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INFLUENCE OF LORENTZ FORCE ON PENETRATION OF WELDED JOINTS BY THE GMAW PROCESS WITH ELETRIC WIRE

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Abstract: When welding structures with high collapse potential, it is important that the penetration of the welded joint is guaranteed to ensure system reliability. The proposal of this work is to use the surplus energy of the GMAW (Gas Metal Arc Welding) process and insert an additional wire (GMAW-CW) (Gas Metal Arc Welding - Could Wire), energizing it with different values of electric current from a secondary source, using the welding technique by pushing on the auxiliary electrode, in order to evaluate the effect of the Lorentz force on the penetration of the melting pool. The results showed that the penetration is directly proportional to the current of the system showing that the influence of the Lotentz force on the acceleration of the drops, really increases the exchange of value with the workpiece. However, with the excessive increase of the current in the auxiliary electrode, the appearance of a small influence of the cathodic jets that reduce the penetration occurs.

1. INTRODUCTION

With the great competitiveness of the current industrial market, the search for increased productivity in industrial maintenance, cost reduction in the recovery and the need for faster production on a large scale, has motivated researches with welding processes that present higher rates of deposition. For these purposes the GMAW process with double wire was developed, adding a "Cold Wire" (CW) to take advantage of the heat that would be lost to the environment in the welding process (Ribeiro, 2011).

According to "Michie *et al*., 1999", the attempt to use the double wire MIG/MAG (Metal Inert Gas / Metal Active Gas) comes from the year 1955, but the technological limitations of the sources of the time prevented the process from reaching its potential. Nowadays, welding process technology is in a very advanced stage, always innovating, establishing standards in welding processes and perfecting them (Sanches, 2007).

With the goal of greater productivity and lower time of operation, the GMAW-CW process was improved (Filho 2011), which in addition to the high efficiency, works with high current density rates, can provide higher melting rates and allow higher welding speed and more larger welded joints, if associated with the (MIG / MAG) process (Groetelaars 2005), according to "Silva, 2005" with the addition of more material to the melting pool, a reduction of the penetration area occurs and, consequently, the dilution. To improve these aspects, it is necessary to add a current to the auxiliary electrode, increasing the energy used in the melting pool to increase the penetration, this process is called GMAW-EW (Gas Metal Arc Welding - Could Wire).

The penetration is influenced by the presence of the Lorentz force, "Resnick and Halliday, 1980" defines Lorentz force as the result of the interaction of the generated current, by the movement of the load with its own magnetic field, acting individually on each particle of charge, acting independently of the way of the electric field, this force can be divided into two components Axial and Radial that act in complementary ways to each other.

The axial component of the Lorentz force occurs when a conductor has a section of variable geometry, an axial force acts on the conductor, being directed from the region of smaller to that of greater area of circular section of passage of current, exactly the conditions found in MIG/MAG welding since the electrode wire constantly changes its geometry with the deposition of metallic material, thus allowing the Lorentz force to act (Baixo, 1999). "Amson, 1965" estimated that high currents cause the contrition effect, thus raising the axial component of the Lorentz force, creating conditions for the acceleration of the molten globule toward the melting pool.

When a conductor in fluid state and incompressible, it is under the influence of its own magnetic field, this conductor undergoes a radial compressive force, which is the radial component of the Lorentz force or Pinch force (Serdjuk, 1962). In high currents this force moves the fluid material, facilitating the exchange of heat of the molten metal with the solid electrode, accelerating the formation of the droplet thus directly contributing to constriction, giving the conditions for the acceleration of the droplet by the axial component.

"Essers and Walter, 1981" estimates that 25% of the heat transferred to workpiece is provided by the overheated metal droplets, and with Lorentz force increasing the frequency and velocity of the droplets, that metal is carried deeper into the molten pool, enhancing the penetration and decreasing the reinforcement proportionally with the increase of the current.

The objective of this paper is to observe the increase in penetration influenced by the Lorentz force using the GMAW-EW process, by varying the current of the auxiliary electrode in order to show the Lorentz force relation with the penetration.

2. EXPERIMENTAL PROCEDURE

For the realization of the welds, a workbench made of the following was used: a welding source, a feeder head and an independent source for energized wire feed, welding torch, displacement systems and welding table as shown in fig. 1. The base metal used was AISI / SAE 1020 carbon steel in the form of a flat bar with dimensions of 9.50 mm x 56.00 mm x 225.00 mm (thickness x width x length), with coatings deposited on the base metal, parallel to the rolling direction of the material.

For the development of this work, two AWS-class ER70S-6 wires were used as addition metal, with the electrode wire having a diameter of 1.2 mm and the energized wire having 1.0 mm, according to AWS 5.18 standard.

The specimen (CP 01) was welded in the flat position by the GMAW-CW process, having as a welding parameter, a voltage of 23.6 V, a 15 mm Stickout and a current of 180 A, in the pulling welding technique, which corresponds to the electrode feed rate of 5.00 m/s, with an auxiliary electrode feed rate of 50% corresponding to 2.5 m/s.

Test specimens CP 02 through CP 05 were welded by the GMAW-EW process using the same parameters as above and adding 40 A, 80 A, 120 A and 150 A of electric current in the auxiliary wire with direct polarity.
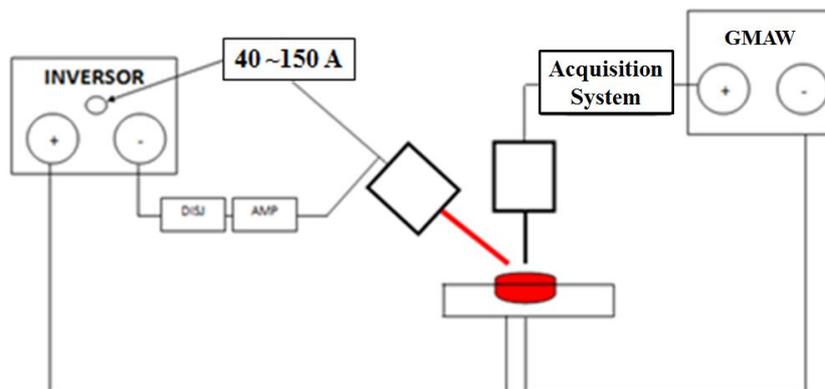

Figure 1. Scheme used in the GMAW welding process.

For the accomplishment of the measures of the reinforcement, width and dilution the specimens were sectioned in the central region of the joint as shown in fig. 2.
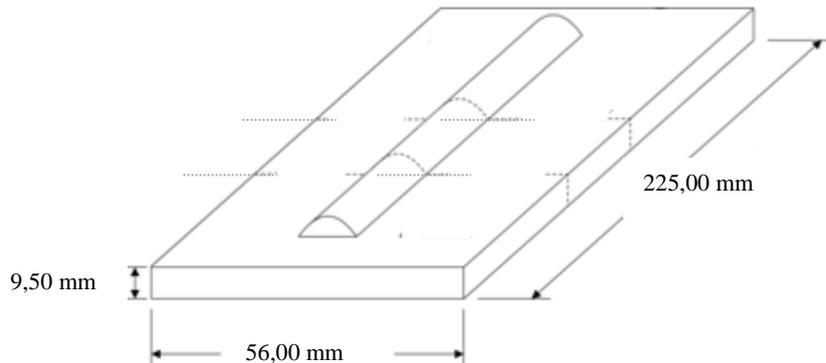

9,50 mm

225,00 mm

56,00 mm

Figure 2. Sectional diagram of the joint.

The measurements were performed as shown in fig. 3 using AutoCAD® Software. Where A is the area of reinforcement, B is the area of penetration, C is the area of HAZ, W is the width, R is the height of reinforcement, and P is the depth of penetration.
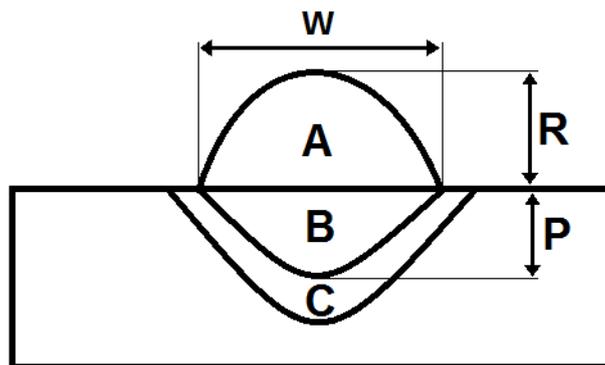

Figure 3. Scheme of realization of measures.

3. RESULTS AND DISCUSSION

Table 1 presents the differences in the measurements of the geometry of the test specimens with the variation of the current in the auxiliary electrode. You can see their respective macrographs in figure 4.

Table 1. GMAW-CW and GMAW-EW welded joint measurements.

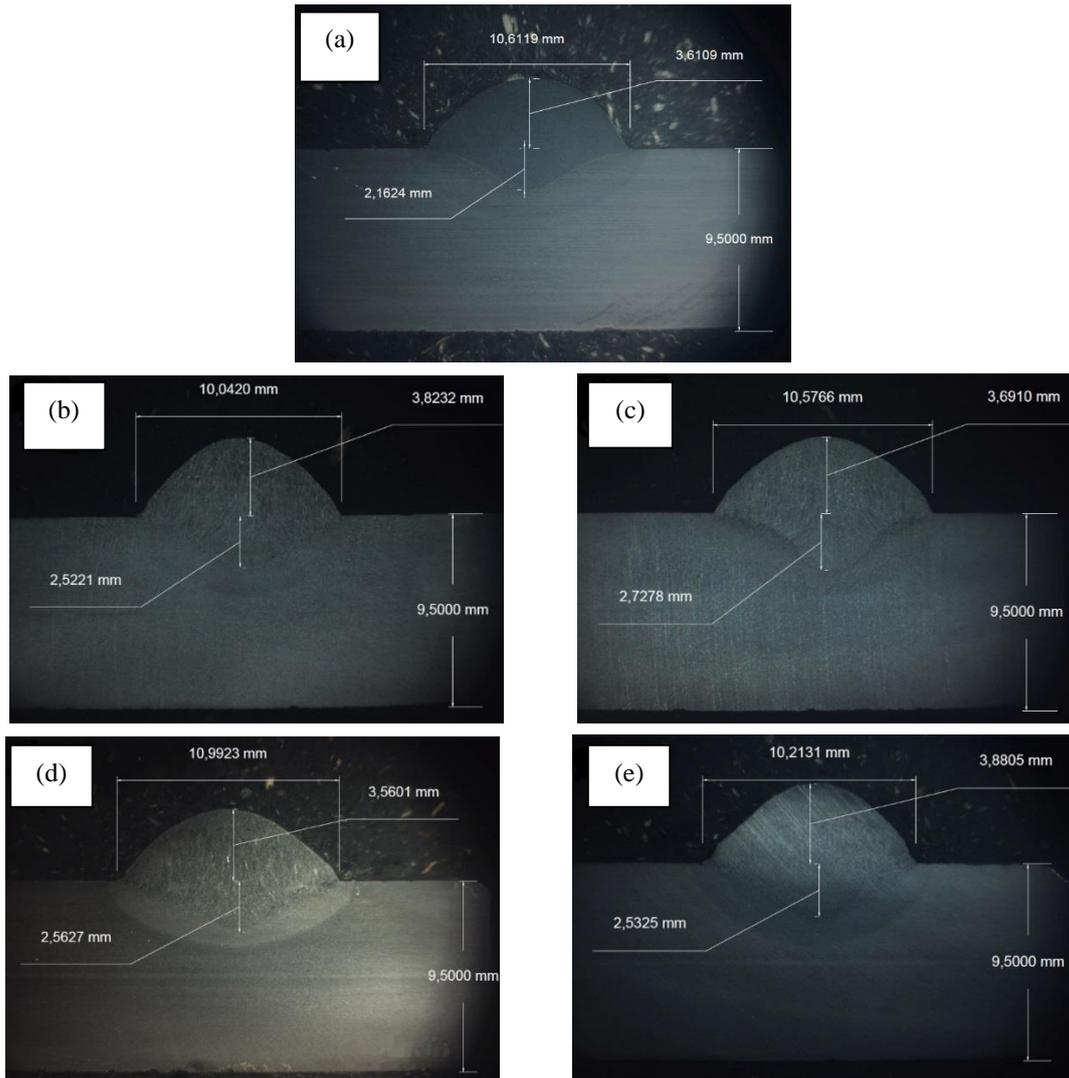| CP	Auxiliary current (A)	Width (mm)	Reinforcement		Penetration		Area HAZ (mm²)	Dilution (%)
			(mm)	(mm²)	(mm)	(mm²)		
1	0	10,6119	3,6109	26,3003	2,1624	10,6079	22,9484	28,74
2	40	10,042	3,8232	25,2296	2,5221	12,9157	21,849	33,86
3	80	10,5766	3,691	26,544	2,7278	12,0929	22,9421	31,3
4	120	10,9923	3,5601	26,0849	2,5627	15,3011	15,3898	36,97
5	150	10,2131	3,8805	26,1134	2,5325	12,0636	22,9282	31,6

Figure 4. Direct polarity GMAW test specimens with pulling welding technique. (a) CP 1; (b) CP 2; (c) CP 3; (d) CP 4; (e) CP 5.

When the GMAW-EW test specimens were analyzed, a better penetration was observed when the 40 A current was added at CP 2 (fig. 4b) compared to CP 1 (fig. 4a) with a cold electrode, increasing with 80 A at CP 3 (fig 4c), but maintaining penetration areas close to the surface, and presenting the best values with 120 A at CP 4 (fig. 4d) that obtained the largest penetration area and the lowest Heat-Affected Zone (HAZ) besides a good dilution, but by increasing to 150 A at CP 5 (fig. 4e), there was a small decrease in the penetration area which may be associated with the presence of cathodic jets or plasma jets, the electric discharges tend to settle from the oxide particles until vaporization occurs due to joule effect, the concentration of the arc at one point on the melting pool gives rise to the appearance of an axial component of the Lorentz force which starts to act in order to retain the drop at the end of the electrode (Kim and Eagar 1993).
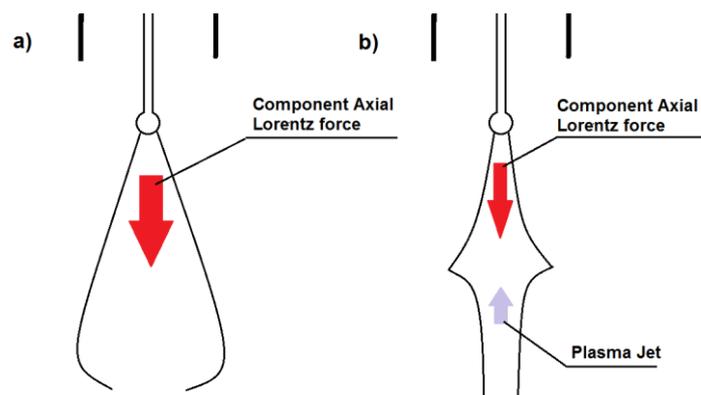
Figure 5. Effect of the cathodic jet action on the plasma column: a) Normal arc b) Arc under the influence of cathode (plasma) jets.

4. CONCLUSIONS

The GMAW-EW process presented increased penetration and dilution, compared to the GMAW-CW process, the results showed that the penetration by the Lorentz force is directly proportional to the current of the auxiliary electrode, but for the value of 150 A of auxiliary current had a small retreat in dilution and penetration area, due to the presence of cathodic jets causing the appearance of a force contrary to the detachment of the droplet thus decreasing its speed and consequently negatively influencing the drop heat exchange with the workpiece, that error could be solved with a more careful withdrawal of the oxide layer thus favoring the Lorentz force's performance.

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