Controlled Short-Circuiting MIG/MAG Welding Process (CCC) Applied to the Root Pass in the Construction of Offshore Oil Pipelines – Process Analysis Tools

Régis Henrique Gonçalves e Silva
Jair Carlos Dutra
Raul Gohr Jr
Moisés Alves de Oliveira
Welding Laboratory, Mechanical Engineering Department, Technology Center, Federal University of Santa Catarina
(LABSOLDA – EMC – CTC – UFSC)
Florianópolis, Santa Catarina, Brazil

ABSTRACT

This work consists in the study and development of the Controlled Current Short-circuiting MIG/MAG (or GMAW) Welding (CCC) with enphasis on the analyis tools designed specifically for this process.
Currently, root pass in pipe welding is performed predominantly with SMAW, of inherent lower productivity. The semi-mechanized, slag free process herein developed (CCC) yields satisfactory properties welds with higher productivity, obtains the advantages of short-circuiting metal transfer and avoids its inconveniences by means of current waveform control, providing arc and weld pool stability with low welder training time. The developed software based CCC analysis tools are described.

KEY WORDS: root pass; pipeline; oil and gas transport; welding; productivity; mechanization.

INTRODUCTION

One of the biggest challenges in today's production area is the seek for productivity increase. Especially in a global marketplace, 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 root pass welding can be, and indeed is predominantly performed by means of the SMAW process in brazilian pipelines construction plants. Due to its nature, compared to the GMAW process, the SMAW 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 SMAW.

What lacked before was some (GMAW) 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 GMAW, it is a slag free, continuously wire fed process. The difference lies on its very low spattering and high drop transfer regularity and consequently low average current variation. This last feature is specially desired in offshore aplications, since the sea balance would increase the tendency of variation in the contact tip-to-work distance (CTWD), implicating in increased current variation and root heterogeneities, as well as tendency to lack of fusion and burn through. Other GMAW modes, 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). Additional advantages can be achieved by the CCC technology: 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 this, formulation and implementation of unprecedented process analysis tools dedicated specifically to the CCC were imperative. 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.

WAVEFORM DETERMINATION

Several philosophies of waveforms are either on the market or have already been investigated in some scientific and/or technological work. The Welding Laboratory of the Federal University of Santa Catarina (LABSOLDA/UFSC) started investigating this GMAW variant in the

90’s and the application by that time was hyperbaric welding. The final goal then was underwater dry welding for the oil and gas industry.
Fig. 1 shows some of the waveforms in the literature, and Fig. 2 shows the first LABSOLDA’s software controlled version.

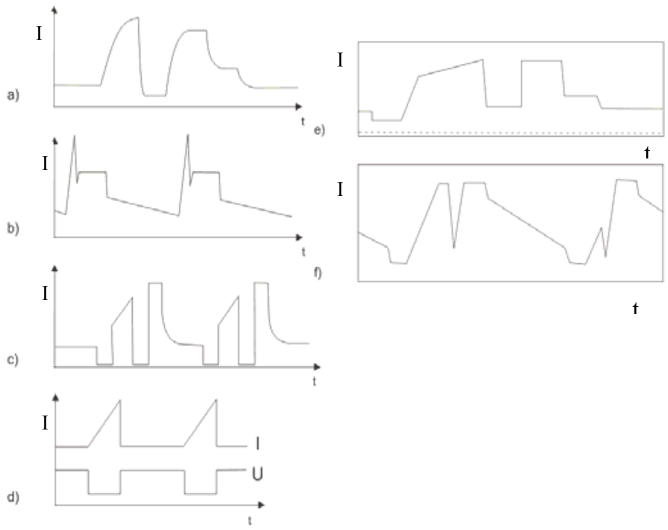


Figure 1. Different designs of current waveform used in current controlled short-circuiting MIG/MAG welding: a) Wohlfahrt, 2003; b) Wohlfahrt, 2003; c) Stava, 1999; d) Eassa, 1983; e) MILLER COMPANY, 2004; f) Maruyama, 1995.

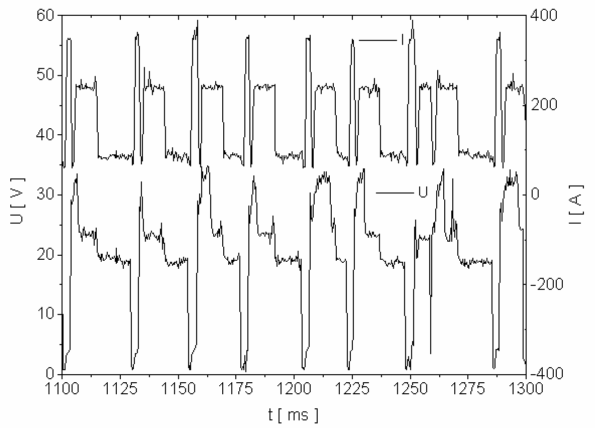


Figure 2. Three level waveform, first used at the LABSOLDA. (Baixo, 1999).

Each of these philosophies has its own process control strategy and objectives. Most of them, 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 maintainance. 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 welding circuit voltage. Also liquid bridge dynamics is monitored for collapsing imminence detection. 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.

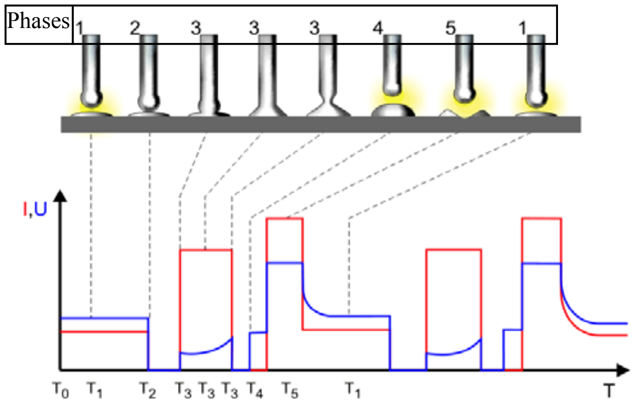


Figure 3. Regular phases of most controlled current short-circuiting MIG/MAG welding systems.

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. Fig. 4 shows this waveform, the CCC itself.

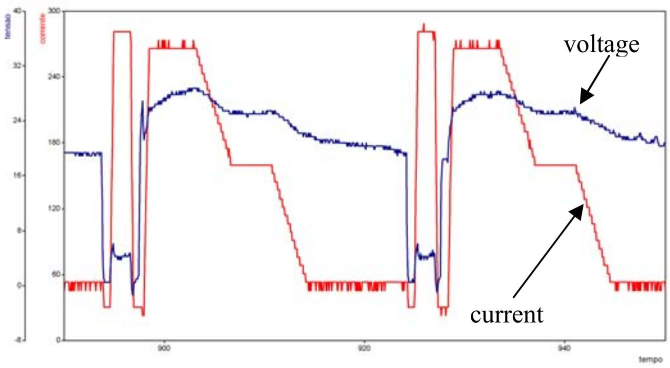


Figure 4. CCC waveform, with two slopes between phase 5 and 1. (red-current, blue-voltage).

DEVELOPMENT OF THE CCC PROCESS ANALYSIS TOOLS

In order to refine the waveform, some software 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. Only in this way could the process be evaluated and developed along the experiments.
Then, it was decided that each weld made would provide a files package (named DIGI2000 Package), which, transformed in histograms, show the system’s performance. Table 1 shows the files and their respective functions.

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. In fact, the files consists in data tables of welding time, current, voltage and resistance. As mentioned before they are input in a graphic generating software yielding histograms, oscillograms and graphics. The files that originate histograms (DIGI20TA, DIGI20TC, DIGI20TP, DIGI2TF1, DIGI2TF3, DIGI2TF4) also output the total number of occurences of that specific phase throughout that weld (in the case of DIGI2TF4, differently, the number of arc restrikes in phase 4). For example, besides the time distribution (histogram) of all "phases 1", the file DIGI2TF1 also provides the number of "phases 1" that occurred in a weld (consequently, the number of short-circuits). The histograms permit a regularity analysis.

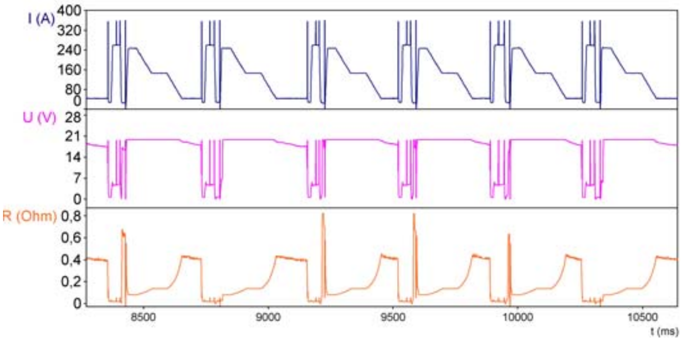


Figure 5. DIGI2000.0 file.

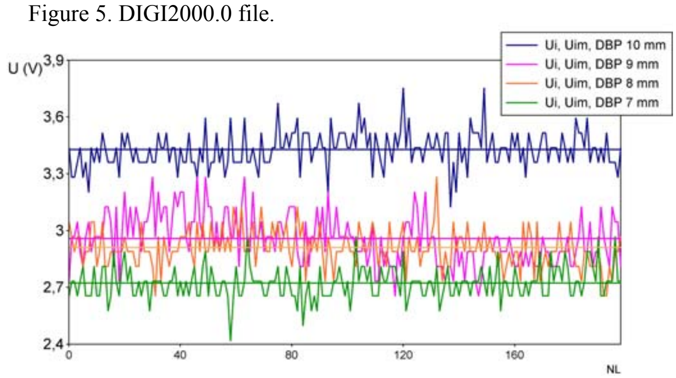


Figure 6. DIGI 200R.0 file, providing CTWD reading through voltage (U).

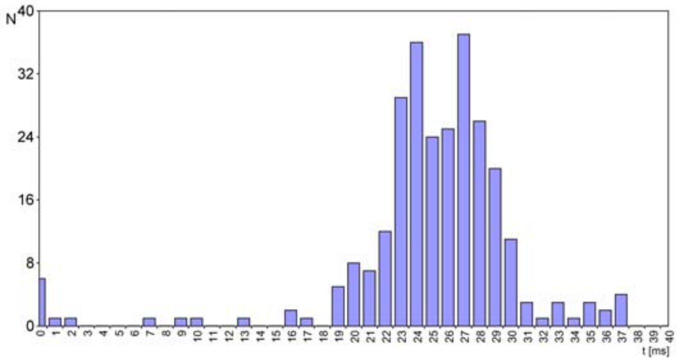


Figure 7. DIGI20TA.0, histogram of arcing time for each droplet transfer.

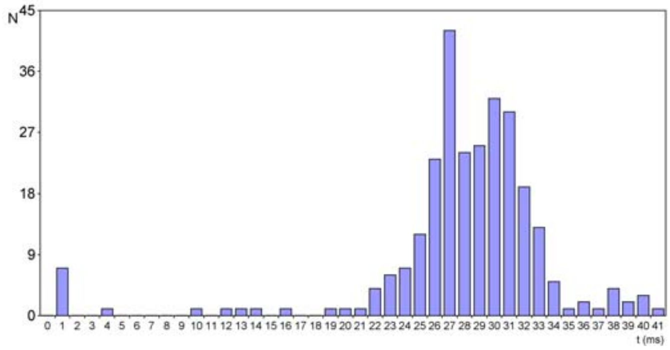


Figure 8. DIGI20TP.0 file, histogram of periods. This file provides also the total time monitored.

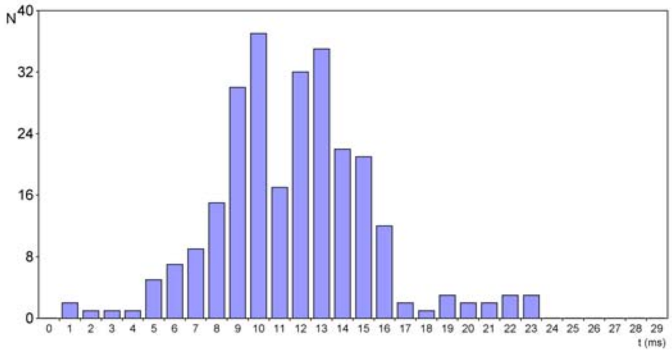


Figure 9. DIGI20TF1.0, histogram of times of phase 1

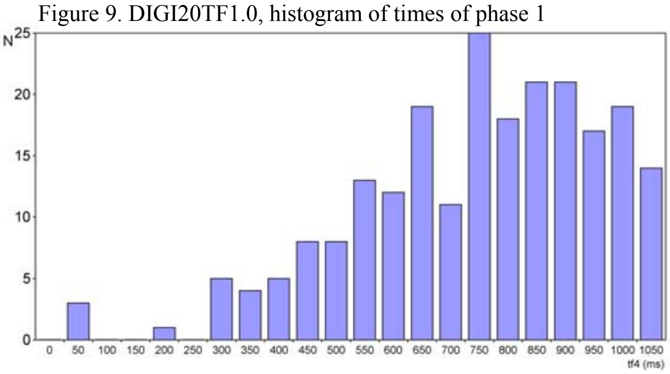


Figure 10. DIGI2TF4, histogram of occurrence of arc restriking inside phase 4.

The histogram in Fig 10 translates more than the regularity of the welding. Actually, it also gives information about the efficiency of the regulated CCC variables and parameters in reducing the spatter generation. That is, if most arc restrikings are ocurring inside phase 4 (low current) and, additionally, the restrikings concentration is central or a bit displaced to the end of this phase, that represents a good situation. Better explained: it is well known that even weld machines with best dynamics have a certain current drop rate. So, a current transition from phase 3 to phase 4 is actually a slope, rather than a straight fall. If the restrikings were concentrated in the inicial part of phase 4, they would more likely occur inside the current fall, still at a high current. And more likely the restriking would be violent, with higher spattering.
During the work another adequate method of stability analysis was noticed and used: the voltage x current static curve, which is shown in Fig. 11. The cleaner the graphic, the more regular the metal transfer (or vice-versa).

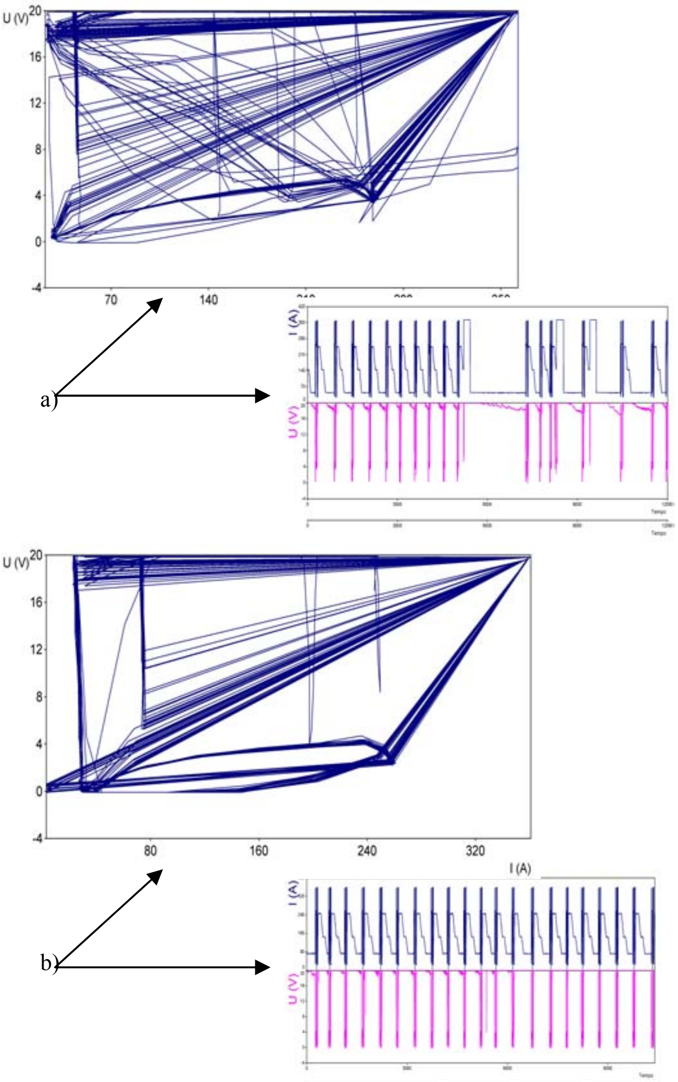


Figure 11. UxI curves: a) unstable case; b) stable case.

FLAT POSITION CCC PROCEDURE

Once an 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.

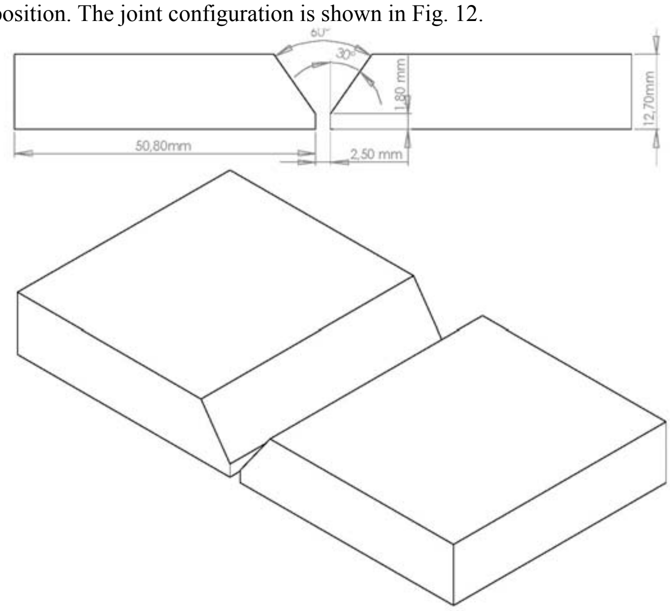


Figure 12. Joint configuration adopted in the tests.

In Fig. 13 one can see the remarkable spatter reduction provided by the CCC compared to the SMAW. The procedure is described in Tab. 2.
In the present development stage, the power source (a multiprocess electronic machine developed by LABSOLDA) is controlled by a computer, where the CCC software ran. In the future, it will be incorporated to microprocessed machines.

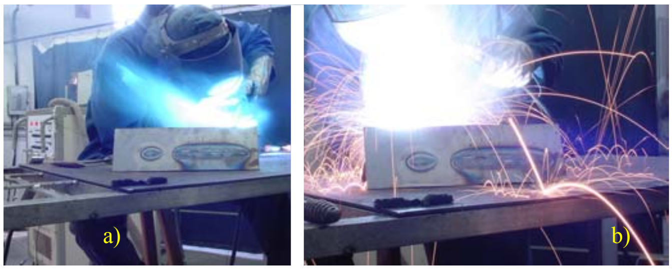
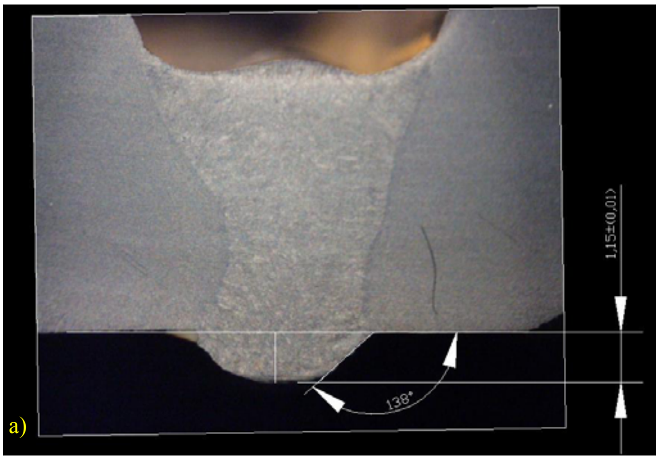


Figure 13. Spatter reduction achieved by the CCC (a). For comparison, b) shows the SMAW.

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 obtained with the SMAW.



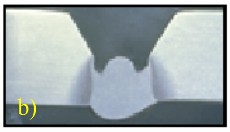


Figure 14. Root passes geometry: a) CCC, b) SMAW.

PROCEDURE FOR THE 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. Spatter increased significantly and the pool tends to flow down. Further trials showed some difficulty in finding an adjusment set 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.

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 analysis 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. Additionally, the methodology materialized in the DIGI2000 Package and the type of information generated can be useful for monitoring any other system working with controlled current short-circuiting GMAW technology.

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

REFERENCES

Baixo, C. E. I. Estudo da soldagem MIG/MAG pela técnica hiperbárica a seco (Study on dry hyperbaric MIG/MAG Welding). 1999.169 p. Thesis (Engineering Doctorate Thesis) – Federal University of Santa Catarina, Florianópolis, Brazil.

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. Availabe at www.millerwelds.com Access on 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.

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