

FEASIBILITY STUDY OF NON-CONVENTIONAL PARAMETERS FOR DISTURBANCES MONITORING AND DETECTING IN SHORT CIRCUIT GAS METAL ARC WELDING

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Abstract. *The welding is one of the manufacture processes most used in the metallic building industry. When the welding reached industrial scales, the demands and quality requirements also were multiplying. To guarantee the welding quality certain issues should be considering, as visual inspections, non-destructive testing and destructive testing. Usually, these inspections and tests are made after the welding process that increases the final production cost, because they need necessary qualified technicians, sophisticated equipment and working hours. During the welding, the electric arc generates physical phenomenons as the infrared emission, electromagnetic fields, luminosity, acoustic pressure, and so one. Some those phenomenons are noticed by experienced operators to monitor and to control the welding operations. Based on that fact, in the present work was made a study of feasibility to use the sensing some of these phenomenons to monitoring and detection of disturbances welding that could be interpreted as defects. With a preset optimal welding parameters setting on the power source, were made two bead on plate welding experiments groups. The first experiments group was welds free of the interferences in the weld trajectory on the plate. In the second group the welds were made with induced interferences in the weld trajectory on the plate. In both experiment groups were acquired luminosity intermitence, infrared radiation and acoustic pressure signals generated by the electric arc in the GMAW process. After multiple analyses based on sensorial fusion and statistical techniques it was ended that is possible monitoring and to detect disturbances in welding starting from sensing of some phenomenons produced during the welding.*

Keywords: GMAW, Parameters, Monitoriment, Disturbances, Detection.

1. INTRODUCTION

Gas Metal Arc Welding (GMAW) is widely used in industry due to its high metal deposition rate, flexibility and low cost. It is attractive for high-productivity manufacturing application and is well suited to automatic or robotic welding (Bingul, 1999). To maintain the high-productivity followed from a high weld quality, the process monitoriment is indispensable. The welding quality is a function of many factors: satisfactory welding parameters selection, maintaining the same parameters in production, monitoring internal and external changes in the process and correcting them (Bingul, 1999). Therefore, the monitoring of the weld quality is very important to avoid time-consuming, post-weld and repair (Wu *et al.*, 2007). Many sensing systems have been designed to monitoriment the weld quality. The arc voltage and welding current monitoring are the most used on-line quality meter because these parameters are inherent process parameter and also responsible for the stability in the welding process. The curves of transient values over time of these two parameters reflect many peculiarities of the welding process in their shape. Each kind of arc welding process is characterized by certain transient variations of the welding voltage and current typical of the process (Adolfsson *et al.*, 1998). Any disturbances or faults occurrences during welding inevitably result in the variation of the transient values to some extent and therefore the sensing and examining the welding voltage and current can be used to welding quality monitoriment (Wu *et al.*, 2007). The present work proposes the study of any non-conventional welding parameters that can be used to evaluate the welding quality.

1.1. Welding Parameters Monitoring for the Quality Evaluation

There are many welding process parameters classifications. Cook *et al.* (1997), separates these parameters on two categories: direct weld parameters (bead width, penetration, porosity, etc.) and indirect weld parameters (current, voltage, travel speed, etc.). However, Cook does not mention any welding phenomenons produced by the electric arc (WPA). The American Welding Society (AWS) separates the welding parameters into input weld parameters (IWP) and feedback weld parameters (FWP). In the AWS classification the WPA are not clearly represented in the FWP. A modified welding parameters classification is showed in the Fig. 1. In the IWP the fix parameter and adjustable parameter are setting before the start of the welding process. Some adjustable parameter as current and voltage waveform, contact distance tip to work piece (CTWD), wire feed speed and travel speed can be varied on-line during the process. The FWP is separate into direct weld parameters (DWP) and WPA. DWP are those relating to the weld reinforcement, fusion zone geometry, weld mechanical properties, weld microstructure, and discontinuities. IWP are those input variables that collectively control the DWP, such as welding equipment set-point variables, such as voltage

and current waveform, torch travel speed, wire-feed speed, travel angle, electrode extension (stick-out), focused spot zone, and beam power

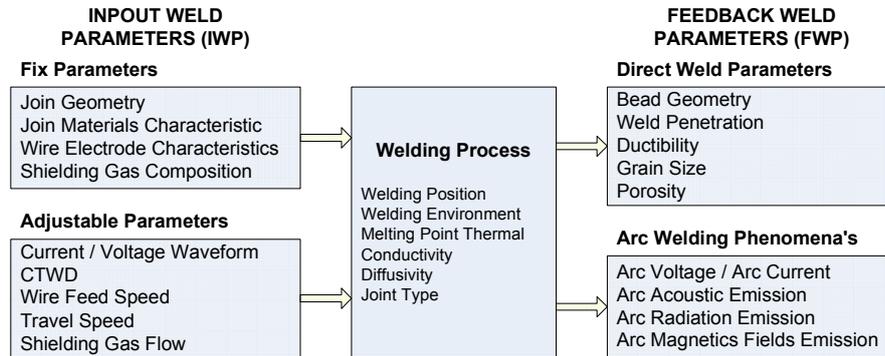


Figure 1. Input and feedback welding process parameters

The welding quality will be considered high when the DWP fulfills with the quality standards established. Therefore is important to determine a set of IWP that will produce the desired DWP. Classically, the arc voltage and arc current are measured to evaluate their disturbance and instabilities to assure the welding quality, (Cook *et al.*, 1997, Adolfsson *et al.*, 1998, Hermans *et al.*, 1999, Quinn *et al.*, 1999, Di, 2000, Wu *et al.*, 2001, Xiaoqing *et al.*, 2005, Luksa, 2006, Wu *et al.*, 2007). Also are measured weld parameters as wire feed speed, travel speed, etc. These measured parameters are known as conventional parameters. During the welding process apart from arc voltage and arc current are produced the WPA's as acoustical, radiation and magnetic fields emission. These last set of WPA is known as non-conventional parameters. Some non-conventional parameters are used by human skill welders to monitors and to evaluate the welding stability. It is a well established fact that human skill welders are able to maintain and direct the welding arc using a combination of their visual and auditory senses (Kralj, 1968).

1.2. Sensors for Quality Control

There are some metallurgical properties, such as porosity and cracking that need to be monitored and controlled on-line to ensure proper weld quality. Some of the visual indications characterizing the weld quality are cracks, porosity, undercuts, micro fissures, etc. (Anderson, 1993). Three levels of on-line quality control have been adopted by the industry (see Fig. 2).

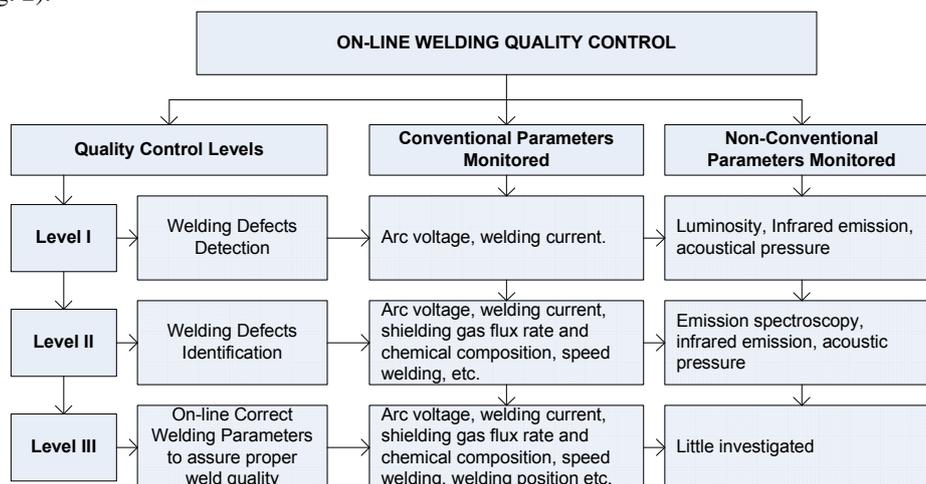


Figure 2. On-line welding quality control levels

In the first level one should be able to automatically on line detect production of bad welds. In the second level, one should be able to search and to identify the fault and what are the reasons for the fault occurrence (changes in welding process induced by disturbances in shielding gas delivery, changes in wire feed rate and welding geometry, etc). In the third level one should be able to correct welding parameters during the welding process to assure proper weld quality (Grad *et al.*, 2004). The conventional parameters (voltage and current welding, shield gas flux rate, speed welding, etc) are usually used to detect and to identify defects. Moreover, the non-conventional parameters are not used enough to evaluate the welding quality. They are some non contact methods to welding process monitoring developed as

acoustical sensing (Drouet 1979, Drouet 1982, Mansoor, 1997, Mansoor, 1999, Polajnar *et al.*, 2007, Poopat, 2006, Cayo, 2007, Cayo, 2008a, Cayo, 2008b, Yaowen 2000), spectroscopy emission (Alfaro *et al.*, 2005, Alfaro *et al.*, 2006a, Lacroix *et al.*, 1999, Mirapeix *et al.*, 2006, Mirapeix *et al.*, 2007, Li, 2000, Sforza, 2002, Szymansky *et al.*, 1997), infrared emission (Fan *et al.*, 2003, Nagarajan *et al.*, 1992, Nagarajan *et al.*, 1989, Wikle III *et al.*, 2001, Wikle III *et al.*, 1999) and some that consist in the sensors combination (Alfaro, 2006b and Bonss *et al.*, 2004).

2. EXPERIMENTAL PROCEDURE

2.1. Data Acquisition Equipments

Virtual instrumentation software, data acquisition card, welding source and an equipment set up as shown in the Fig. 3. They were used for the acquisition and to process data based on the arc voltage, welding current, sound pressure, luminous intermittence and infrared radiation of the arc welding at sampling of 20 kHz. The sound pressure was measured using the analogical output decibelimeter which uses a microphone 4189 (Sensor 1) with $-26 \text{ dB} \pm 1.5 \text{ dB}$, 50 mV/Pa sensitivity. The luminous intermittence was measured using the voltage output from monolithic photodiode with on-chip transimpedance amplifier (Sensor 2); this sensor uses an optical filter with 380 a 430 nm wavelength band pass. The sensors 1 and 2 were positioning together and located to 200 mm from the pool fusion. The infrared radiation was measured using the TL-S-25 pyrometer (Sensor 3). This sensor has a lens array that regulates the focal distance to 600 mm and works on the 800 a 1000 nm wavelength. The sensor 2 and 3 measure the radiation emissions produced by the electric arc. The sensor 2 operates on the ultraviolet region and the sensor 3 operates on the infrared region. The pyrometer was located to 600 mm from the pool fusion due to focal distance. The output pyrometer source a current signal from 4 to 20 mA. As data acquisition card does not has loop current inputs, was used a current loop to voltage converter.

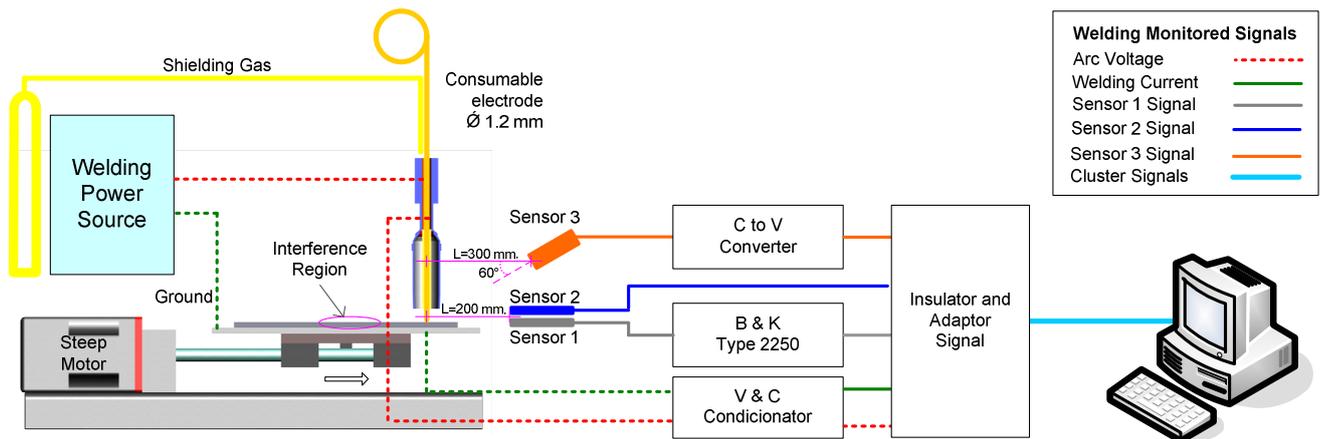


Figure 3. Experimental Setup

2.2. Data Acquisition Parameters

The welding parameters using in the present work is showing in Tab. 1. The welds were carried on steel plates AISI 1020 (30 mm x 200 x 6,50 mm), electrode wire AWS A5.18 ER70S-6 with 1 mm of diameter, shield gas was the mixture of argon and carbonic anhydride M21 (ATAL 5A/Ar 82% + CO₂ 18%). The induced interferences were located on center of the welding trajectory and it was called weld interference region (Fig. 3).

Table 1. Set of Welding Parameters

Arc Voltage [V]	Wire Speed [m/min]	Travel Speed [mm/s]	CTWD [mm]	Shield Gas flow [l/min]
20	6	10	12	15

Was execute 20 weld runs without induced interferences to obtain the non-conventional profiles. Also was made two welding run groups with induced interferences detailed as shown in Tab. 2; the welds were deposited in flat position following a rectilinear trajectory of 180 mm.

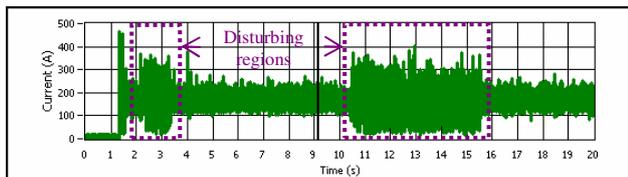
Table 2. Set of Welding Experiments

Weld experiment	
1	Shield Gas absence
2	Paint presence

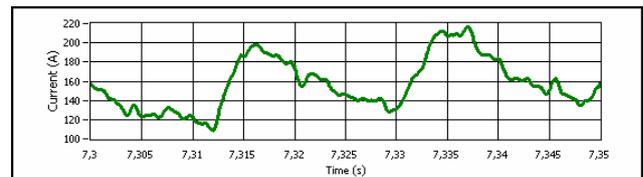
3. EXPERIMENTAL RESULTS

3.1. Welding Parameters Monitored

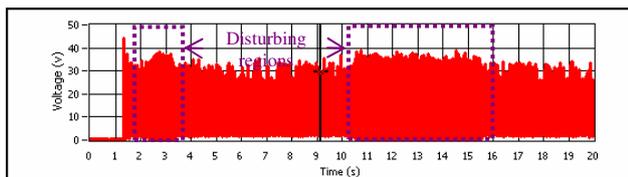
The Fig. 4 shows the sequential charts of the current welding (a), arc voltage (b), sound pressure (c), luminous intermittence (d) and infrared radiation (e) monitored simultaneously.



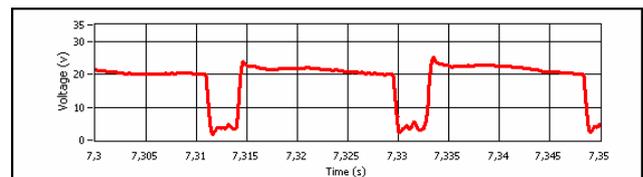
a. Welding Current



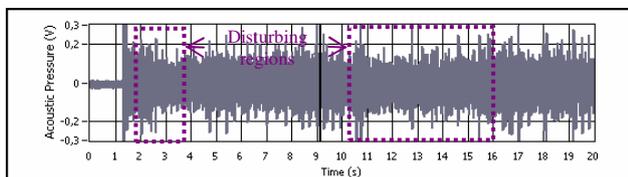
a. Welding Current window



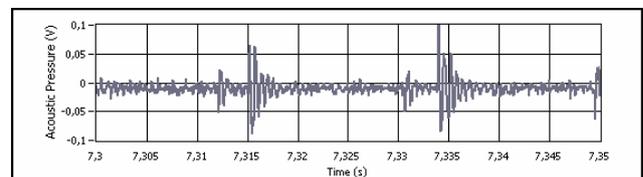
b. Arc Voltage



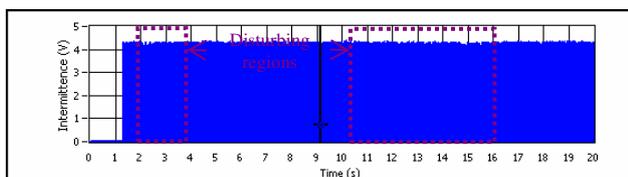
b. Arc Voltage window



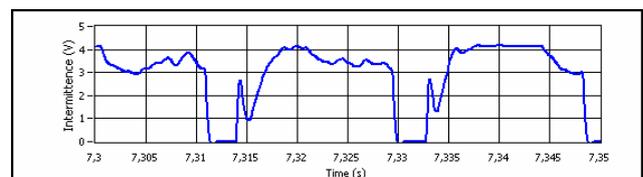
c. Sound Pressure (sensor 1)



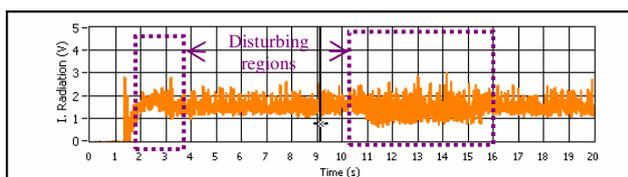
c. Sound Pressure window



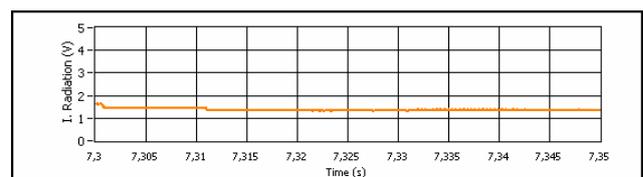
d. Luminous Intermittence (sensor 2)



d. Luminous Intermittence window



e. Infrared Radiation (sensor 3)



e. Infrared Radiation window

Figure 4. Welding Parameters Monitored

Figure 5. Relation between Welding Parameters Monitored

It can be seen that when the welding torch enters the disturbing region of the workpiece (see Fig. 3), all measurement parameters varies suddenly. From the three non-conventional parameters monitored, the pressure sound and luminous intermittence amplitude seemingly do not vary in comparison with the infrared radiation amplitude. But when it is observed on 50 ms data window of each parameter described above, it is possible to notice that the sound pressure and the luminous intermittence have the same effect of the welding current and arc voltage on the dynamic metallic transference of the GMV welding process. (See Fig. 5 - a, b, c, d).

The first non-conventional parameter monitored is the sound signal produced by the electric arc. The sound pressure is a longitudinal mechanical wave, produced by the difference of pressure in a medium that can be solid, liquid or gaseous; in this work the transport medium is the air. The metallic transference from the welding process produces changes in the air volume of the electric arc environment. This air volume changes produces pressure variations that are airborne transported and perceived by the sensor 1. The sound pressure from the electric arc is a consequence of amplitude modulation of arc voltage and welding current (Drouet, 1979). This relation is expressed by the equation (1).

$$S_a(t) = \frac{d(k.V(t).I(t))}{dt} \quad (1)$$

Where: $S_a(t)$ is the amplitude of the sound signal at time t measured in (V), $V(t)$ is the voltage across the arc at time t (V), $I(t)$ is the current flowing through the arc at time t , k is a constant of proportionality.

It can be seen that there are relationship between the conventional parameters behavior (welding current and arc voltage) and the arc sound pressure. The airborne nature of the sound pressure generates a pronounced delay that represents the metallic transference behavior related to arc voltage, welding current and luminous intermittence sensors (see Fig. 5 - a, b, c). Studies in psychoacoustic has determined that if the electric arc sound signal delay does not exceed 400 ms, this will be a good indicator of the behavior weld process (Tam, 2005).

The second and third non-conventional parameters are the luminous intermittence and infrared radiation respectively; these parameters are the indication of the radiation emissions. These emission radiations are originated by the electromagnetic energy emitted for the welding electric arc. The radiation emission occurs at visible (V), ultraviolet (UV), and infrared (IR) wavelengths. Intensity and wavelength of energy produced depend on the welding parameters, electrode and base metal composition, fluxes, and any workpiece material. Visible brightness (luminance) of the arc increases at a much lower rate, but the ultraviolet radiation increases approximately as the square of the welding current (Mitsodie, 2007). This electromagnetic phenomenon is expressed by the Planck's black body radiation law (Eq. 2).

$$L(\lambda, T) = \frac{2\pi c_1}{\lambda^5} \frac{1}{\exp\{c_2 / (\lambda T)\} - 1} \quad (2)$$

Where constants c_1 , c_2 are defined as: $c_1 = 5.9548 \times 10^{-17}$ (W. m²), $c_2 = 0.014377$ (m K) and variable L is defined as $L(\lambda, T)$ (W m⁻³ sr⁻¹) as a luminance temperature, $T(K)$ as a true temperature of objects, and $\lambda(m)$ as wavelength of radiation.

In the Fig. 6 is showed the spectral irradiance to different wavelengths and temperatures calculated using the equation 2. In this figure is can be seen that the on ultraviolet region the radiation emission varies suddenly when the temperature varies but on the infrared region the emission radiation varies too lower. It is the reason for which the sensor 2 that works on the ultraviolet region (see Fig. 6) can represents the extinction and ignition sequence (see Fig. 5 - d) and the sensor 3 which works on the infrared region (see Fig. 6) can not represents the transference metallic behavior (see Fig. 5 - e), but its amplitude decrease lingering when the weld run enters the disturbing region of the workpiece (see Fig. 4-e).

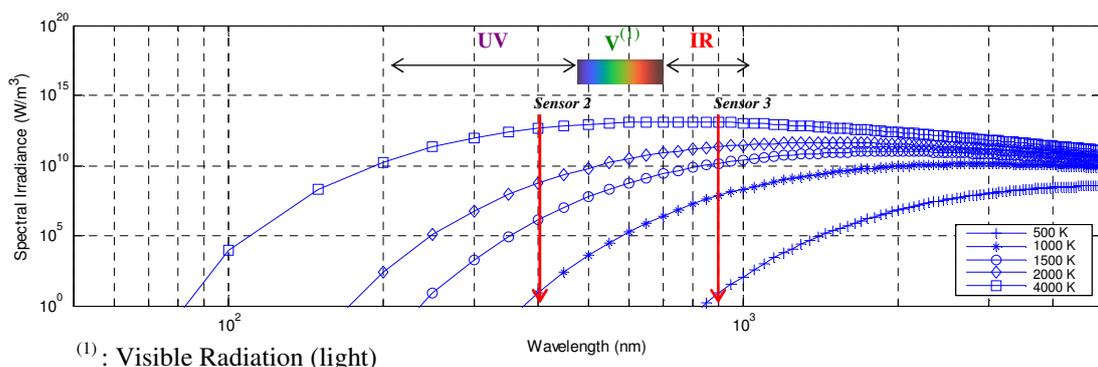


Figure 6. Spectral Electromagnetic Emissions

3.2. Perturbances Detection through Non-Conventional Parameters

The quality control in the welding processes is subject of many researches. The weld quality evaluation is not a trivial task, even for the experienced quality inspector. This is particularly true when it comes to specifying in quantitative terms what attributes of the weld affect its quality and to what extent. Different types of discontinuities have been categorized for this purpose, such as cracks, porosity, undercuts, microfissures, etc. (Cook *et al.*, 1997). Generally, good quality GMA welds are uniform and contain slight or no artifacts on the bead surface. Furthermore, the bead width is relatively uniform along the length of the bead (Cook *et al.*, 1995). To reach the standard weld quality is fundamental maintain the continuity of the welding stability. The stability of the short circuit gas metal arc welding process is directly related to weld pool oscillations (Hermans *et al.*, 1999). Optimal process stability corresponds to maximum short-circuit rate (Number/s), minimum standard deviation of the short-circuit rate, a minimum mass transferred per short circuit and minimum spatter loss, Cook *et al.*, (1992), Adolfsson *et al.*, (1999) and Wu *et al.*, (2001). As the sound pressure and luminous intermittence follows the arc ignition and extinction sequence (see Fig. 5 - c, d) and the infrared radiation follow the amplitude variations of the arc voltage and welding current is expected also that through these signals can be evaluated the welding stability. For the welding stability evaluation using the three non-conventional parameters measured, were calculated the acoustic ignition frequency (AIF) through the arc sound pressure and the luminous intermittence frequency (LIF) through arc luminous intermittence. As the infrared radiation signal information is in its amplitude was made and noise canceling treatment to use it signal also the welding stability evaluation.

3.2.1 Acoustic Ignition Frequency (AIF)

The AIF was calculated counting the acoustic pulses produced every time that an extinction or ignition of the electric arc. The pulses produced were counted to each 250 ms data window of sound pressure. For reach this objective was made a pre-processing treatment of the acoustic signal. As the acoustic amplitude pulses produced by the arc ignitions are greater than acoustic amplitude pulse produced for the short circuits, consequently, the arc ignitions counting are easier than the short circuits counting. For this, in the first place the envelopment sound pressure signal was determined using a quadratic demodulator. Squaring the signal effectively demodulates the input by using itself as the carrier wave. This means that half the energy of the signal is pushed up to higher frequencies and half is shifted towards DC. The envelope can then be extracted by keeping all the DC low-frequency energy and eliminating the high-frequency energy. Nevertheless, due to the sound pressure have a stochastic behavior (Cayo, 2008a), it can be concluded that were needed low-pass filters with an elevated order; a filter with an elevated order produce a pronounced delay and deformation in the envelopment signal. Due to these characteristics of the acoustic signal and the low-pass conventional filter, was used a statistical filter: the “kalman filter”. This statistical filter instead of letting pass low frequencies follows the statistical tendency of the squared signal obtaining in the envelopment sound pressure (Cayo, 2008b). In the Fig. 7 is showed the 150 ms moving window data extracted from the sound pressure signal (as also show in Fig. 5 - c) and can also be observed the sound pressure signal and its envelopment sound pressure. Starting from envelopment sound pressure signal is calculated the arc ignitions for each moving window data. An ignition takes place whenever the envelopment sound pressure signal surpasses the ignition threshold established ($k = 0,1$).

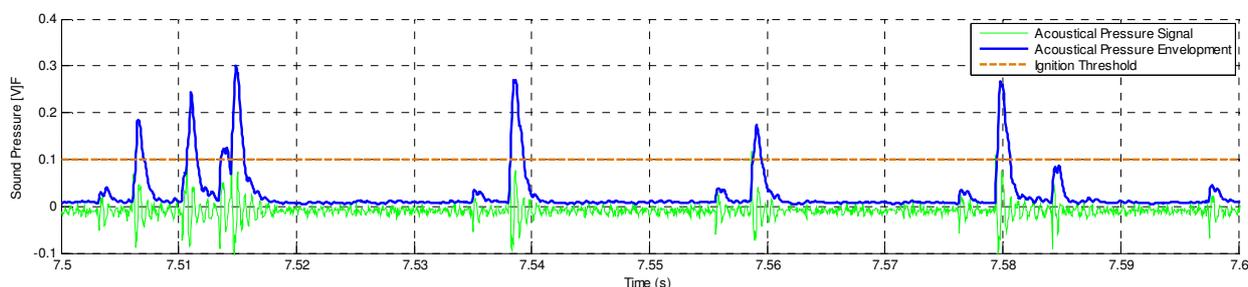


Figure 7. Acoustic Pressure Frequency Parameter

3.2.2 Luminous Intermittence Frequency (LIF)

Contrary to the sound pressure signal, the luminous intermittence signal does not require a pre-processing treatment because the original signal can represent clearly the pool fusion dynamic (see Fig. 4 a, b and d). The luminous intermittence and the arc voltage have the similar behavior. When the arc extinction is produced the luminous intermittence signal amplitude is nearly to 0 volts and when the arc ignition is produced the luminous intermittence amplitude signal change suddenly and oscillates around the 4 volts (see Fig. 8). These sudden changes on the amplitude intermittence signal are counting to obtain the luminous intermittence frequency. As well as in the AIF case, the LIF

was counted to each 250 ms data window of luminous intermittence.

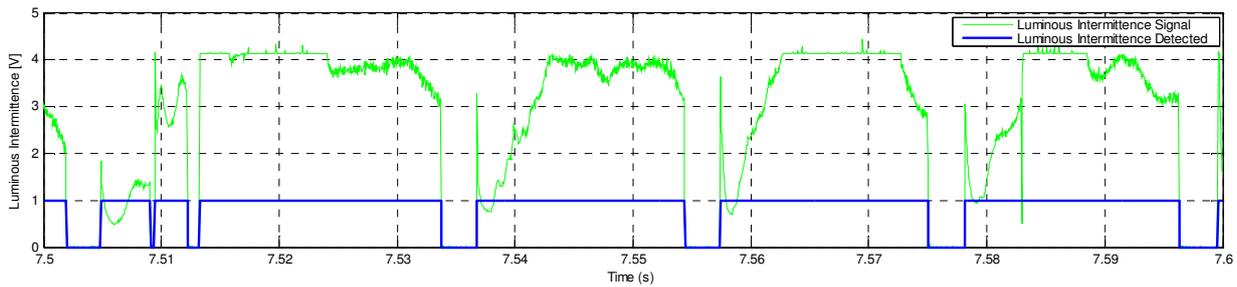


Figure 8. Luminous Intermittence Frequency Parameter

3.2.3 Infrared Radiation

According to explain in the 3.1 section, the infrared radiation does not follow the short circuit and ignition sequence from the electric arc behavior. Nevertheless, after welding experimental was noticed that they are perturbations that produce imperceptible variations on the welding current and arc voltage. In the Fig. 9 is shown the root mean square – RMS of the arc voltage and the infrared radiation. In this figure can be see two perturbation detected clearly by the infrared radiation sensor, but these perturbations are imperceptibles o the RMS arc voltage.

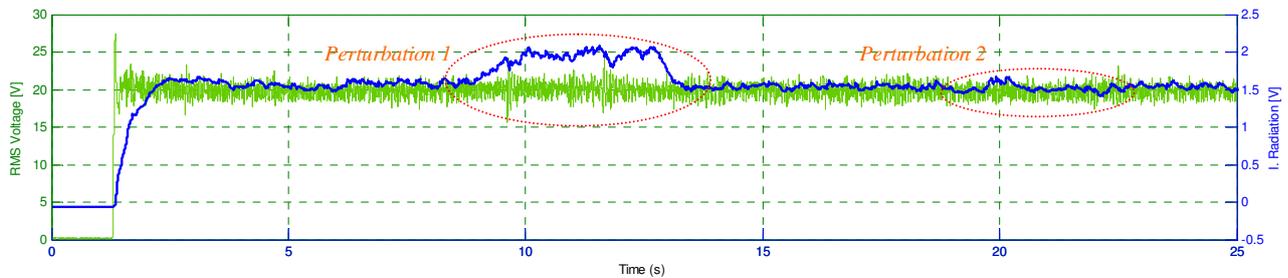


Figure 9. Infrared Radiation and RMS arc Voltage

3.3 Detection of the Induced Welding Perturbances

3.3.1 Profiles for Welding Interferences Detection

The general approach used to evaluate GMA welds was to examine the variation of weld profiles, sampled across the weld bead in a sequence of locations. A high quality weld would generally yield small variation in the weld profiles, while low quality weld profiles would vary substantially, as irregularities and various discontinuities are encountered in the distinct profile scans (Cook *et al.*, 1995). The non-conventional parameters profiles obtained were the acoustic ignitions frequency (AIF), luminous intermittence frequency (LIF) and the infrared level amplitude signal. The profiles were obtained carrying out welding runs without presences of disturbances and their profile values were determined using a moving windows signal of the 150 ms applied on them. The Tab. 3 shows the resultant profile values obtained to each welding parameter.

Table 3. Profile values of the Welding Parameters

Welding Parameter	Average Profile	S.D. Profile
RMS Welding Current (A)	190.00	5.00
RMS Arc Voltage (V)	20.00	1.00
Acoustic ignition frequency (Ign./W) ⁽¹⁾	16.00	1.65
Luminous intermittence frequency (Ign./W) ⁽¹⁾	16.00	0,50
Infrared level amplitude (V)	1.50	0,07

⁽¹⁾: Ignitions per window

The behavior of AIF and LIF information represents the short circuits and ignitions sequence produced during the welding operation. In the Fig. 10 – a, b is showed comparative estimations of the average and standard deviation short circuits per second through the arc voltage, sound pressure and the luminous intermittence to 20 weld runs experiments. This figure similarity between these three results for AIF and LIF as well as arc voltage. The short circuit average

(SCA) obtained from the LIF are closest to the SCA calculated through the arc voltage when compared to the SCA obtained from the sound pressure.

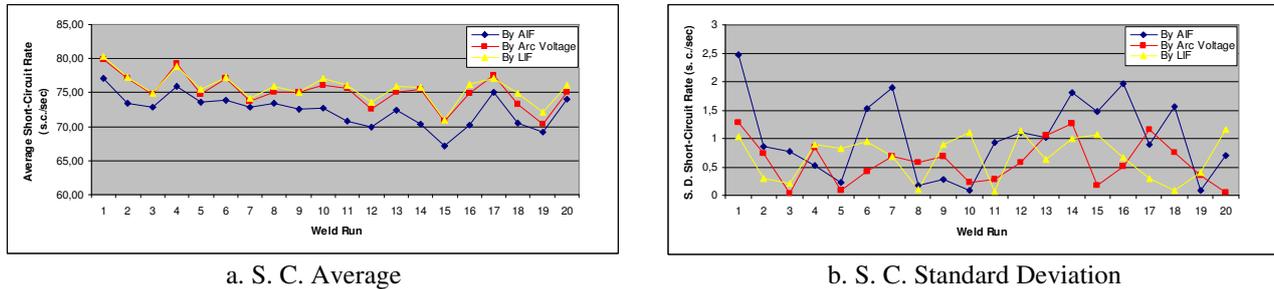


Figure 10. Short circuits average and standard deviation rate measured using simultaneously the Arc Voltage, Arc Sound Pressure and the Arc Luminous Intermittence

3.3.2 Interferences Monitoring and Detection

The disturbances detection was made using a limit control based on the third standard deviation method. This control shows optimal results in the disturbances detection of electric arc voltage and welding current monitoring signals (Cook *et al.*, 1997 and Wu *et al.*, 2007). The Eq. (3), (4) and (5) represents the average, the standard deviation and the disturbances control limits for each moving window data (150 ms) respectively.

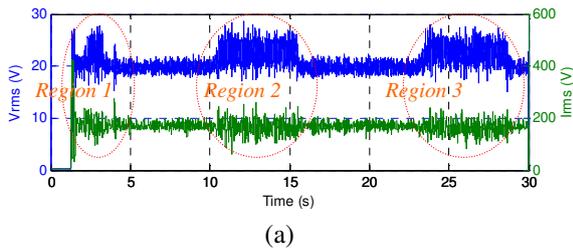
$$\bar{x}_i = \frac{1}{n} \sum_{j=1}^n x_j = \frac{1}{n} (x_1 + \dots + x_n) \quad (3)$$

$$S_i = \sqrt{\frac{1}{n} \sum_{j=1}^n (x_j - \bar{x}_i)^2} \quad (4)$$

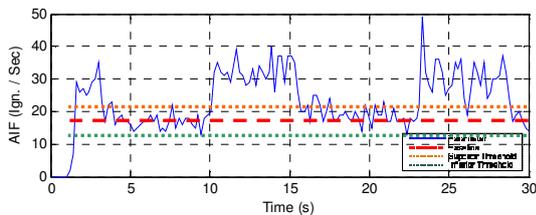
$$\text{Control_Limits} = \bar{P}_N \pm 3 \times S_p \quad (5)$$

Where, \bar{x}_i is the average parameter of the i analysis moving windows (150 ms), x_i is the data i from the moving window, n is the data component number from analysis moving window, S_i The standard deviation for the i analysis moving window data, x_j the j component data from analysis moving window data, \bar{P}_N the signature average established for each parameter, S_p the signature standard deviation established for each parameter.

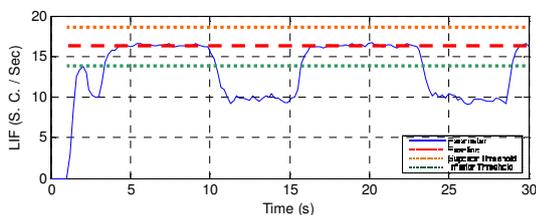
In the Fig. 11 and 12 are showed the parameters behavior for the set weld run experiments described in the Tab. 2. The baselines from the non-conventional parameters chart in both figures indicate the behavior of the desired parameter; these variations are admissible when the parameter signals oscillate between the superior and inferior threshold control limit (third standard deviation value). Oscillations outside of this band are considerate as interferences presence on the weld bead. The Fig. 11 (a), (b), (c) and (d) show the RMS arc voltage and RMS welding current, AIF, LIF and infrared radiation respectively. To simulate the interference due to absence shield gas protection of the electric arc was closed the source valve welding gas cylinder in three regions (see Fig. 11-a). These interferences have lead to porosities formation and higher spatter level. When the weld enter on the interference region the RMS welding current has incremented suddenly and RMS arc voltage and oscillates chaotically, the AIF parameter has incremented suddenly whereas the LIF has decremented on the three interference regions. The infrared radiation also varies chaotically during the interferences. These parameters were varied because the absence of the shield gas causes contamination in the arc welding environment originating the incomplete metallic transference, increasing the short circuit and ignitions rate. The Fig. 12 (a), (b), (c) and (d) show the RMS arc voltage and RMS welding current, AIF, LIF and infrared radiation respectively to one bead when the weld enter on the interference region simulated taking paint on the plate. Under this condition, the induced perturbation not affected the RMS welding current and RMS arc voltage. The AIF parameter has incremented slightly whereas the LIF has decremented also very slightly, but the infrared radiation has incremented suddenly during whole interference. The paint presence on the plate generates temperature variation on the pool fusion when the torch welding enters the interfered region. These temperature variations do not vary significantly the short circuit and ignitions sequence and therefore the AIF and the LIF parameters do not indicate clearly the interference presence on the weld trajectory. The infrared radiation sensor could detect the disturbance when the weld enters on this interference region.



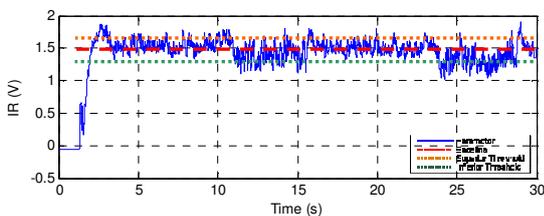
(a)



(b)

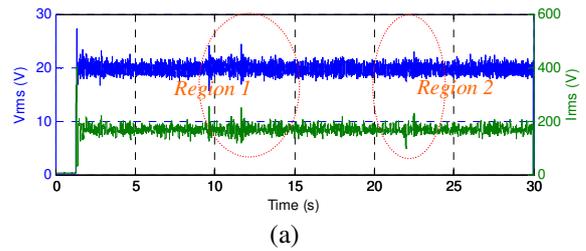


(c)

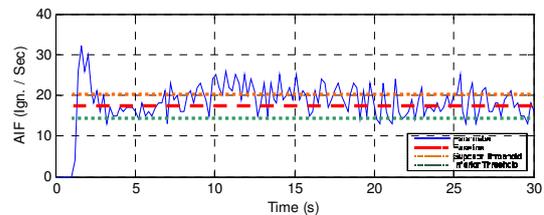


(d)

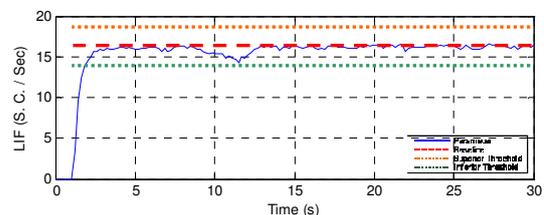
Figure 11. Shield Gas absence Experiment



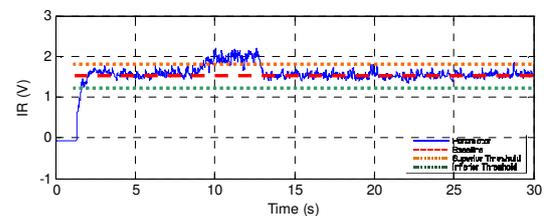
(a)



(b)



(c)



(d)

Figure 12. Paint presence Experiment

4. CONCLUSIONS

Signals of the arc voltage, welding current, sound pressure, luminous intermittence and infrared radiation were tested to monitor the welding process. Each non-conventional parameter signal has a characteristic behavior when they are under abnormal interferences on the welding trajectory and, therefore can be concluded that the three non-conventional parameters monitored can be used for welding monitoring. From sound pressure were calculated the AIF, from sound pressure were calculated LIF, the infrared radiation signal was used to directly monitoring the welding process. The monitoring of the GMAW-S process by digital analysis of these three non-conventional welding parameters enables to detect disturbances related to phenomena that take place in welding arc and can influence the welding arc stability. This fact shows that the three non-conventional welding parameters are a non-intrusive potential tool that can be used for the weld quality evaluation.

The gas shielding absence with the paint presence affects the whole protection of the welding pool. The paint presence and the lack of shielding gas affect the gas shield of welding arc. Oxygen, nitrogen and hydrogen as components of the air or the products of decomposition of paint change the welding arc shield properties as ionization potential, the surface tension of molten metal, the condition of welding arc ignition and other essential conditions of the arc burning.

The instability profiles can be used to identify each type of induced disturbance. The instabilities and disturbance identification in real time based on the three non-conventional welding parameters can become a feasible approach to control the GMAW welding process promotes the increase the productivity and quality assurance

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