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ANALYSIS OF THE ADDITION OF A NON-ENERGIZED WIRE UNDER GAS MIXED PROTECTION IN GAS METAL ARC WELDING (GMAW)

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Abstract. Nowadays, Gas Metal Arc Welding (GMAW), is widely used and one of the most important metal welding processes, characterized by continuous wire feed and shielding gas in the molten pool. In order to improve the conventional MAG (Metal Active Gas) welding process, a non-energized and shielded gaseous cold wire was added using a slave torch. The cold wire, also under gaseous protection, was added to the molten pool formed by the electric arc established by the energized wire fed by the main torch. The gas also influences on the transfer of the addition metal through the electric arc, as in its stability and the characteristic form of the weld bead. The metallic transfer mode is spraying metal, due the welding parameters and the slave torch position. For a behavioral analysis of the arc formed by both energized and cold wires and the influence of the respective mix of gasses in the molten pool, it was used synchronized filming, and data acquisition equipment receiving voltage and current signals. The results show stability of the electric arc and improvement in deposition rate and penetration profile when compared to the traditional process.

Keywords: Cold Wire, Gas Metal Arc Welding, Shielding Gas, Double Wire, CO₂, Active Gas

1. INTRODUCTION

In its broadest context, welding is a process in which similar materials or non-similar materials are joined by chemical interaction and/or plastic deformation under pressure action, heat action or the combined action of heat and pressure (Messler, 1993).

During the evolution of manufacturing processes, overall, the technologies became greater in the precision and quality control context, as well as the discovery of better properties materials. In the welding field it was no different. The process of joining materials that guarantees continuity between parts accompanies man throughout history, but since the Industrial Revolution, with the discovery of the electric arc, technology has undergone great evolutions (Singhal, 2001). In 1948, in order to increase the productivity and diversity of the welding at manufacturing processes of ferrous and non-ferrous materials, the MIG (Metal Inert Gas) fusion welding process was used for the first time (Ibrahim et al., 2012). However, the MAG (Metal Active Gas) welding process, a variation of the MIG appeared at the industry in 1953. MIG/MAG, also known as GMAW (Gas Metal Arc Welding) has become one of the most commonly used weld methods in the industry (Bohme et al., 1996). Mainly characterized by the protection of the molten pool by one or more gases, inert or active.

The different ways in which material is transferred to the workpiece affect process characteristics such as arc stability, amount of gas intrinsic to the molten metal, welding position, and amount of spatter (Marques et al., 2011).

In the tests was used the spray metal transfer, also called aerosol transfer. It occurs when it is used high current rate, above the transition current, which demands where the transfer changes from globular to spray (Mondenese, 2007).

The value of this current is determined by the diameter and material of the wire and by shielding gas or its mixture. The formation of the bow makes the droplets have a very small diameter and they are transferred when the resultant forces acting in them is big enough to do it (Mondenese, 2007).

The first double wire MIG/MAG welding was executed in 1955, due to the need for higher productivity of the manufacturing industry (Michie et al., 1999). From then on, there were several attempts to further increase productivity and quality. In 2008, a consumable double electrode gas metal arc welding (DE-GMAW) was presented in order to increase productivity and reduce heat distortion (Li and Zhang, 2008). Lately, Shi et al. (2014) proposed an indirect double-arc welding, called TWIA (Twin-Wire Indirect Arc), with argon, which presented a high melting rate, high efficiency and low weld deformation, on the other hand, also showed a low depth of penetration at weld joint. Finally, according to Santos et al. (2018), a way to better use the energy that was

previously wasted, is GMAW with just one live wire, by taking advantage of excess heat to melt the other wire. The MAG-CW (Metal Active Gas – Cold Wire) welding can provide an increase of about 24% in the width of the weld bead and 46% in its height, among the reduction of energy consumption when compared to the process with two energized wires. The penetration was reduced by 40% due to the energy required to melt the cold wire. The electric arc was stable throughout the process.

The objective of this paper is to show the results of a further variation of the MAG-CW welding process, in which shielding gas with different compositions was also added in the slave torch in order to increase the metal deposition rate and improve the penetration profile of the weld bead, maintaining and improving the quality of the weld bead together with optimizing the MAG-CW welding process.

2. EXPERIMENTAL PROCEDURE

A SAE 1020 steel sheet was placed on a bench designed to keep the torch assembly in the correct position and to move it uniformly, eliminating possible human interference. The wire used in both torches was the AWS E 70S-6, with a diameter of 1.2 mm. Although the use of 1.6mm wire diameter was ideal to improve the results, the electronic system's limits didn't allow a higher diameter than 1.2mm. For the main torch, energized, an ESAB source (AristoPower 460) was used, where the electrical parameters of the tests were defined: voltage between 30 and 32 V and current intensity between 220 and 235 A, in order to guarantee the spray metallic transfer mode. The feed velocity of the energized wire was between 5.0 and 6.0 m/min, and the cold wire was added by an OrigoFeed 304N P4TM head at a rate of 3.0 to 3.5 m/min. Welding process was performed using the technique of "pulling", with a movement speed of the torches of 330 to 360 mm/min.

To maintain the stable process and desired metal transfer, the cold wire was added in the anodic region of the electric arc, as shows the Fig.1.

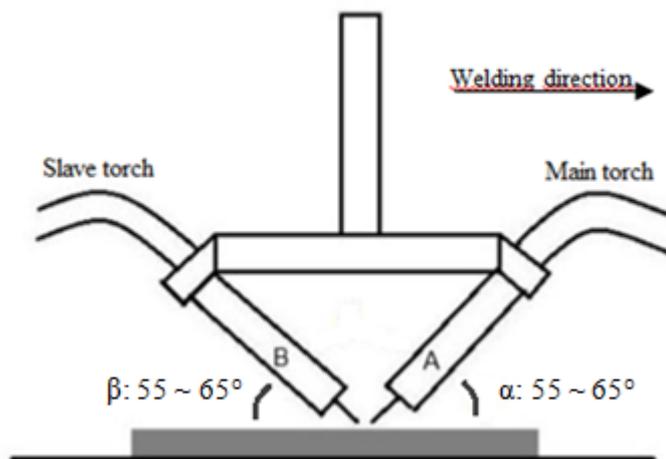


Figure 1. Torch position scheme used in the tests.

The energized torch receives a gas mix contains 15% CO₂ + Ar bal., always kept constant. For the other torch, were used a binary argon mix with CO₂ concentrations ranging from 12 to 25%. The gas mix was measured by a Thermco gas analyzer. To ensure the stability of the electric arc during the process, the ESAB (AristoPower 460) source was connected to an HBM data acquisition amplifier module (QuantumX MX440B) to collect the voltage values and current intensity in real time, which were stored and analyzed later by the HBM software Catman Easy. The process was filmed by the GoPro Hero3 in an attempt visualize the transfer of the drops from the wire to the melting pool, and in observe the behavior of the electric arc. From there, at the end of the welding process, the workpiece was cut at the cross-section, and a small sample containing weld bead deposited and workpiece material was submitted to standard preparation for a macrographic testing, where the dimensions of the bead were obtained.

3. RESULTS AND DISCUSSION

A preliminary test without addition of cold wire, was executed, and it was compared with several tests: with the cold wire addition, shielding gas on the slave torch in different proportions of gas mix (Ar + CO₂), and without it. The performed welds were prepared and tested. Figure 2, (a) and (b), shows a linearity which is observed in the parameters of voltage (V) and current intensity (A), that indicates a stability of the electric arc. This result can elucidate by welding process film registration, as shows the Fig.3.

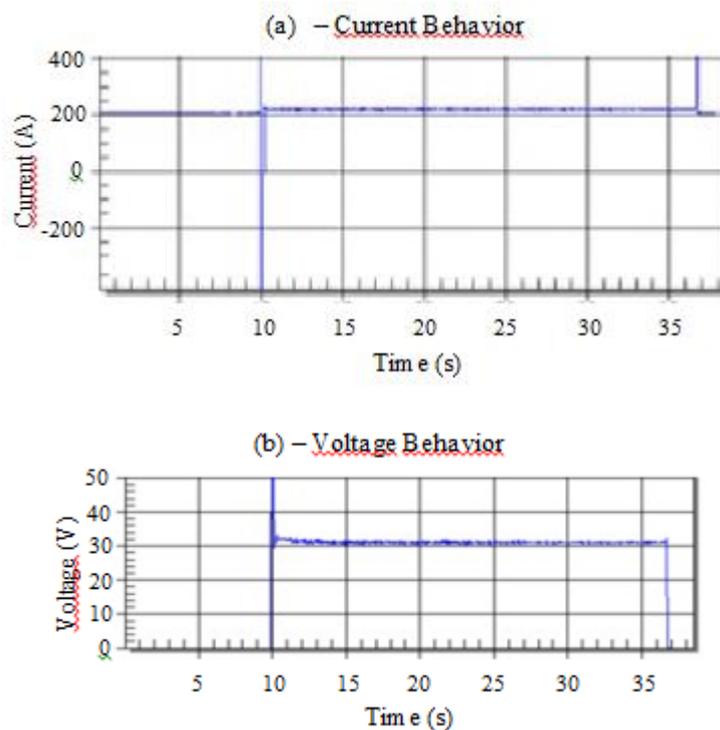


Figure 2. Graphs from the Catman Easy of the data given by QuantumX MX440B (a) Current intensity; (b) Voltage.

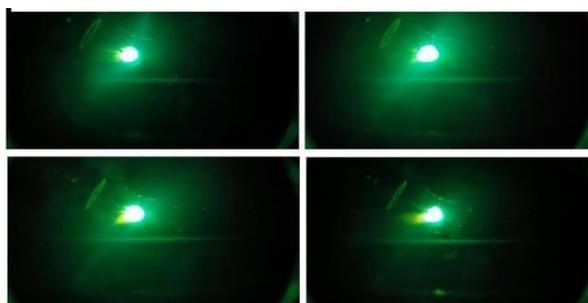


Figure 3. Filming registration of the welding process

It was also noticed a stability of the electric arc, with addition of gaseous mix in the cold wire. Therefore, it can confirm that the electric arc between the wire and the molten pool in the main torch was not influenced by the cold wire, neither the mixes of gases injected through the slave torch. For this reason, it was possible to keep the spray transfer mode. Taking the penetration profile under consideration, when the gas mixture was injected into the slave torch, the reinforcement of the bead decreases, promoting a deeper and more uniform penetration, as exhibited in Fig.4.

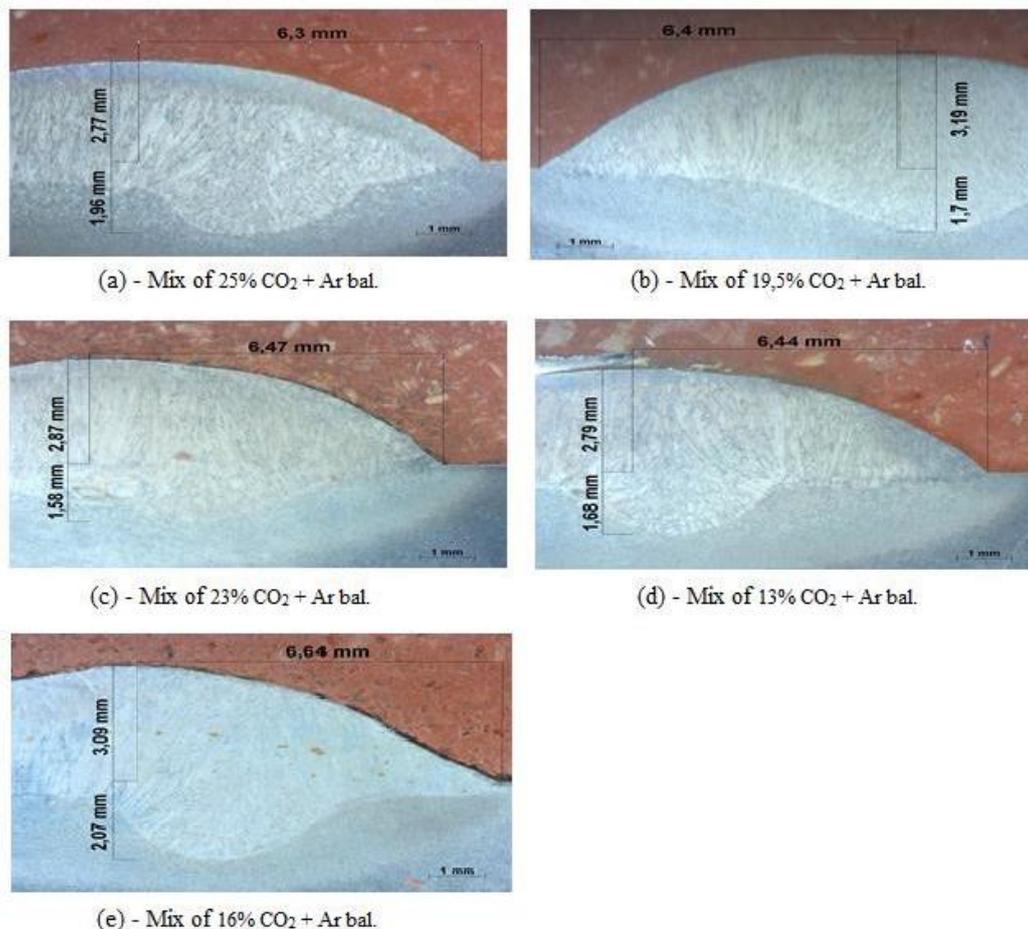


Figure 4. Weld bead results of MAG-CW welding with shielding mixes gases.

The behavior shown in the figure is due to the influence of the gases in the molten pool, probably in its surface tension, promoting a convection effect at the molten pool, from top to bottom, also called as Marangoni effect, thus increasing the penetration profile (Lu et al., 2010). On that account, the experiment shows that there was an improvement in the performance of the weld bead when used the MAG-CW method accompanied of a gas mix injected into the slave torch.

The use of CO₂ in gas mixture provides an “extra energy”, due to its dissociation and recombination potential that makes at the same arc temperature we have a higher generated heat in the welding pool (Ibrahim et al., 2012). This is because molecular gases, when heated to high temperatures (such as working arc temperatures), dissociate and, in contact with the part, region with very lower temperature than that of the electric arc (plasma), recombination of atoms occurs, releasing heat energy (exothermic reactions) (Lucas, 1992).

The difference between surface tension and stress in the puddle is called Marangoni convection. Gas properties may alter the physicochemical characteristics of the weld pool and thus alter the surface tension gradient. Where heat flows to the bottom of the weld pool, causing reducing bead width and increasing penetration (Dreher et al., 2013).

Lower bead convexities result in the so-called “finger effect”, where there is greater penetration but with a smaller diameter than the weld pool superficial. The addition of gases such as carbon dioxide help in reducing the surface tension and as a consequence of this effect on the bead (McIntosh et al., 2016).

This becomes more evident when compared with the bead's profile welding without addition of shielding gases in the melting pool and under them welding parameters, as shown in figure 5.

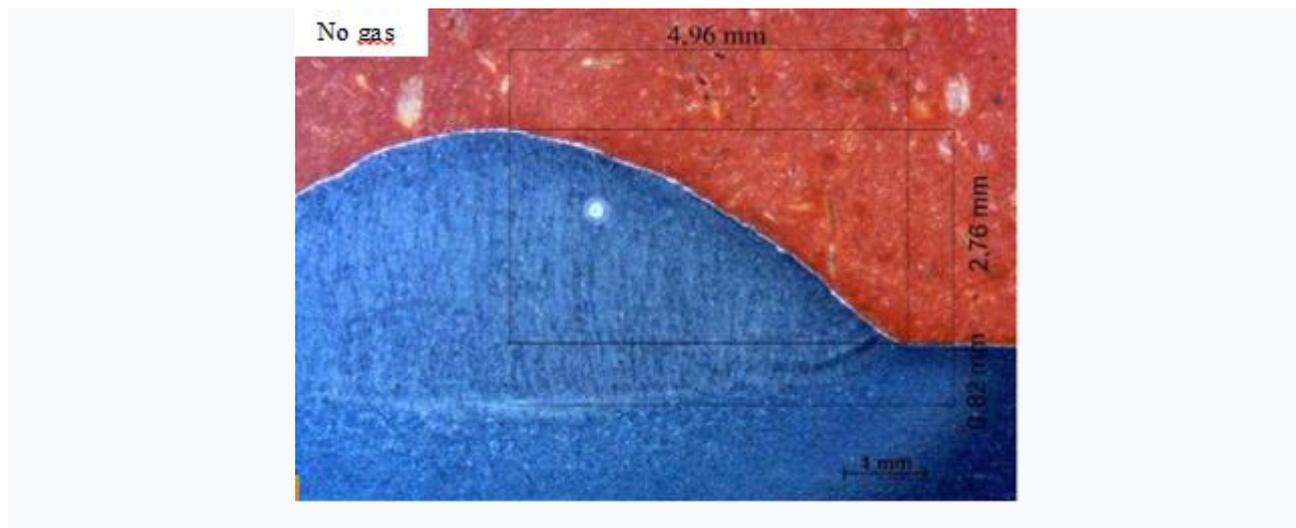


Figure 5. Weld bead results of MAG-CW welding without shielding gas in slave torch.

The table below shows the results of the tests performed by Santos et al. (2018) for conventional MAG-CW welding and MAG-CW with shielding gases in slave torch, all using the same parameters, with the respective values found for reinforcement, penetration and width of the weld bead.

Process	MAG-CW	MAG-CW with shielding gas in slave torch	Increase (%)
Width (mm)	4,96	6,64	33,9
Height (mm)	2,76	3,09	12,0
Penetration (mm)	0,82	2,07	252,5

4. CONCLUSIONS

As shown at presented results, initially, the injection of gases into the slave torch gives a positive result performance of the weld bead. The electric arc remained stable even with the presence of the cold wire and the gases mixes in the slave torch. It was reaffirmed both in film registration and in stability voltage and current parameters presented in the graphs given by the data acquisition system. It also possible to observe that the change in the penetration profile related to the increase of the temperature of the molten pool and the arc stability.

Due the limits of current and voltage of the on-board electronic system, it was not possible to increase the rate of deposition rising the wire diameter.

The injection of the gases mixes into the slave torch made it possible to increment penetration of the bead. This was observed because in the bead of MAG-CW welding without gas mix, the penetration profile produced had higher reinforcement and lower penetration if compared to those with gases mixes into the slave torch.

Maybe was possible due to Marangoni effect that promoted a convection effect at the molten pool from top to botton caused reduced weld bead width and increase the penetration profile.

The presence of a gas (oxygen) that reduces the surface tension of the liquid metal became possible the Marangoni effect and also the phenomena of dissociation and recombination the carbon dioxide gas by mean exotherm chemical reaction releasing sufficient energy to influence the weld bead penetration profile while minimizing “finger” size

5. ACKNOWLEDGEMENTS

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