

# A Review of Effect of Shielding Gases Mixture on Welded Joint Properties of Low Carbon Steel in Mig/Mag Welding Process



## Engineering

**KEYWORDS :** MIG/MAG process, shielding gas, mechanical properties, inclusion and microstructure

**Nischal Chhabra**

Department of Mechanical Engineering, DAV University, Sarmastpur, Jalandhr

**Vipan Bansal**

Department of Mechanical Engineering, DAV University, Sarmastpur, Jalandhr

### ABSTRACT

*MIG/MAG process is widely used for fabrication of wide variety of materials. This process is widely used because it can be applied for all welding positions. Industries as well as researchers are engaged to improve the properties and quality of the welded joint. The selection of the shielding gas is a very typical work because it effect the mode of metal transfer, inclusion volume, melting rate of electrode, current setting etc. Lot of research work has been done regarding the effect of shielding gases on the welded joint characteristics on the MIG/MAG process. Based on the study of various works, the present paper provides a review of the effect of Ar+CO<sub>2</sub> and Ar+CO<sub>2</sub>+O<sub>2</sub> (with different quantities) on the mechanical properties, inclusion and microstructure.*

### 1. Introduction

MIG/MAG welding process is a welding process that used to join by heating with an arc between continuous filler metal electrode and the work piece. A protection to the welding pool and arc is provided by shielding gases [7].

The welding operation quality, efficiency and overall operating acceptance are dependent on the shielding gases and its mixture, since it controls the mode of metal transfer. The shielding gas controls the size of the weld beam and depth of penetration. The shielding gas also controls the residual contents of hydrogen, nitrogen and oxygen dissolved in the weld metal [8].

Various methods are adopted such as gas, slag, combination of gas and slag, vacuum and self-protection can be used to protect the weld pool and arc during the fusion welding. Obviously, different protection methods provide different degrees of weld pool protection [5].

The selection of shielding gas and its mixture depends on the kind of material to be welded. During the selection of shielding gas, a due attention should be given to chemical-metallurgical processes

between the gases and the molten pool that occur during welding [1].

When the welding current value is increased, then it increases the depth of penetration. Although, arc voltage and welding speed are also the parameters which control depth of penetration [2].

From the earlier study with MIG / MAG welding process, it realised that the penetration depth increased when the welding current value is increased but reduced with decrease in voltage and the penetration increased when arc travel rate decreased until it attained a minimum value depends on the arc power [4].

The neural network is a method that can be used as an alternative way for calculating the gas mixture according to the presented conventional calculation method. Gas mixtures (such as Ar, O<sub>2</sub> and CO<sub>2</sub>) were used in the input layer and, tensile strength, impact strength and elongation of the weld metal hardness were used in the output layer [6].

The experimental results showed that if activating flux is used in GMA welding process then it increases the weld area and penetration and tended to decrease the angular distortion of the weldment. The MgCO<sub>3</sub> has given the remarkable effect. Furthermore, the joint presented better tensile strength and hardness [3].

A number of researchers have worked in this area and the present paper provides a review on the effect of mixture shielding gases on the welded joint properties after study of various research works performed in the field. An effect of shielding gas mixture (Ar+CO<sub>2</sub>+O<sub>2</sub>)

on HSLA steel regulates the inclusion characteristics, microstructure and mechanical properties. The influence of variation in the shielding gas mixture (Ar + CO<sub>2</sub>) on the weld joint properties of the steel ST 37-2 was investigated. The compositions of the test materials are presented in the table 1. Four shielding gas compositions were 97.5% Ar + 2.5% CO<sub>2</sub>, 90% Ar + 10% CO<sub>2</sub>, 82% Ar + 18% CO<sub>2</sub>, 75% Ar + 25% CO<sub>2</sub> used for ST 37-2 material. For HSLA steel the composition of the shielding gas was 80% Ar + 18% CO<sub>2</sub> +2%O<sub>2</sub>, 80% Ar + 17% CO<sub>2</sub> +3%O<sub>2</sub>, 80% Ar + 16% CO<sub>2</sub> +4%O<sub>2</sub>, 80% Ar + 15% CO<sub>2</sub> +5%O<sub>2</sub>. For both of the base metal materials, ER70 S-6 filler metal was used whose composition is given in table 2.

**Table 1 Composition of test materials**

Designation	Chemical Composition, max wt%					
	C	Mn	P	S	Si	Fe
ST 37-2	0.113	0.417	0.007	0.01	0.024	Bal
HSLA	0.14	1.33	0.026	0.005	0.44	Bal

**Table 2 Chemical compositions of ER 70S-6**

Designation	Chemical Composition, max wt%				
	%C	%Mn	%Si	%P	%S
ER 70S-6	0.06-0.15	1.40-1.85	0.80-1.15	0.025 max	0 . 0 3 5 max

**Table 3 Chemical compositions of ER 70S-6 (Continuous)**

Designation	Chemical Composition, max wt%				
	%Ni	%Cr	Mo	V	Cu
ER 70S-6	0.15 max	0.15 max	0.15 max	0 . 0 3 max	0.5 max

For welding of ST 37-2, shielding gas flow rate was set steadily at 10 L/min. The welding was performed in constant voltage mode with automatic wire feeding. During welding, welding voltage, welding current and arc travel speed were 20 V, 180 A, 30 cm/min respectively.

### 2. CO<sub>2</sub> effect in the shielding gas on the weld metal toughness

In accordance with the fig 1, toughness of the specimen first increases for both of the temperature and then remains stable at room temperature but there is a minor decrease in value at -10°C. The variation in the absorbed energy by the specimen corresponds to the microstructure and inclusion and porosity in the weld metal.

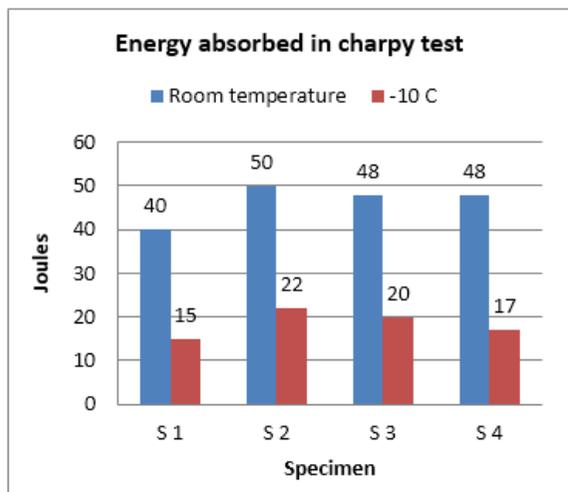


Fig 1 Charpy absorbed energy

Oxide inclusions promote accicular ferrite formation and it is the reason which leads to improvement for the toughness of the material. The energy absorbing capacity of the specimen increases with the increase of volume fraction of accicular ferrite in the weld metal. There are three types of phase structures were found namely accicular ferrite (AF), widmanstatten ferrite (WF) and polygonal ferrite (PF). Out of these, AF has the higher toughness. The accicular ferrite interlocking nature together with its fine grain size gives the maximum resistance to crack propagation by cleavage. Increasing of CO<sub>2</sub> tend to decrease in the amount of inclusion which compensates the effect of decreasing of the accicular ferrite.

3. CO<sub>2</sub> effect in the shielding gas on micro hardness

Fig 2 shows that Heat affected zone (HAZ) for all the Specimens have higher toughness in the in comparison to fusion zone (FZ) and base metal. As the percentage of the CO<sub>2</sub> increased, the value of micro hardness decreased successively. Specimen numbered 1 has shown maximum hardness compared to Specimen numbered 2 and this trend was followed for the Specimen 3 and Specimen 4. Decrease in the value of hardness is due to lower amount accicular ferrite formation and more amount of WF and PF. As the percentage of CO<sub>2</sub> increased, it leads to lower amount of inclusion which can be the reason for lower hardness of fusion zone for specimen 3 and 4.

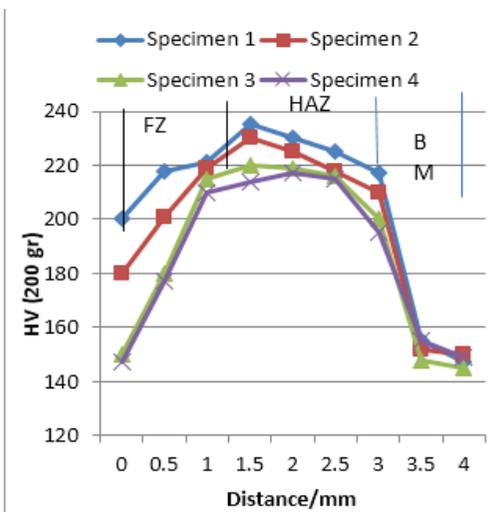


Fig 2 Variation of hardness across the cross section

4. CO<sub>2</sub> effect in the shielding gas on the weld pool shape

The picture of depth of weld pool illustrates that with the increase of CO<sub>2</sub> in the shielding gas, the depth of penetration increases with the increase of carbon dioxide.

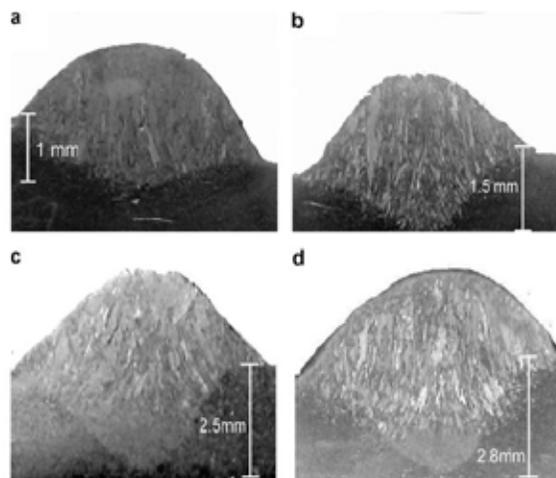


Fig 3 Cross-section of the weld pool specimens

Due to higher dissociation and ionization potential of the carbon dioxide in the shielding gas, the temperature of the arc increases.

5. CO<sub>2</sub> & O<sub>2</sub> effect in the shielding gas on inclusion

The unetched samples of micro graph, the black spot shows the inclusions and porosity. It decreases with increase of carbon dioxide in the shielding gas composition.

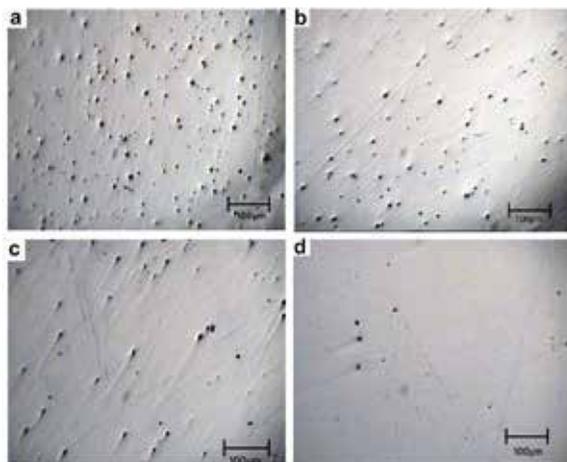
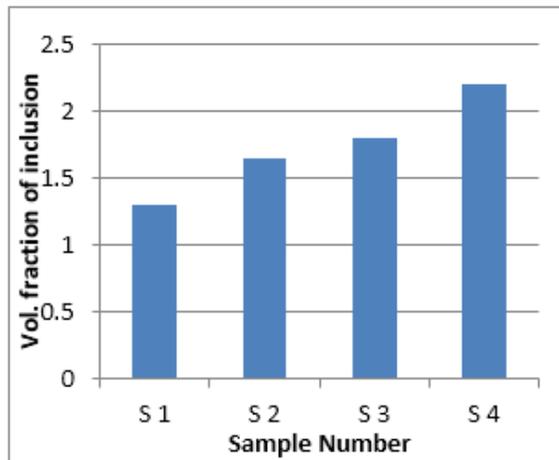


Fig 4 The amount of inclusion in four samples

The four samples which are welded by solid filler wire and whose volume fractions of inclusion are presented in the fig 5. The figure illustrates that with the increase of oxygen percentage in the shielding gas from 2% to 5%, the size of the inclusion increased from 0.4 to 0.8 μm and volume



**Fig 5 Volume fraction of inclusion in four samples**

fraction increased from 0.0012 to 0.0022. The varying levels of manganese, silicon, aluminium, titanium, etc. in the inclusions are evident. Increasing the oxygen activity of the shielding gas increased the weld metal shielding content, as represented by the volume fraction of inclusion. Since most of the oxygen will combine with other elements to form oxides due to its low solubility in iron.

#### 6. Shielding gas mixture effect on tensile properties of the weld

With increase of oxygen content (up to 5%) in the shielding gas, the yield strength of the weld metal progressively increased. Contrarily, Ultimate tensile strength (UTS) increased with increasing oxygen content up to 4% oxygen and then goes down with further increasing oxygen content. A similar pattern can be revealed for the toughness that when the oxygen content is increased up to 4% promotes toughness at both of the temperature and then its values falls at 5% oxygen content.

**Table 3 Mechanical properties of specimens**

Sample No.	YS MPa	UTS MPa	%EL	Charpy impact toughness (J)	
				At 27° C	At -30° C
S1	265	504	12	84	31
S2	277	543	14	87	32
S3	287	600	14	98	37
S4	289	567	10	88	31

YS and UTS increases with oxygen content increasing from 2% to 4% could be related to the increase in the proportion of Accicular ferrite due to its fine grain size and high dislocation density. However, a reduction in UTS and % elongation at 5% oxygen content, probably depicts that long ferrite veins acts as a preferential crack path through the microstructure

#### 7. Conclusion

In view of the results presented, the following points can be concluded

The value of toughness first increases and then remains constant with the increase in the amount of carbon dioxide in the shielding gas. The oxygen content has also increased the toughness but up to 4% oxygen and thereafter its value went down. Oxide inclusions considered to be the reasons for higher toughness because it promotes accicular ferrite.

- The weld metal micro hardness decreases with the increase of carbon dioxide content. Decrease in the value of micro hardness accompanied by the lower amount of accicular ferrite.
- The depth of penetration increases with the increase of carbon dioxide content and this is due to increase of temperature of an arc.
- Increase the content of oxygen increases the amount of inclusion but decreases with increase of carbon dioxide.
- Yield strength and UTS increases with increasing oxygen content from 2% to 4%. However, a decrease in UTS at 5% oxygen content.

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