CONTROLLED SHORT-CIRCUITING MIG/MAG WELDING (CCC) APPLIED TO THE ROOT PASS IN THE CONSTRUCTION OF OFFSHORE OIL PIPELINES – PROCESS ANALYSIS TOOLS

Régis Henrique Gonçalves e Silva
LABSOLDA-Universidade Federal de Santa Catarina, Campus Universitário, CP 476, Trindade –Florianópolis, SC, CEP 88040-900
regis@labsolda.ufsc.br

Raul Gohr Junior
LABSOLDA-Universidade Federal de Santa Catarina, Campus Universitário, CP 476, Trindade –Florianópolis, SC, CEP 88040-900
rgj@labsolda.ufsc.br

Moisés Alves de Oliveira
LABSOLDA-Universidade Federal de Santa Catarina, Campus Universitário, CP 476, Trindade –Florianópolis, SC, CEP 88040-900
moises@labsolda.ufsc.br

Abstract. *This work consists in the study and development of the Controlled Current Short-circuiting MIG/MAG Welding Process (CCC) and Procedure dedicated to the root pass of pipes butt weld, for the construction of offshore oil pipelines.*
Currently, this operation is performed with the Coated Electrode Process, of inherent lower productivity. The semi-mechanized, slag free process herein developed (CCC) yields satisfactory properties root welds with higher productivity.
Given the significant influence of the welding process over the chronogram, and then over the elevated construction costs, R&D on this technology is highly justifiable, since the aim is make it available to national companies at low cost, increasing their competitiveness in a globalized marketplace as the oil sector.
The CCC obtains the advantages of short-circuiting metal transfer and avoids its inconveniences, enabling its use in pipelines root welds, by means of a specific current waveform control, providing stability to the process and weld pool, with low welder training time. The developed procedure permits the making of a continuous root pass, whereas good results were accomplished in the flat position. This was made possible by the stability analysis tools developed. As expected, it was noticed that further work is needed for downwards and overhead positions. The future goal is as on line regulated system, where the welder is able to adequate the process to the current welding position, along the weld girth.
As a result, software and hardware, as well as powerful stability analysis tools, suited to the CCC, were generated. By applying them, a waveform was defined, whose phases' times and relative current levels are adequate to the mentioned weld pass, producing standards meeting root welds with higher productivity than the Coated Electrode. Information concerning the process behavior, when subjected to out of position welding, was generated.

Keywords: *metal transfer, oil and gas transport, productivity*

1. Introduction

One of the biggest challenges in today's production area is the seek for productivity increase. Especially in a global market place, as the oil and natural gas sector, this is of most significance. And the possibility of having a differential ahead of its competitors comes with the quantity and innovation level of one company's technology and staff specialization.

The problem approached in this work deals with this matter in a very understandable way. Actually the root pass welding can be, and indeed is performed by means of the coated electrode (CE) process in brazilian pipelines construction plants. The fact is that, due to its nature, compared to the MIG/MAG process, the CE has lower productivity. Mainly because of the need for slag cleaning, electrode changes during a root pass, and other secondary times caused by the explosive spattering characteristic of the CE.

What lacked before was some MIG/MAG variation that could achieve good results in this specific application. That came with the technology of current waveform control in short-circuiting transfer mode. LABSOLDA's version of this process is called CCC. As a variation of the MIG/MAG, it is a slag free, continuously wire fed process. The difference lies on its very low spattering and high drop transfer regularity. Other MIG/MAG variations, namely spray transfer and pulsed current, have limitations for this task, either because of energy excess (spray), or because of poor drop access to the joint bottom (pulsed). So, additional advantages can be achieved by systems like the CCC: less fumes, better pool visualization, better pool control, lower susceptibility for weld defects and better weld geometry.

This work deals, as an objective, with the determination of the waveform to be used, for which formulating and implementation of process analysis tools were needed. Then, as a result, a procedure for the root pass welding of thick wall steel sheets could be developed. At this first stage, the flat position was approached. Experiences were carried out also in the downwards welding, showing that other combinations of variables must be used. The final goal is a system that can be regulated along the weld girth.

2. CCC Waveform

Several philosophies of waveforms are either on the market or have already been investigated in some scientific and/or technologic work. The Welding Laboratory of the Federal University of Santa Catarina (LABSOLDA/UFSC) started investigating this MIG/MAG variation in the 90's and the application by that time was hyperbaric welding. The final goal was underwater dry welding for the oil and gas industry.

Figure 1 shows some of the waveforms in the literature, and Fig. 2 shows the first software controlled LABSOLDA's version.

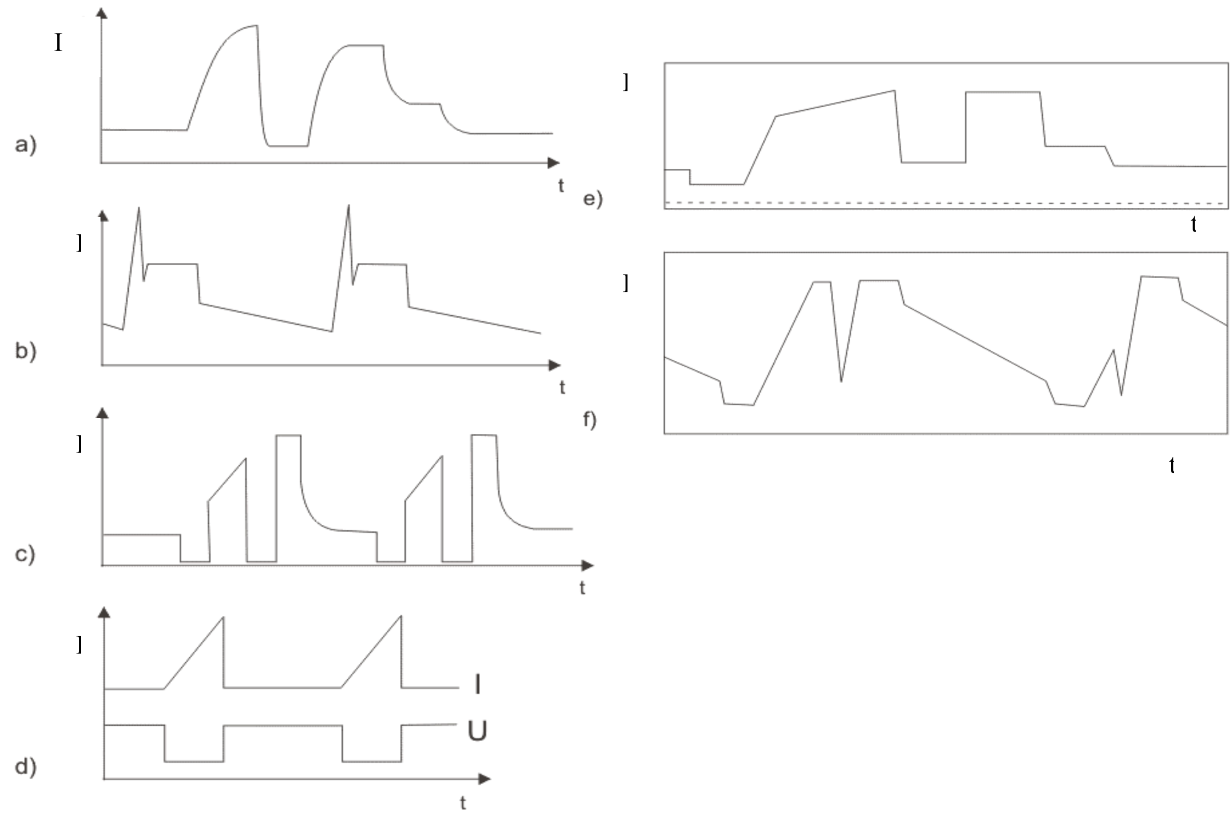

Figure 1. Different designs of current waveform used in current controlled short-circuiting MIG/MAG welding: a) Wohlfahrt, 2003; b) Wohlfahrt, 2003; c) Stava, 1999; d) Eassa, 1983; e) MILLER COMPANY, 2004; f) Maruyama, 1995.

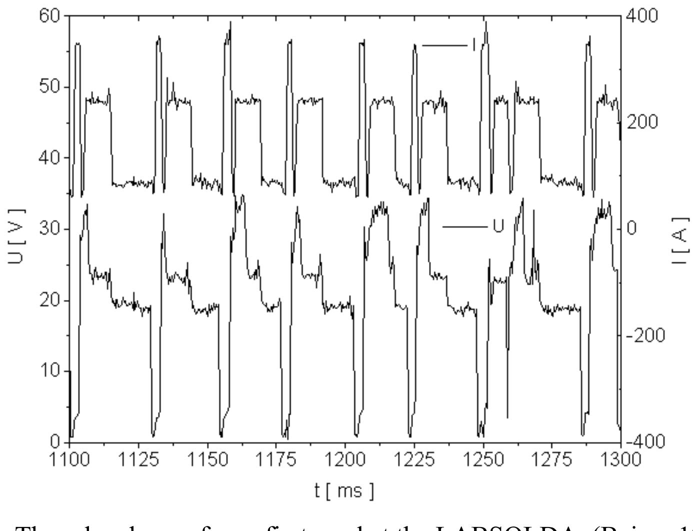

Figure 2. Three level waveform, first used at the LABSOLDA. (Baixo, 1999)

Each of these philosophies has its own process control strategy and objectives. Most of them, the more advanced and known ones, including the CCC work in the following way (Fig. 3): in the first phase the arc is active, and the current is low for arc and temperature maintaining. When the short-circuit is detected, phase 2 starts. The current is lowered, and the drop is transferred smoothly. Phase 3 provides a high level of current for the Pinch effect. During this phase, contact tip-to-work distance (CTWD) is read, in the case of CCC, through circuit voltage. Also liquid bridge dynamics is monitored for collapsing imminence. In CCC, resistance reading provides it. When the bridge brake is imminent, but has not occurred yet, the current is lowered, going to phase 4, where the drop is finally totally transferred, also smoothly without tendency to spattering. The system goes, then, to phase 5. Back fed by the CTWD reading in phase 3, the system provides a high current level and knows for how much time it should actuate to keep the regularity of drop size and, thus, regularity. It goes back to phase 1, where other phases may be introduced.

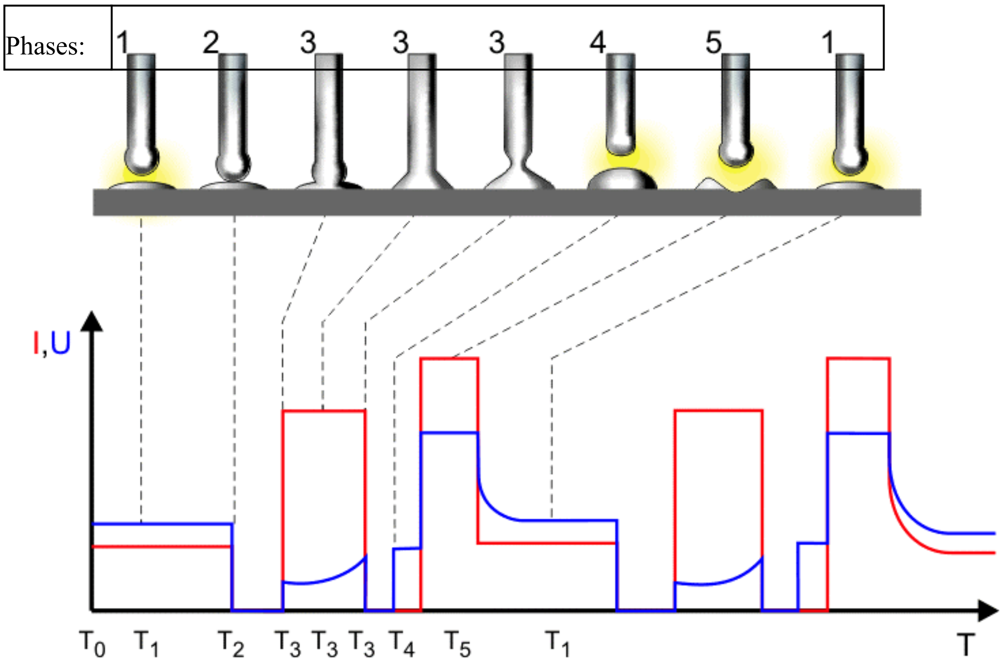

Figure 3. Regular phases of most controlled current short-circuiting MIG/MAG welding systems.

Taking into consideration the information acquired in the literature and the previous LABSOLDA's experience, an optimized waveform was reached. In this phase, process regularity and stability were visually evaluated. Figure 4 shows this waveform, the CCC.

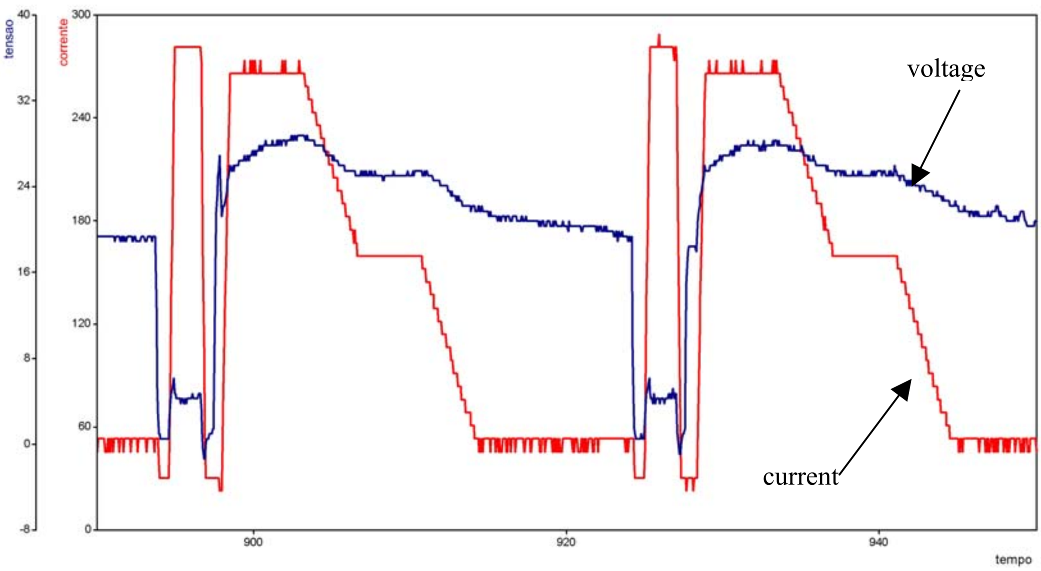

Figure 4. CCC waveform, with two slopes between phase 5 and 1. (red-current, blue-voltage)

3. CCC Stability and Regularity Analysis Tools

In order to refine the waveform, some tools had to be developed, that provided more accurate information about the course of the weld. These tools must provide statistical information regarding to regularity of the drop size and transfer and quality of transfer. More than that, these tools must show, in a very visual way, if the system is working properly.

So, it was decided that each weld made would provide a file package, which, transformed in histograms, show the system's performance. Table 1 has the files and their function.

Table 1. File package developed and incorporated to the CCC software for process analysis.

File	Function
DIGI2000.0	Complete current (I), voltage (U) and resistance (R) waves, indicating phase transition points
DIGI200R	I, U e R in CTWD reading moment
DIGI20TA	Arcing times histogram
DIGI20TC	Short-circuit times histogram and number of short-circuits
DIGI20TP	Transfer period histogram and total monitoring time
DIGI2TF1	Phase 1 times histogram
DIGI2TF3	Phase 3 times histogram
DIGI2TF4	Histogram of arc restriking in phase 4 and number of restrikes in this phase

Figures 5 to 10 show examples of the files in Tab. 1. The histograms permit a regularity analysis.

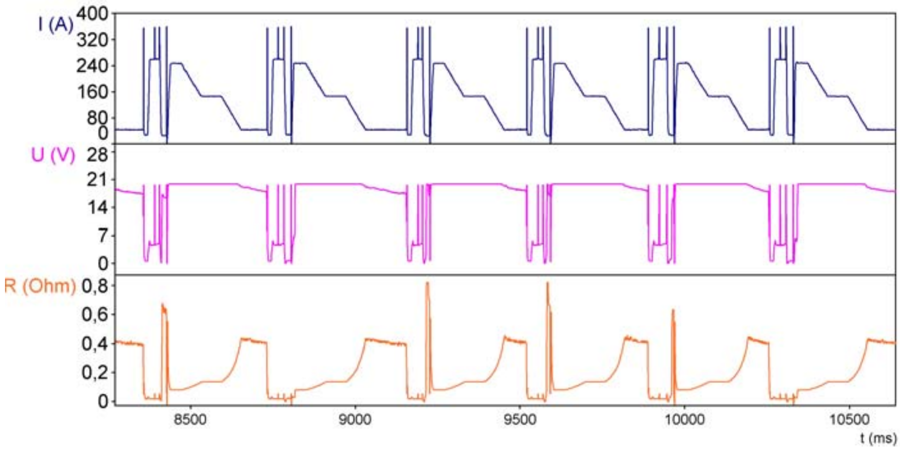

Figure 5. DIGI2000.0 file.

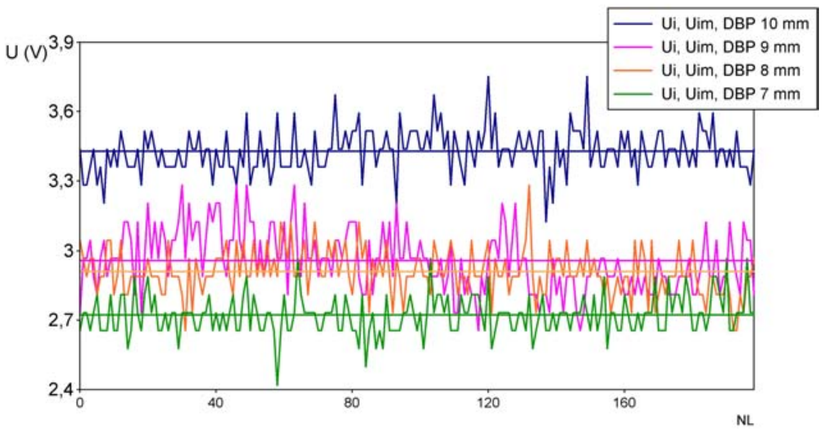

Figure 6. DIGI 200R.0 file, providing CTWD reading.

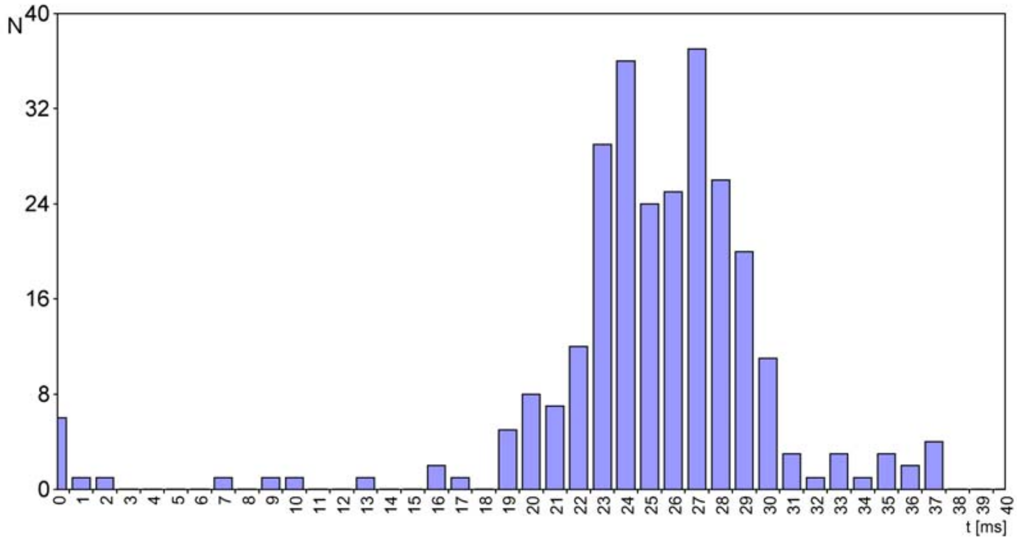

Figure 7. DIGI20TA.0, histogram of arcing time for each droplet transfer.

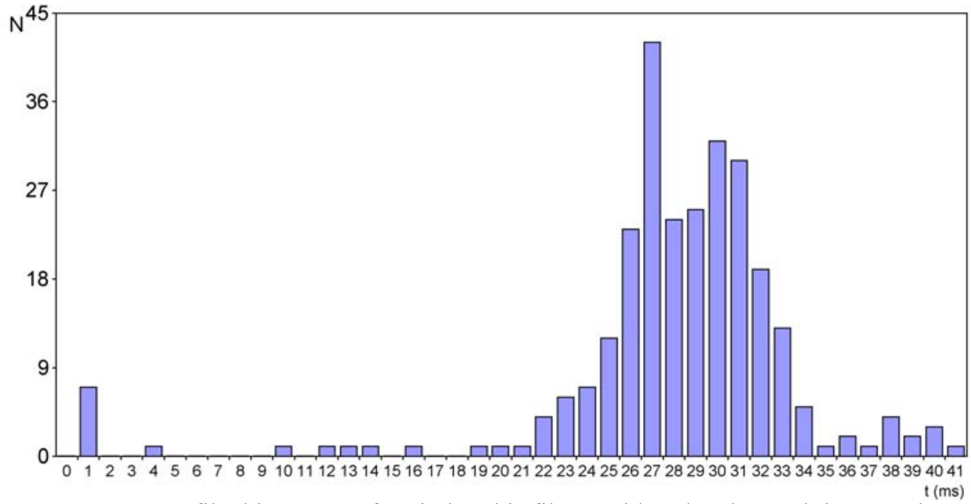

Figure 8. DIGI20TP.0 file, histogram of periods. This file provides also the total time monitored.

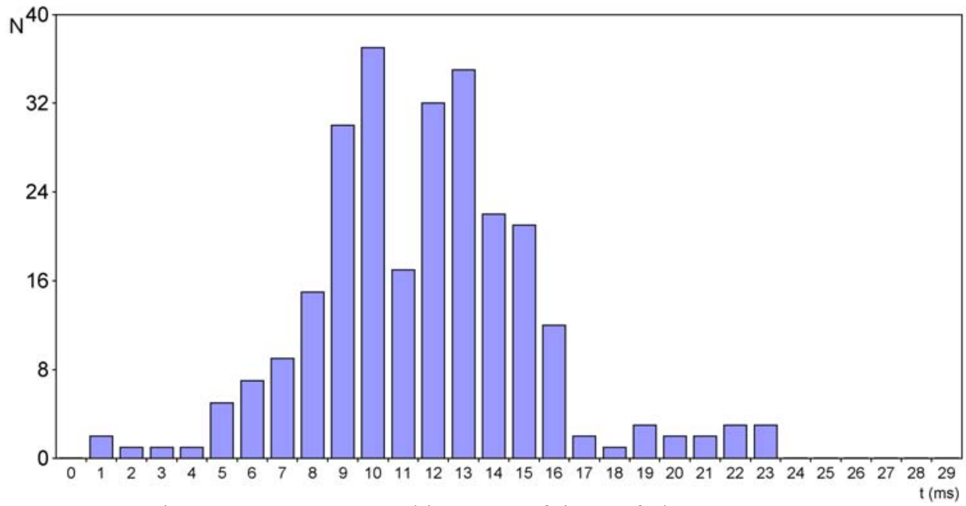

Figure 9. DIGI20TF1.0, histogram of times of phase 1

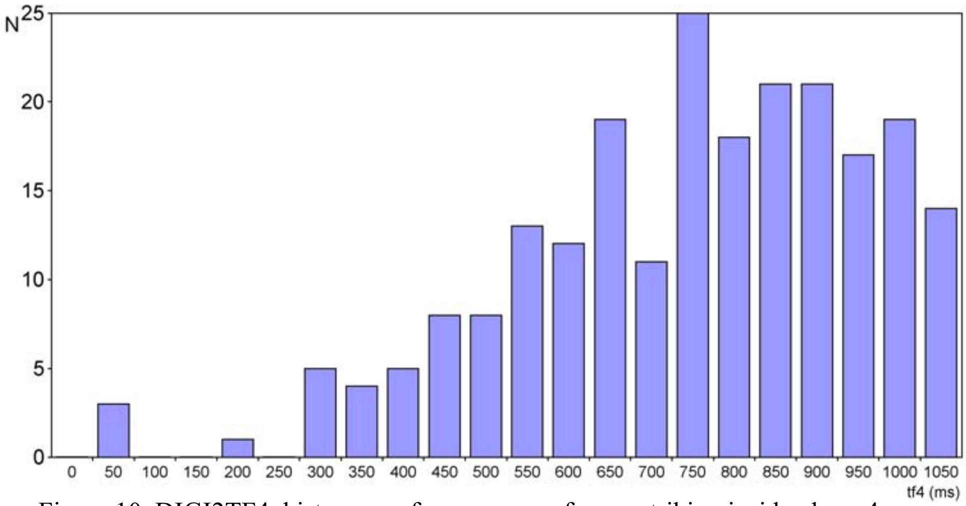

Figure 10. DIGI2TF4, histogram of occurrence of arc restriking inside phase 4.

During the work, another adequate method of stability analysis were noticed, and afterwards, also used: the voltage x current static curve, which is shown in Fig. 11..

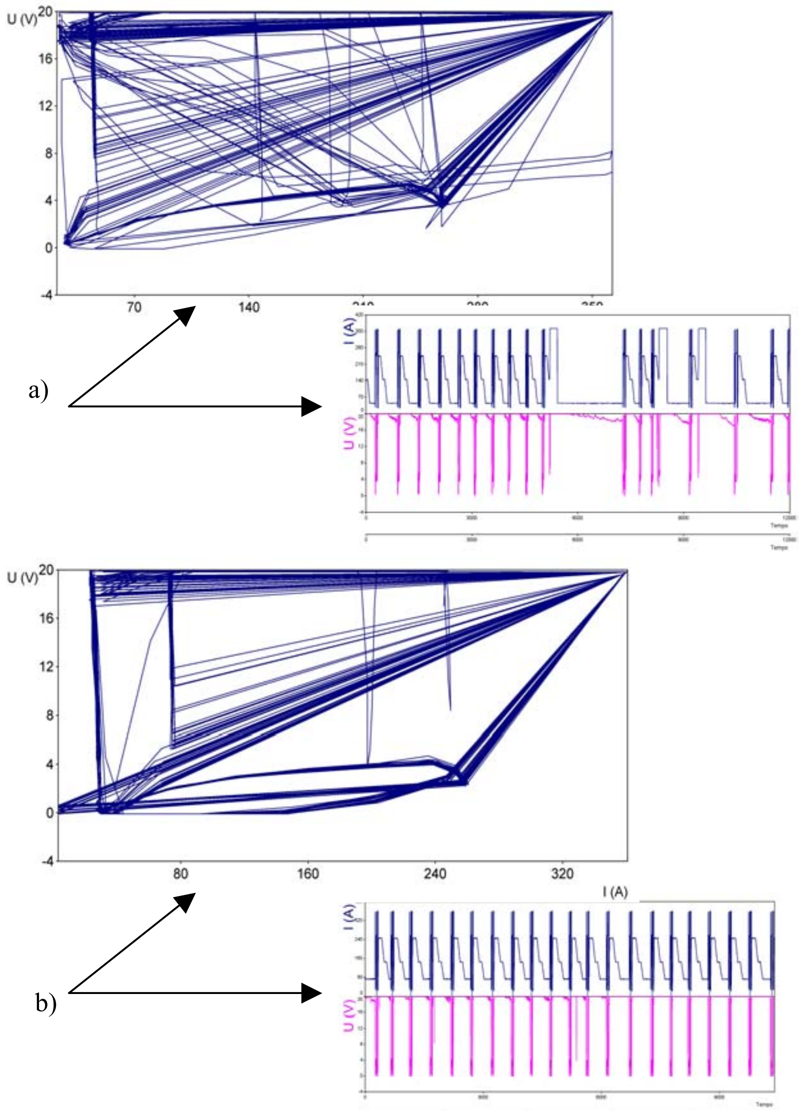

Figure 11. UxI curves: a) unstable case; b) stable case

4. CCC Procedure

4.1 Flat Position

Once a more accurate and reliable method of assessing the results was available, the tests lead to the determination of a procedure to perform root pass welds that simulate the real pipe situation, firstly in the flat position. The joint configuration is shown in Fig. 12..

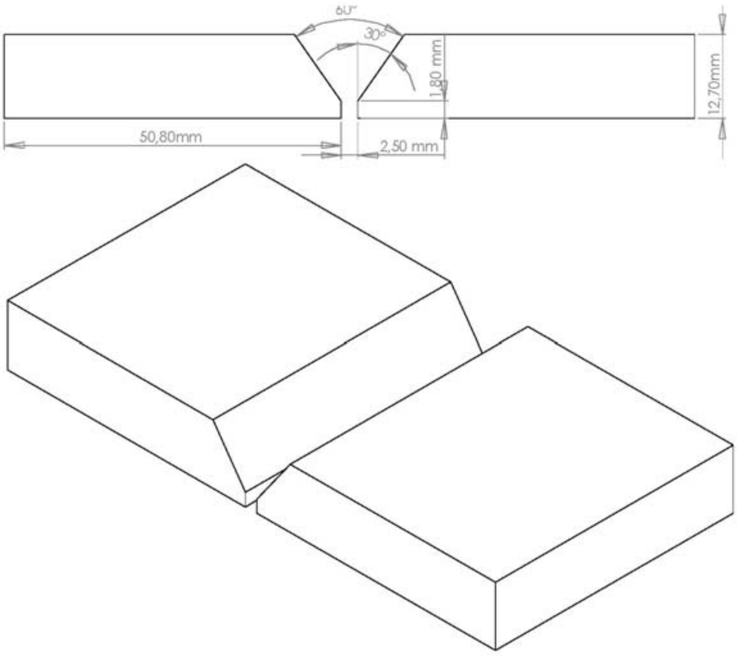

Figure 12. Joint configuration adopted in the tests

In Fig. 13 one can see the remarkable spatter reducing provided by the CCC compared to the CE. The procedure is described in Tab. 2.

In this development stage, the power source (LABSOLDA developed INVERSAL 300) was controlled by a computer, where the CCC software ran. In the future, it will be incorporated to microprocessed machines.

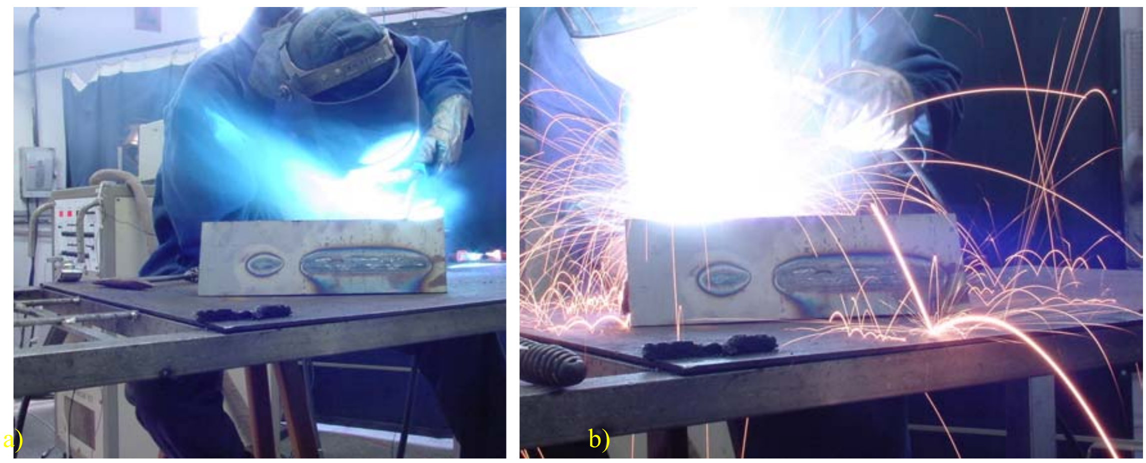

Figure 13. Spatter reduction achieved by the CCC (a)). For comparison, b) shows the CE

Table 2. CCC procedure for the joint above.

Wire	ER70S-6 1,2 mm	**Feed speed**	3 m/min
Gas	Ar + 25%CO_2	**Gas flow rate**	13 l/min
Welding speed	Approxim. 30 cm/min	**Base metal**	SAE 1020 steel
Torch angle	Approxim. 30^o with the normal line, pull technique	**Average current/voltage**	130 A / 19 V

The quality of the CCC welded root pass can be seen in Fig. 14., compared with a root normally gotten with the CE.

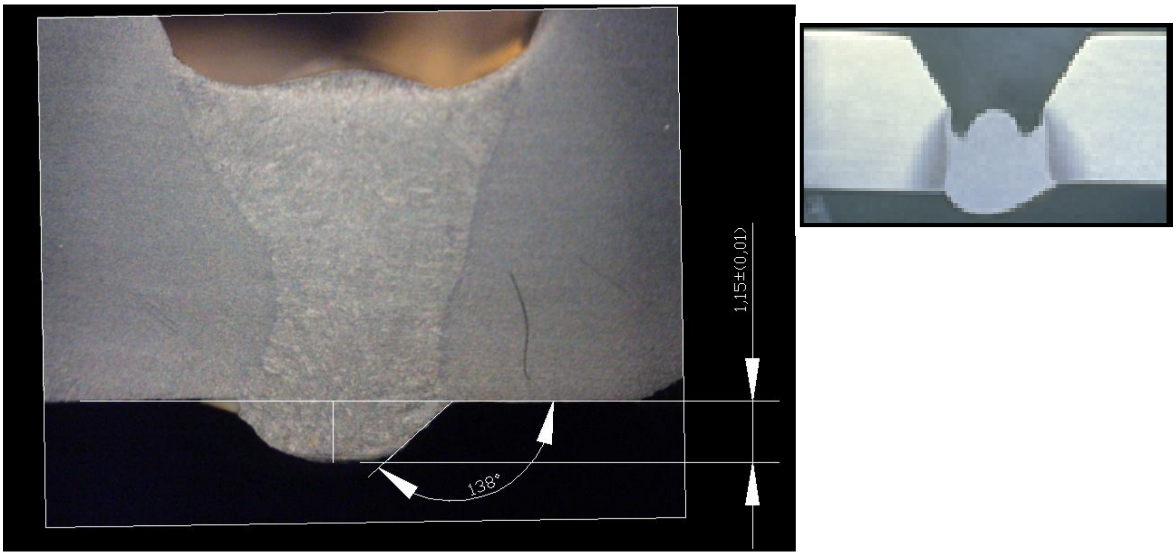

Figure 14. Root passes geometry: a) CCC, b) CE

4.2. Vertical Down Position

In an attempt to develop the procedure for the whole perimeter of weld, some tests were carried out in downwards welding, using the CCC. It was started with the values for the flat position. These parameters proved quickly not to be adequate for this case. Further trials showed some difficulty in finding a regulation suited to this position. Actually, it is known that the vertical welds demand also more training from the welder.

Further work is being conducted to find suitable CCC adjusting points for the vertical down and overhead positions. The future objective is a system that can be regulated on line, in real time during the welding, by the welder. As he gets to different welding positions, he acts upon the machine through the torch or a pedal, without stopping the weld. Then, the machine responds by delivering the adequate CCC parameters.

5. Conclusion

Stability and regularity analysis tools, suited to the CCC were developed. Being a very promising process in increasing the productivity of the pipelines constructors, the use of CCC can now be extended to other welding configurations, materials, gases… The tools (called DIGI2000 Package so far) showed their usefulness in developing the CCC as a process, and are of most interest when finding other applications for it.

Further experiences are being carried out to determine a welding procedure for the whole weld girth in thick wall pipe weld.

6. References

BAIXO, C. E. I. **Estudo da soldagem MIG/MAG pela técnica hiperbárica a seco**. 1999.169 f. Tese (Doutorado em Engenharia) – Universidade Federal de Santa Catarina, Florianópolis.

EASSA, H. E. et al. A High Performance Welding Power Source and its Application. **IEEE**. p. 1241-1244. 1983.

MARUYAMA, T. et al. Current Waveform Control in Gas Shielded Arc Welding for Robotic Systems. **Kobelco Technology Review.** n. 18, p. 10-14, Apr. 1995.

MILLER'S new, software driven RMD process overcomes short circuit MIG limitations. **MILLER NEWS RELEASES.** Appletown, jan. 2004. Disponível em www.millerwelds.com Acesso em mar. 2004

STAVA, E. K. New Surface Transfer Tension Process Speeds Pipe Welding. **Pipe Line & Gas Industry**. v. 82, n. 9, p. 55-57, Sep. 1999.

WOHLFAHRT, H. et al. Metal inert gas welding of magnesium alloys. **Welding and Cutting**, Duesseldorf, v. 55, n. 2, p. 80-84, fev. 2003.

7. Responsibility notice

The authors are the only responsible for the printed material included in this paper.