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A HYBRID PLASMA-MIG WELDING SOLUTION TO IMPROVE PRODUCTIVITY IN PIPELINES CONSTRUCTION

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Abstract

New welding procedures and applications are often developed in order to attend the increasing demand of productivity and quality, keeping lower costs. During the pipelines assembly, slower low-energy welding procedures might be used due the position limitation, which can vary between flat and overhead position, but whenever is possible on and off shore, high-energy welding procedures are chosen. Submerged arc welding (SAW) is widely used in such applications due its high heat input, still it has limitations, mostly by bevel preparation. Laser-MIG hybrid welding on the other hand has a great performance on higher wall thicknesses welding, although the initial investments are strictly high. The Plasma-MIG hybrid welding has appeared as an intermediate alternative for these procedures, having lower investments compared to laser hybrid procedures, and better performance compared to individual wire arc procedures. It consists in two arcs acting on the same welding pool, while the plasma arc starts the melting and initiates the keyhole, the MIG arc goes right after consolidating the penetration and bridging space between the plates to be welded. Therefore, experimental tests were carried out in 12mm AISI 1020 carbon steel plates laid out at 1G position, to develop initial groove necessary and welding parameters. After the initial parameters for this condition were found, it was applied in the circumferential single pass welding of API X-70 pipe under two different backing materials. The electrical parameters were monitored online welding, which allowed identifying great electrical stability during weld, the welding bead was continuous during weld and macrographs analysis showed no signs of discontinuities, porosity or lack of fusion.

Keywords: Plasma-MIG; weld bead; penetration; speed; keyhole.

1. Introduction

The oil and natural gas demand advances, and so its matrix distribution. The best common alternative to flow the hydrocarbons is the use of pipelines. The wide pipeline matrix area that Brazil needs to cover for oil and gas distribution is at increasing development, so are the welding

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procedures involved. In order to reach lower distribution costs, lower investments in pipelines settling are needed. One way to go is by increasing welding productivity.

A common procedure to build pipelines is submerged arc welding (SAW). Although it is a high-energy procedure that can reach a high deposition rate, SAW requires extensive bevel preparation and to minimize welding defects and distortion, multilayer welding on thicker plates is commonly chosen which reduces considerably its productivity.

Laser-MIG hybrid welding on the other hand, combines the concentrated heat from the light beam with the welding wire bridge-ability, granting a higher penetration at single pass welding [1], Figure 1 shows a comparison of a 35mm thick plate welded by SAW+GMAW and Laser-MIG welding. While twelve multiple layers and a giant groove opening was needed in the SAW welding, laser-MIG managed to weld the same plate by only two steps.

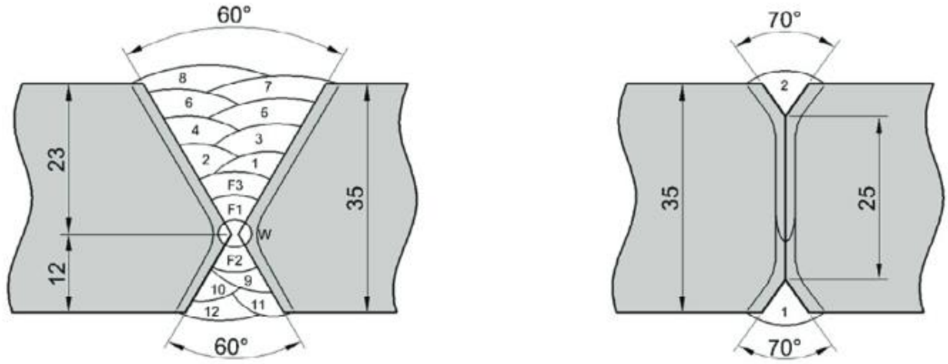

Figure 1. Comparison of SAW (left) and Laser-MIG hybrid welding (right) [1].

Even known the great advantages of the laser-MIG hybrid welding and its advances recently, it is still a very expensive procedure in terms of investment. Thus, alternate hybrid procedures are being developed as cheaper options to such applications.

Plasma-MIG welding, works with a similar methodology. The concentrated plasma arc initiate the melting generating a keyhole while the GMA welding advances right after the plasma arc accentuating the keyhole and adding filler wire in the weld pool, shown in Figure 2.

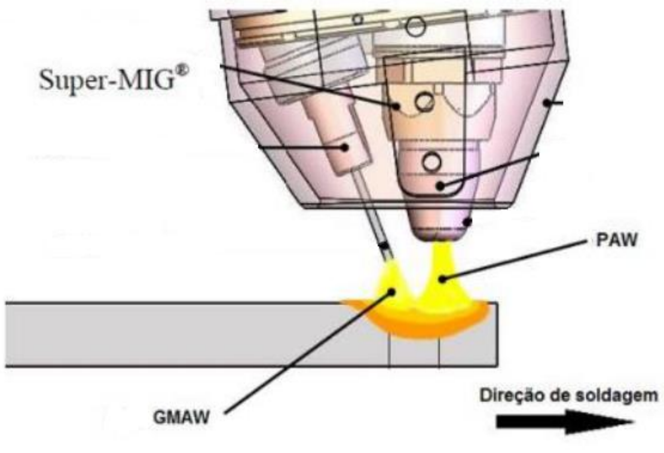

Figure 2. Schematic of Plasma-MIG torch [PLT, 2014].

In the welding field, the keyhole is a state of higher performance, the concentrated heat in a narrow deep zone generates an overlap effect, which enables deeper penetration profiles [2]. Laser beam welding are usually associated with the keyhole mode, but in plasma arc welding, the great constriction and pressure of the electric arc increase the energy density per area, allowing also a keyhole formation [3]. Surely, manage a keyhole might be complex, the high concentrate current trends humping defects on the molten puddle. Although, the additional material supplied by the GMAW arc and the extra energy provided prevents it from happening, increasing process stability [4].

Research showed that for the desired thickness (12.7 mm), SAW procedures can achieve a single pass welding with speeds up to 50 cm/min. Even though in the universe of welding this speed is already satisfactorily high, there is a demanding groove preparation, with large gaps to be filled, making the process less productive and more costly on welding consumables [5][6].

In the same conditions, Laser-MAG hybrid welding may reach up to 200 cm/min welding speed, requiring less edge preparation [7]. Common grooves for SAW and Laser-MAG are shown in Figure 3.

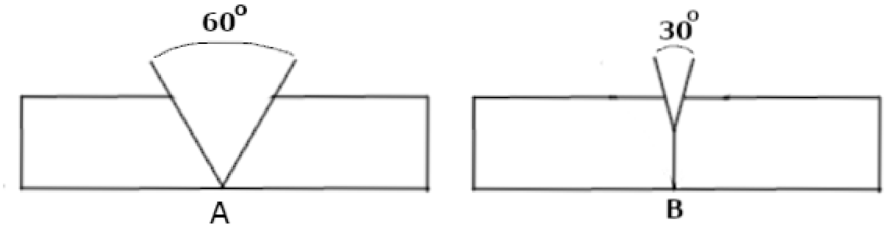

Figure 3. Illustration of a common joint welded by SAW (A) and laser-hybrid process (B).

The main objective of this work is to perform a circumferential welding of a pipe, achieving higher productivity than conventional methods (SAW, GMAW) and a given satisfactory quality that could be compared to laser-MIG hybrid procedures. Considering there is not much bibliography on this suggested application, to reach the main objective it was preliminary tested starting parameters on butt joints so them it could be applied in the pipe welding, under the use of two backing materials for effect of comparison.

2. Materials and Method

An AISI 1020 steel plate 1/2" (12,7 mm) thick was used as base material in the preliminary tests, then an API X-70 pipe 1/2" (12,7 mm) thick and 15” (381 mm) of diameter. As filler wire was applied the AWS ER70S-6 1,2mm of diameter. In the plasma arc was used pure argon, as shielding and plasma gas. The MIG gas used was a mixture of 92% argon and 8% CO_2. The cathode was a Tungsten electrode doped with 2% Cerium with 3,2 mm of diameter and 2 mm recoil and sharpened with 30º. The initial groove design was a butt joint with a gap varying from 0 to 2 mm.

Two backing materials were used: ceramic, cheaper, however the shape of the root is fixed according its structure, and is more susceptible to porosity and inclusions; Fiberglass, adjustable root shape, less susceptible to porosity and inclusions, however more expensive, both are shown in Figure 4.

Figure 4. Ceramic backing (left). Fiberglass backing (right).

It was used pulsed mode on the MIG welding due its high energy control and great behavior under difficult welds. The plasma source, was used a SUPERMIG welding source and a SUPERMIG welding torch medium duty.

The welding was performed with the torch (same presented in figure 2) held by a robot on the top of the groove with the plasma torch at 90º with the surface and the MIG torch 15º with the plasma torch, while the pipe rotate circumferentially clockwise, as shown in Figure 5.

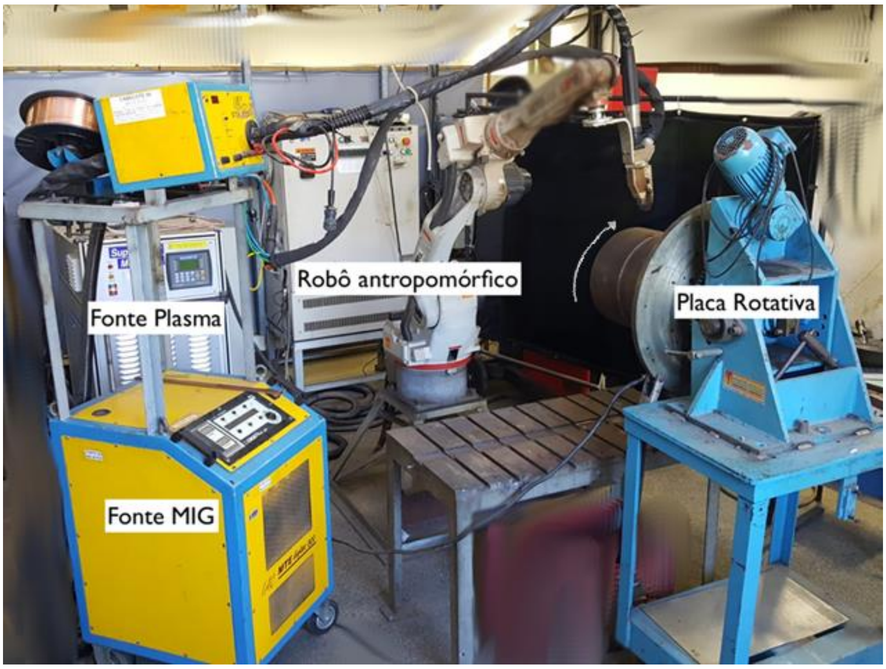

Figure 5. Welding setup.

Since the Plasma-MIG is suggested as a middle term process between SAW and Laser-MAG, the starting parameters of the tests try to add the approximate welding speed of the SAW process with the narrow bevel of the laser arc hybrid process. In order to facilitate the primary tests, no bevel was made in the butt joint, instead, it was applied a 1 mm root opening, so the weld could easier reach full penetration. The groove configuration can be seen in Figure 6. As for this particular joint, the optimal Plasma/MIG parameters to perform a satisfactory weld were found.

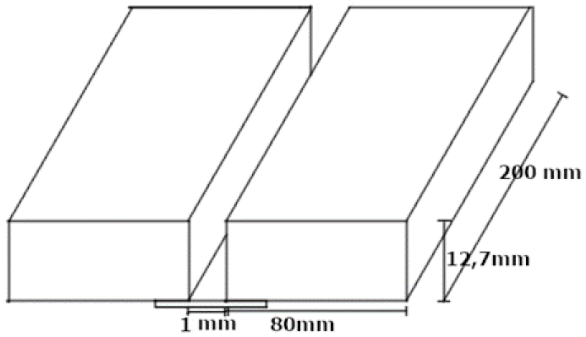

Figure 6. Groove configuration of preliminary tests (Root opening – 1 mm, backing material – ceramic).

3. Results and Discussion

3.1 Butt Joint Welding

Starting with a pulsed GMAW with wire speed of 12 m/min, travel speed of 45 cm/min, plasma current at 100 A, and plasma gas flow at 3 L/min, it was gradually raised plasma current and plasma gas until the groove reached full penetration. The respective result is demonstrated in Figure 7. As well, the optimal parameters found for this condition are shown in table 1.

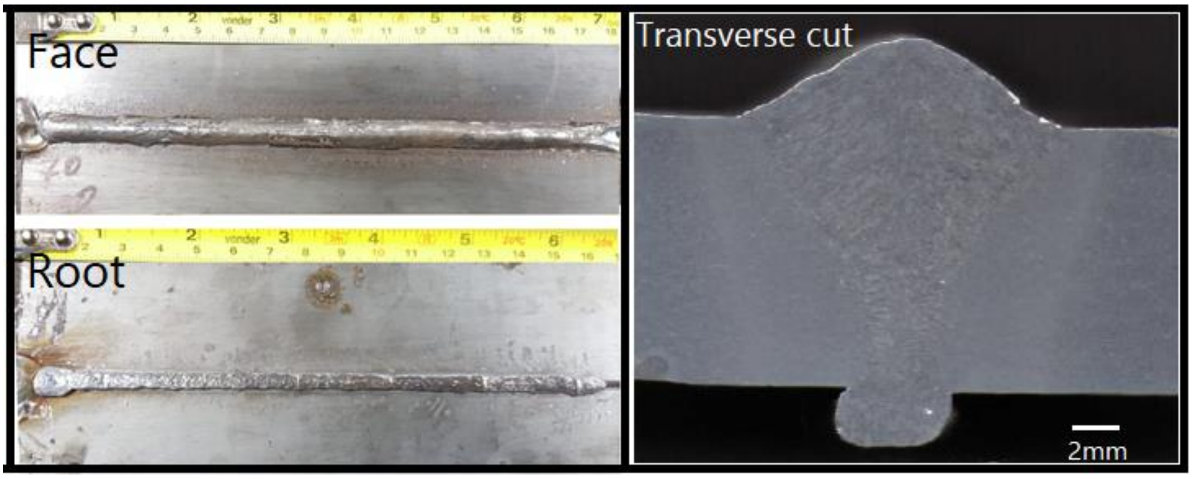

Figure 7. Face and root of the weld (ceramic backing).

Table 1. Welding parameters for the four filing passes.

	MIG Source	**Plasma Source**
Mean Current (I)	290 A	200 A
Gas Flow (Pf)	15 L/min	15 L/min
Mean Voltage (V)	35 V	20 V
Plasma Gas (Pg)		4.0 L/min
Wire Speed (Ws)	12 m/min	
Travel Speed (Ts)	45 cm/min	
Distance electrode-piece (DEP)	15 mm	5 mm

In laboratory conditions, the weld may have performed well, but in the industry or in the field, any variations in the daily conditions might be catastrophic for the weld. Therefore, the conditions reproduced in laboratory must be as robust as possible. Two ways of verifying if the weld is sturdy stable are by verifying the electrical parameters and record the weld puddle behavior. Figure 8 shows the behavior of the weld puddle synchronized with the electrical acquisition. The current and voltage periods are repeatable, which means the electrical parameters are stable during welding, and the images show no signs of instability.

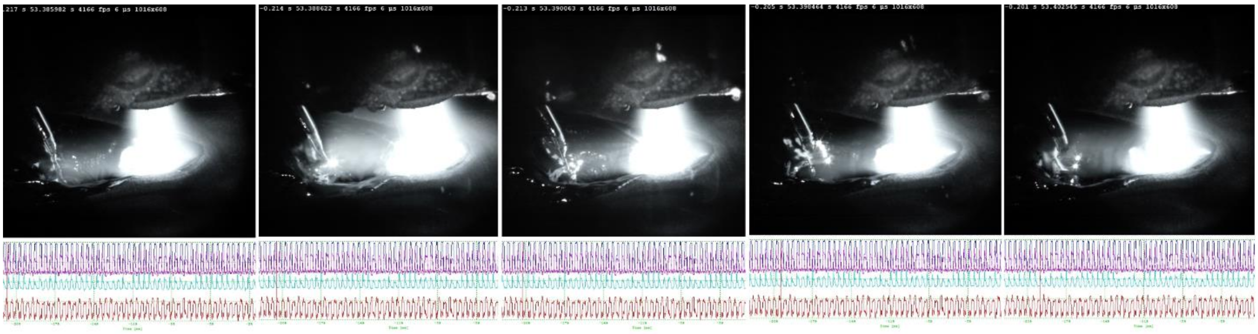

Figure 8. High-speed filming of the welding (Acquisition rate 500fps).

3.1 Pipe Welding

Given the promising preliminary result the next step was to weld the pipe circumferentially, applying the found parameters. Since in the preliminary results, the face of the weld had spare material, it was added a small bevel of 20º within the joint, to better hold the filler material, according to Figure 9.

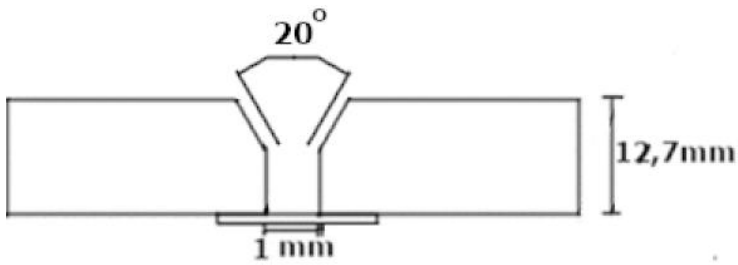

Figure 9. New groove design.

The welds were performed under the two different backing materials. The results were unexpected, instead of better fitting the filler metal, the penetration was far enhanced, causing the phenomena known as burn-through. The Figure 10.A and B represents the welds made with the ceramic and fiberglass backing respectively, even though the fiberglass backing showed a better suit to the root of the weld, both showed excessive root and lack of material in the surface.

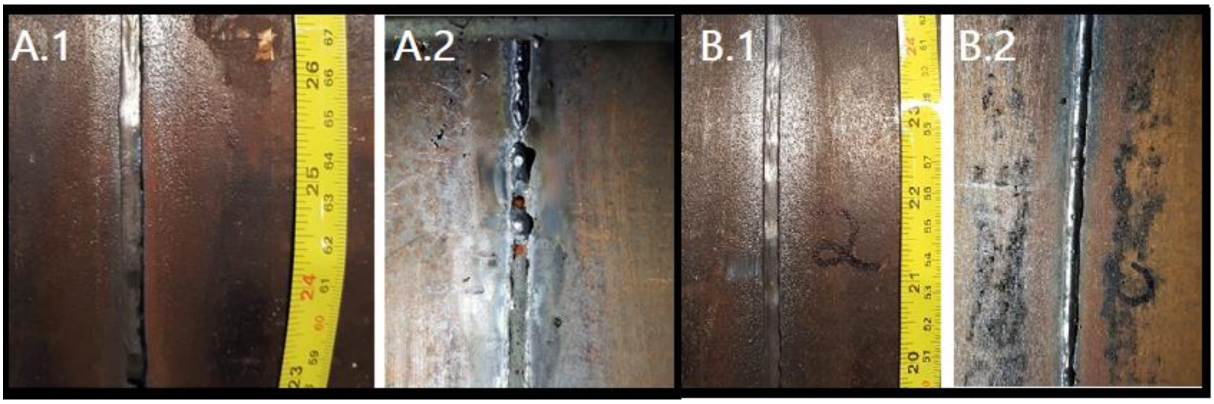

Figure 10. Surface aspects, Ts: 45 cm/min (A/B: ceramic/fiberglass backing; 1/2: Face/root of the weld).

Considering the several methods to solve the present problem, it was decided to increase welding speed to 60 cm/min, keeping all the other parameters the same, which solved the burn through problem, giving a satisfactory quality for the weld, both face and root (Figure 11). Nonetheless, the fiberglass presented better results, the malleable material for the root allowed a better penetration control, which improved the weld shape (Figure 12).

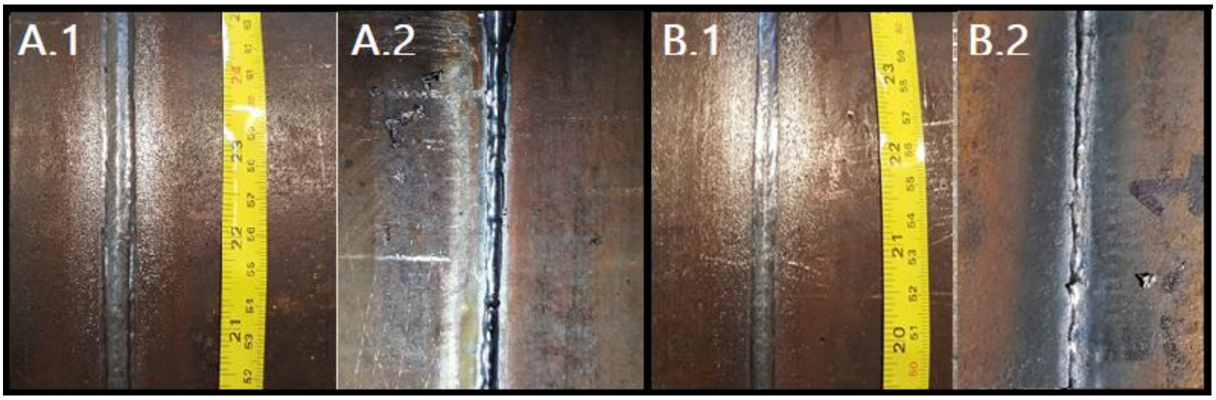

Figure 11. Surface aspects, Ts: 60 cm/min (A/B: ceramic/fiberglass backing; 1/2: Face/root of the weld).

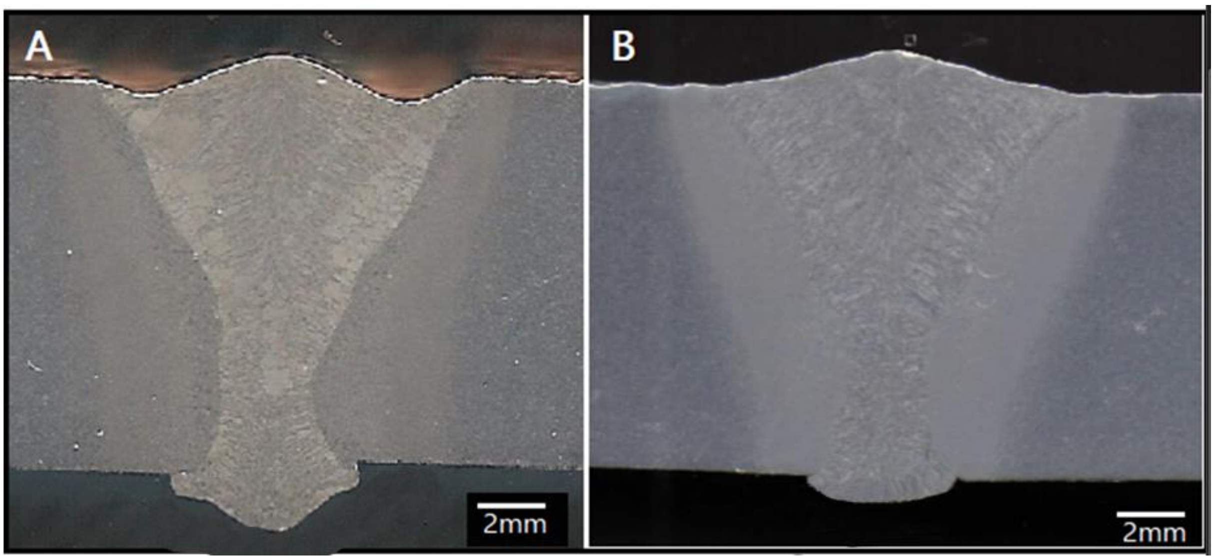

Figure 12. Macrographs of the welds (A- Ceramic Backing; B- Fiberglass backing).

The visual aspect and macrographs showed no sign of defects, therefore the x-ray analysis was made to validate the method. As predicted, the weld with the fiberglass backing showed less to non-existent signs of porosity, while the one with the ceramic backing showed little signs of porosity, no more appreciable defects were found.

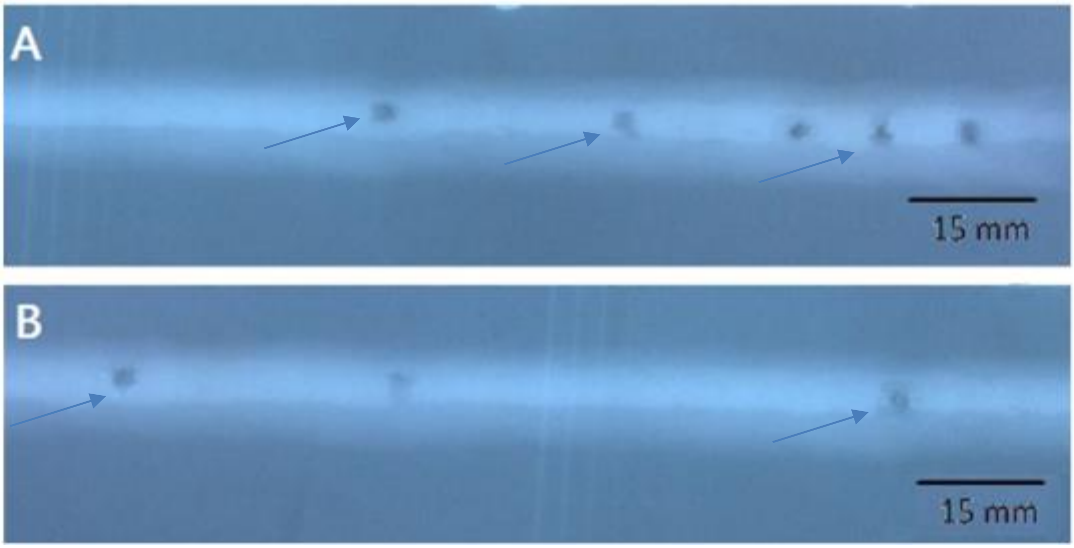

Figure 13. X-Ray analysis (A- Ceramic Backing; B- Fiberglass backing).

4. Conclusion

In order to reduce distribution costs, find more productive manufacturing ways is a solution. Therefore, this work was capable to develop and stablish the parameters to weld pipelines with the Plasma-MIG procedure, reaching higher speeds than the conventional procedures (SAW, GMAW) using less bevel preparation.

Even though it was not possible in this work to reach a speed close to the laser hybrid processes, the approximate groove used was similar to the groove used in laser hybrid processes, which means economy of filler material.

The burn-through was solved by the increase of the travel speed. In addition, the fiberglass backing presented great performance to weld under these conditions, aiding the penetration control and dissipating the welding gasses from the puddle.

5. Acknowledgements

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