conclude that deoxidizers (Mn, Si and Al) used in the electrodes have suppressed the oxidation of alloying elements in both the electrode and base metal. The resistance to hot cracking has been improved due to the reduction of S and P.

Keywords: MAG welding, oxidation, repression

INTRODUCTION

Metal active gas (MAG) welding is a variation of the standard metal inert gas (MIG) welding process. In MAG welding process the active gas is carbon dioxide (CO_2) which acts as a shielding gas. MAG welding overcomes the restriction of using small lengths of electrodes as in manual metal - arc welding and sub dues the inability of the submerged are welding process to weld in various positions [1].

The effects of shielding of CO_2 to carbon and low alloy steels have been examined by several investigators. Under welding conditions, CO_2 decomposes into carbon monoxide and oxygen and becomes oxidising in the arc. The molecular oxygen further changes to atomic form in the weld zone. The atomic oxygen being very active may react with the base metal and other alloying elements as well as with the elements of electrode. Such reactions in the weld bead produce oxides and pin/blow holes that subsequently affect the mechanical properties of weld joints. According to Jilong and Apps, the use of CO_2 shielding produces an aggressive and violent arc [2]. Reddy et al [3] have concluded that the effect CO_2 shielding was equivalent to that of a gas mixture of 90 % argon and 10 % oxygen.

In the MAG welding process, the metal transfer from the electrode tip to the weld pool across the arc is either globular, spray type or short-circuiting type depending upon many factors, which are enlisted as follows:

- The magnitude of welding current
- Shielding gas
- Current density
- Electrode extension and
- Electrode chemistry

With CO_2 shielding, the globular and non-axial, whatever may be the value of the welding current, current density and other factors [4]. Hence there is considerable spatter. Drops become smaller in size as the current increases and they continue to be directed axially and non-axially. Axial transfer means that the metal droplets move along a line that is an extension of the longitudinal axis of the electrode. Non-axial transfer means that the droplets are hurled in any other directions. The non-axial transfer is caused by electromagnetic repulsive force acting on the bottom of the molten drop.
The objectives of the present work were to study the oxidation effect of CO_2 on the weld chemistry and on the all -weld properties and to suppress (repress) the oxidation tendency of CO_2 using deoxidisers.

2. EXPERIMENTAL SET UP

The MAG welding was carried on mild steel plates. The electrodes were of mild steel and low alloy steel. The chemical composition of base plates and electrodes is given in Table - 1. The shielding gas was CO_2.

Table - 1: Chemical Analysis of base metal and electrodes

Constituent	Base Metal	Mild Steel Electrode	Low Alloy Steel Electrode
C	0.080	0.092	0.084
Mn	0.920	1.500	1.620
Si	0.300	0.630	0.770
P	0.040	0.021	0.014
S	0.050	0.017	0.018
O2	0.035	0.009	0.014
Cr.	-	-	0.280
Mo	-	-	0.300
Ni	-	-	1.370
V	-	-	0.086
Cu	-	-	0.015
AI	-	-	0.096
Fe	Remainder	Remainder	Remainder

The welding equipment consists of a DC power source, a wire feeder, a shielding gas supply, a welding gun and controls for governing wire drive, current, gas flow and cooling water. The power source is a constant voltage welding rectifier giving DC, The wire feeder pulls the wire electrode from a reel and pushes it through the welding gun at required speed. As the wire passes through the gun, it picks up electric current from the copper contact tube, which is electrically connected to the power source, and makes an arc with fee work piece. The gun is cooled by water circulation system. Controls are provided to start and stop the water circulation automatically during the welding operation. The pressure and flow of the shielding gas (CO2) to the welding gun is controlled by using gas pressure regulator and a flow meter respectively.

MAG welding was performed using mild steel and low alloy electrodes on the mild steel plates having thickness of 5 mm. The welding parameters are given in Table - 2. Tensile test and impact test specimens were prepared from all - weld metal. The specimens were prepared by machining a groove in a plate of mild steel and then completely filling the groove with deposited weld metal. The surrounding mild steel was then machined away leaving the specimens of weld metal. The weld beads were also analyzed for chemical composition and degree of penetration. All –weld properties (viz. Tensile strength, yield strength, % elongation, % reduction in area and impact strength) were determined..

In order to understand the interrelationship between process variables and weld bead penetration, the stereo-microscope with image magnification of 30X was used to accurately measure the bead penetration on the etched of specimens. Figure 1 defines the bead penetration studied.

Table - 2: Welding Parameters

Parameter	Quantity
Welding Current, amp	280
Wire diameter, mm	1.2
Wire - fee speed, mm/sec	146.5
Melting rate, kg/hr	4.66
Arc travel speed, mm/sec	5.0
Electrode extension, mm	21.0
Gas-feed rate, l/min	15
Electrode to workpiece angle, degrees	85
Position	Flat

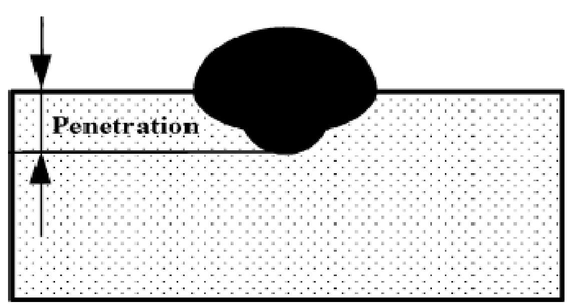

Figure 1: A schematic diagram for bead penetration.

3. RESULTS AND DISCUSSION

Totally six experiments with different electrode and shielding gas combinations were performed and the depth of penetration was measured for all cases.

3.1. Behaviour of CO_2 in the arc

During the welding operation when CO_2 was exposed to the high temperature of the electric arc, it decomposed into carbon monoxide (CO) and oxygen.

$$2\,CO_2 \xrightarrow{\text{heat}} 2CO + O_2$$

Further, the free molecular oxygen was splinted into atomic form due to the intense heat of arc.

$$O_2 \xrightarrow{\text{heat}} 2O$$

The nascent oxygen so produced was extremely active and it might react with iron and the alloying elements of electrode and base metal.

$$Fe + O \rightarrow FeO$$

$$C + O \rightarrow CO$$

$$Mn + O \rightarrow MnO$$

$$Si + 2O \rightarrow SiO_2$$

$$2Al + 3O \rightarrow Al_2O_3$$

$$S + 2O \rightarrow SO_2$$

$$4P + 6O \rightarrow P_4O_6$$

$$Cu + O \rightarrow CuO$$

Molten iron could also react with CO_2 producing iron oxide and carbon monoxide in a reversible reaction.

$$Fe + CO_2 \leftrightarrow FeO + CO$$

$$CO \leftrightarrow C + O$$

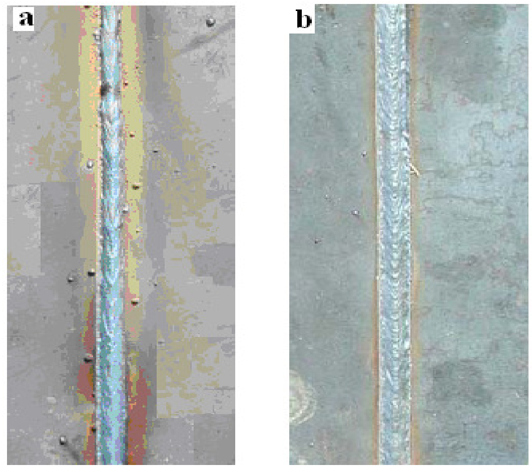

Figure 2: Appearance of weld bead carried with different electrodes (a) mild steel and (b) low-alloy steel

Carbon monoxide might dissociate further into carbon and oxygen. This carbon would dissolve into the weld metal to increase its carbon content. During welding, the spatter particles were spread over a distance of 150 to 200mm. The scattering of small metal droplets away from the electrode was resulted due to the formation of CO bubbles and subsequent growing and eventual bursting of gas bubbles (figure 2a).

The appearances of weld beads under CO_2 blanket is shown in figure 2. The mode of metal transfer was globular. Small glassy scales, which proved to be deposits left by deoxidising elements in the electrode wire, were also revealed along the edges. The welding with mild steel electrode has excessive amount of spatter and undercut (figure 2a). On the other hand, specimens (figure 2b) are free of spatter and undercut. Specimen welded with mild steel electrode having 1.5 millimeters gap distance has penetration of 2.75 millimeters (figure 3a). Specimen welded with low ally steel electrode having 1.5 millimeters gap distance has penetration of 3.04 millimeters (figure 3b).

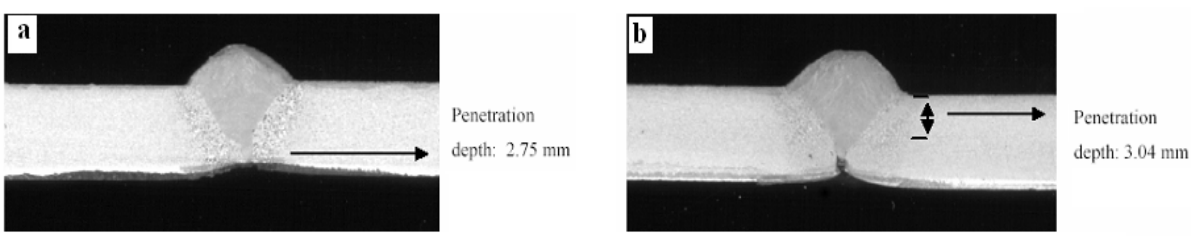

Figure 3: Penetration of weld material (a) mild steel and (b) Low alloy steel electrodes

3.2. Repression of Oxidation

To suppress oxidation effect of CO_2 and to ensure porosity free welds, the electrodes were chosen such a way that the electrode wire should contain the appropriate amount of deoxidisers like Mn, Si and Al. These deoxidisers might have inhibited the oxidation and reduced the oxides by the following reactions:

$$FeO \quad + \quad Mn \quad \longrightarrow \quad Fe \quad + \quad MnO$$

$$2FeO + Si \longrightarrow 2Fe + SiO_2$$

$$3FeO + 2Al \longrightarrow 3Fe + Al_2O_3$$

Oxygen could have reacted with deoxidising elements in preference to iron and carbon. These reactions resulted in a solid material (oxides of Mn, Si and Al) that floated onto the weld bead surface instead of a gas that could form porosity. The iron was also saved due to the oxidation of deoxidisers. The chemical analysis of undiluted weld bead is given in Table - 3. It can be observed that there is a considerable repression of oxidation tendency of CO_2 due to the oxidation of deoxidisers. The amount of oxygen in the undiluted weld produced by low - alloy steel electrode was low. This is owing to the oxidation of Mn, Si and Al, It is important to point out that the alloying elements Cr, Ni, Mo in low – alloy steel electrode were not affected by the oxidising atmosphere of CO_2 gas.

Table 3: Chemical analysis of undiluted weld bead

Constituent	Mild Steel Electrode	Low Alloy Steel Electrode
C	0.100	0.079
Mn	0.950	0.960
Si	0.500	0.360
P	0.018	0.013
S	0.012	0.010
0_2	0.045	0.0.12
Cr.	-	0.780
Mo	-	0.300
Ni	-	1.360
V	-	0.086
Cu	-	0.012
AI	-	0.008
Fe	Remainder	Remainder

CO_2 gas shielding has promoted greater hot - cracking resistance in weld beads. This is attributed to the reduction of phosphorous and sulphur in the deposited weld metal by the oxidation during welding. All - weld metal properties are given in the Table - 4. The tensile and yield strengths are higher with low alloy steel electrodes. This is mainly due to low oxygen content in the deposited weld metal.

Table 4: All-weld metal Properties

Constituent	Mild Steel Electrode	Low-Alloy Steel Electrode
Tensile Strength, N/mm^2	530	708
Yield strength, N/mm^2	411	625
% elongation	27.5	18.4
Impact strength, J	60	44
% Reduction in area	70	69

4. CONCLUSION

To achieve the desired reduction and to restrict oxidation by the CO_2 shielding gas, it is essential to use deoxidisers like Mn, Si and AL in the electrode wires for welding of mild steel. All weld metal properties have been improved by reducing loss of alloying elements and preventing gas porosity in the weld beads. Co_2 shielding provides deeper penetration. The oxidation of phosphorous and sulphur in the weld bead promotes hot-cracking resistance.

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