ACOUSTIC MONITORING OF THE WELDING PROCESS

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Abstract. *Welding still is the cheapest way of joining two metal pieces permanently, but the process of metal fusion by the electric arc is surrounded by uncertainties. Nowdays, not even the most sofisticated welding equipment is able to guarantee 100% of reliability, and non-destructive testing is imperative for quality control. The sound of the welding process is intimately connected with the arc phenomena, carrying useful information for real-time monitoring and quality control. Sound monitoring is non-invasive and low cost, and it is able to detect position error, misalignment, burn-through and defects related to the arc phenomena. This paper reviews the available state of the art, and the tests that reproduces the parameters necessary for acoustic detection of defects.*

Keywords*: welding defects, acoustic monitoring, real-time control, quality control.*

1. INTRODUCTION

Despite the constant need to acquire information surrounding the welding phenomena, there are only a few methods that are effective and available to capture this information, and the reason being is the number of technical difficulties involved. The heat, light, sparks, fumes, acoustic and electromagnetic noise emitted by the electric arc during the process, make the use of conventional measurement techniques unsuitable to fully understand the welding phenomena(Futamata et al, 1979a).

According to Mansoor and Huisson (2004), skilled manual welders represent extremely sophisticated and effective feedback control systems. Visual, audio and tactile feedback cues are sensed, and a sophisticated non-linear adaptive controller processes these data and recruits muscles in response. In developing feedback control systems for automated welding, it is useful to study the sources of feedback utilized by skilled manual welders. One such source of feedback is the arc sound produced during welding (Futamata et al, 1979b)

The sound emitted by the electric arc is not only one of the disturbances created during the welding, but is also intimately related to the process, and capable of being an important source of information. Since the human uses sound to control the welding process, the study of this automation process becomes a little more intuitive.

The necessity of automation is growing all over the world, especially in the field of welding, since the working conditions are very prejudicial to man's health.

However, the majority of the welding processes have no adequate method of guaranteeing the success of the operation. In general the industry discards, over-sizes or performs corrective procedures, but in all three cases with economical losses.

It is expected that with the use of a sound feedback system, even if is only partially implemented, is enough to diminish the over-dimensioning and automate the rejection of non-suitable parts.

This paper has as its main objective increase the understanding of how the human being uses the sound to control the welding process and how to transfer this ability to the machines. The secondary objective is to identify different models and spectrums for different metallic transfers; the possibility to study the sources of noise and errors, along with an evaluation of the equipment necessary for this study.

2. METHODOLOGY

For this experiment, the method used by Mansoor and Huisson (2004) was followed, with three experimental groups formed. The first group would verify and map the influence of variations in the electric current, consequently the metal transfer mode, and the impact in the sound of the electric arc. For the second group, evaluations of the other welding parameters, such as stick-out, tension, and travel velocity, were researched as a possible source of modifications in the arc sound. The third is a control group, where the parameter were repeated and analyzed several times with the verification of repeatability and confidence level of the obtained data.

For the experiment a microphone was positioned at 400mm distance of the electric arc at an angle of 45 degrees. A computer notebook and conventional microphones were used for the acquisition of the data. The test were conducted on steel A-36 plates, 3/8 inch thick, with the GMAW welding process using a 0,8 mm solid wire and a “StarGold Tube” shielding gas, which is equivalent to C-25.

For the analysis of data, the SPECTOGRAM v12.0 program was used, which is capable of analyzing the sound within time and frequency domain. The sound was captured and codified in wave format, mono and at 16 KHz sampling. The FFT was run at a resolution of 6 Hz and the median sample time of 300mS. The limitation of 6 Hz resolution, although low for the 0-300Hz range, is the maximum allowed for the software when studying the full range of 0-8kHz. Also, according to Arata (1979), most of the electric arc information detected by the human ear is located in the 707-2245Hz range, and up to 6kHz with electronic equipment, according to Mansoor (2004), but never in the very low range of 0-300Hz.

3. RESULTS AND ANALYSES

3.1. Background noise evaluation

The first analysis was done to identify all the different noises inherent to the process, like the water cooler of the welding machine, the shielding gas flow, the AC and fluorescent lamps reactors electric noise. Since the prevailing sound when the welding machine is turned off is the welding machine water cooler, then the background analysis were done with the recycler turned off , which is shown in Figure 1 and with the welding machine and cooler turned on, shown in Figure 2. The total sound pressure level (SPL) background noise without the cooler is at 52 dB and 60 dB with it. It is very clear that with all the machines turned off, the dominant noise is from the power line and its harmonics, but it can also be detect a small spike at 1 kHz from the fluorescent lamps.

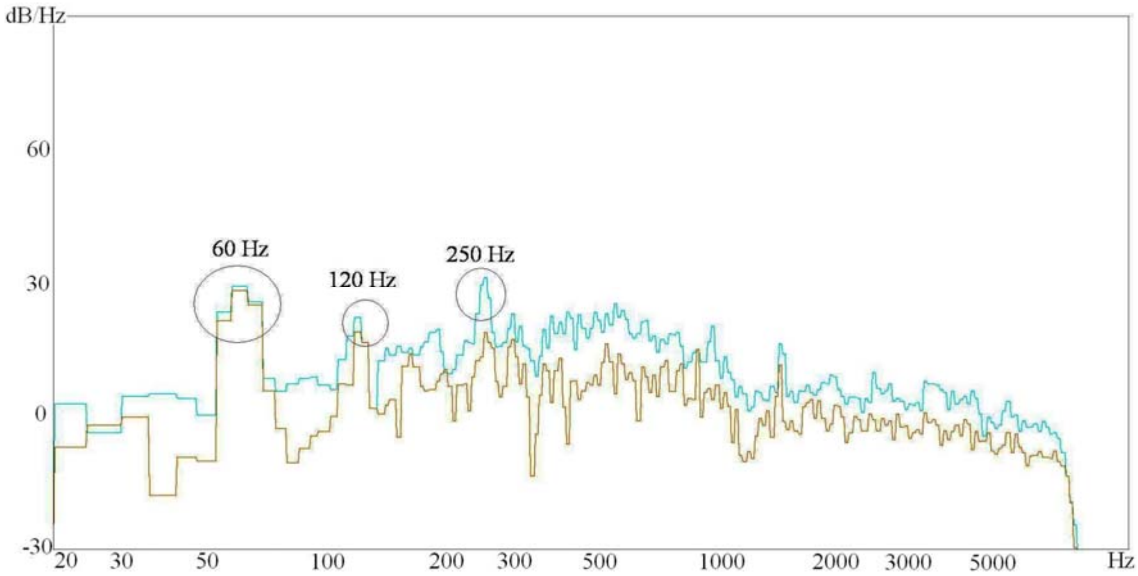

Figure 1. Analysis of the dominant frequencies in the background noise: average (red) and peak (blue).

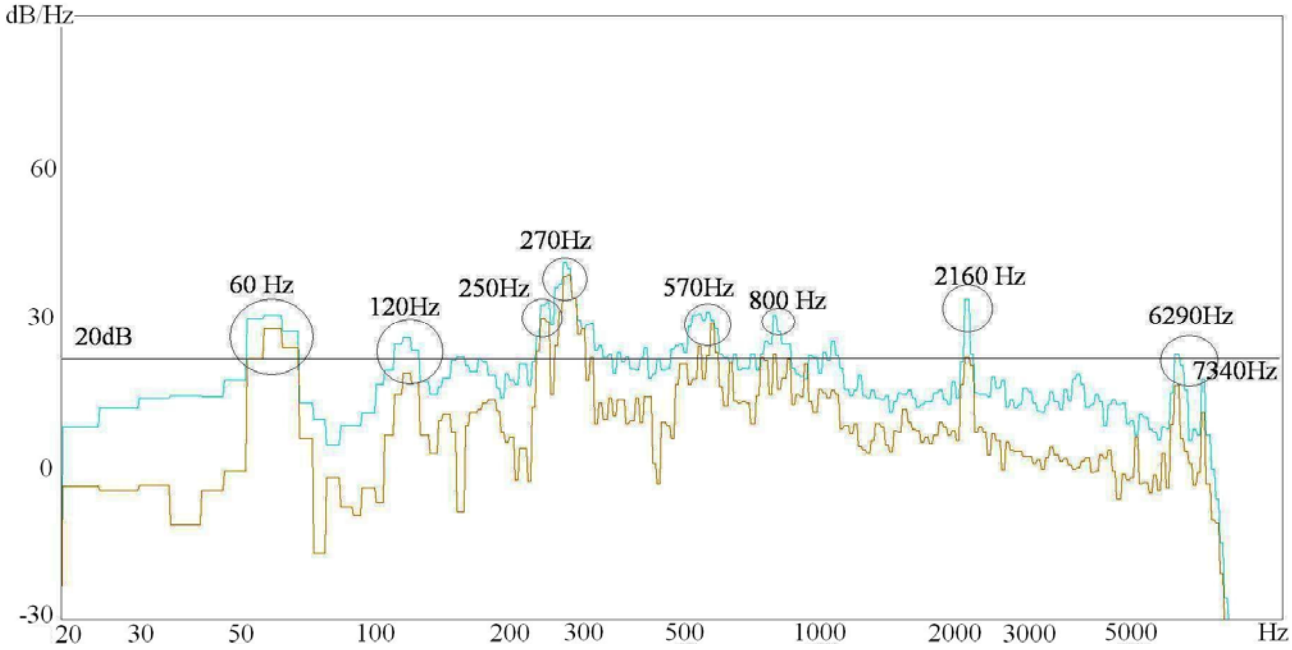

Figure 2.Analysis of the dominant frequencies of background sound and the water cooler: average (red) and peak (blue).

3.2. Sound analysis of the welding process

The initial part of the analysis was done to find out if there is repeatability in the samples spectrum. For this, a control group was formed with welds being made with exactly the same parameters and globular transfer. A comparison of four of these samples, seen side by side in Figure 3, show that although they are not identical, they have a coherent distribution, with the same format and the same sound level(dB) in each frequency.

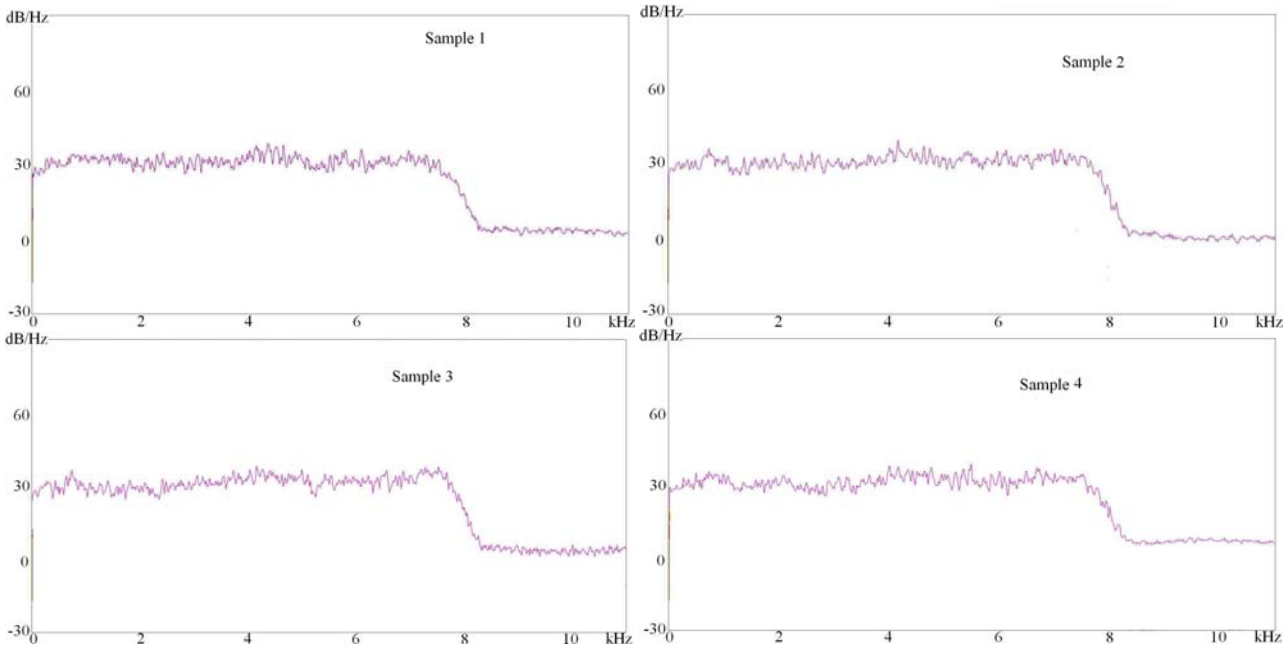

Figure 3. Comparsion of samples in the control group.

Since coherence and repeatability is shown in the analysis, a work of identification of the spectrum characteristics of each form of transference. In the short circuit transference, it was possible to obtain the sharp peaks, with the microphone saturation, which clearly define the short circuit, like in Figure 4.

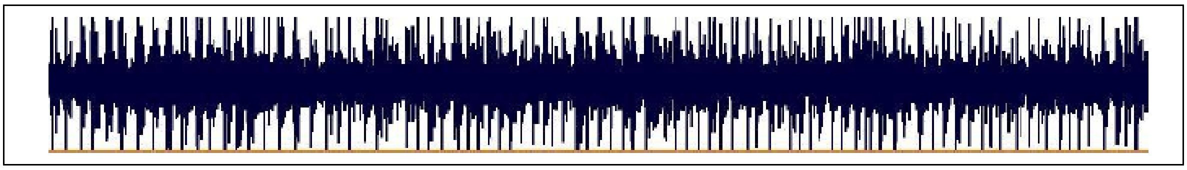

Figure 4. Metallic transference in spray mode displayed in power (volts at input) versus time.

The spectral distribution doesn't show clearly the dominant band because the program only displays a logarithmic scale, however it is still possible to identify that the band is in the same position appointed by Mansoor (2004), observing the noise peak range in Figure 5.

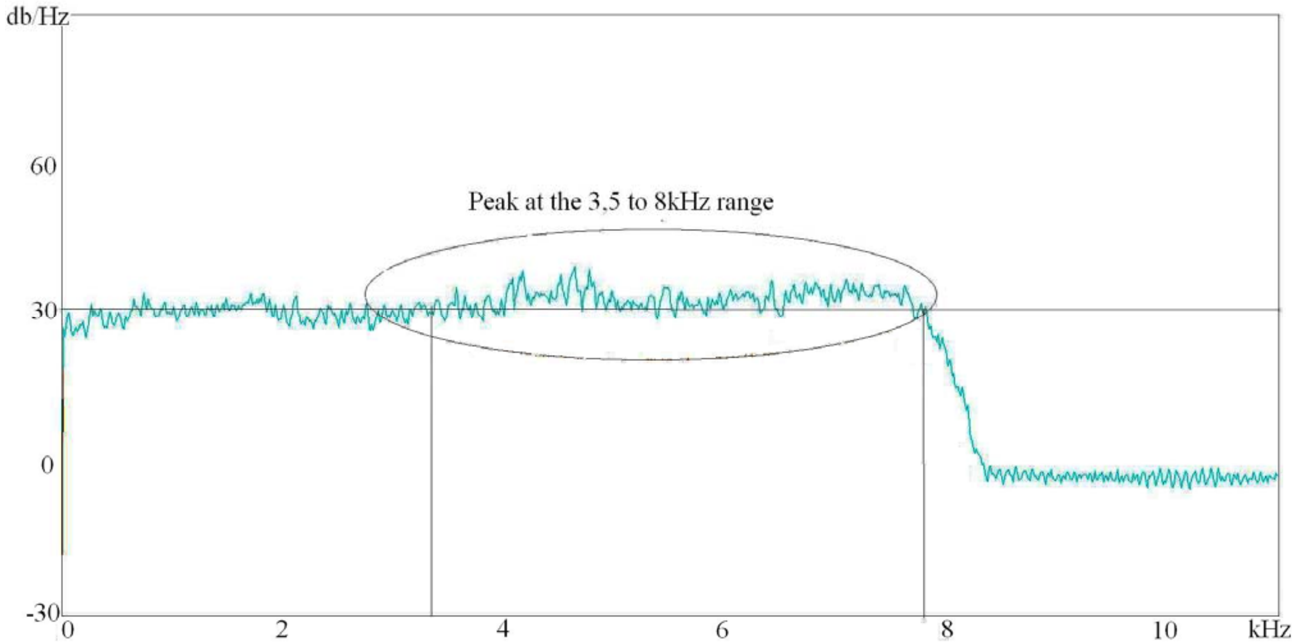

Figure 5. Transfer signature through the short circuit

The globular transfer, due to the greater sound level, up to 80 dB, was due to the fact of the microphone being too close, caused saturation of the microphone and the data acquisition wasn't adequate. Even so, Figure 6 shows that sound in the time domain is very similar to what was described in other references. In figure 7 the peak is between 3,5 and 7,5KHz.

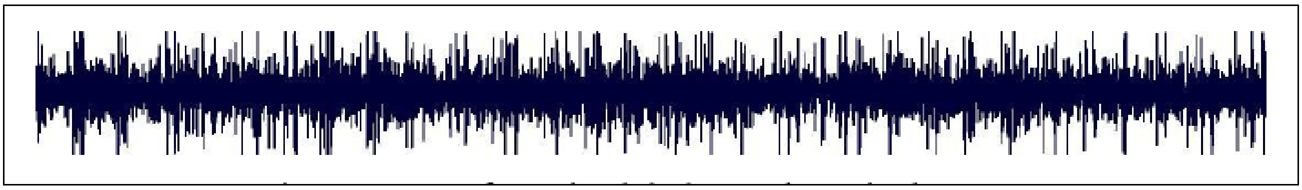

Figure 6. Metallic transference in globular mode displayed in power (volts at input) versus time

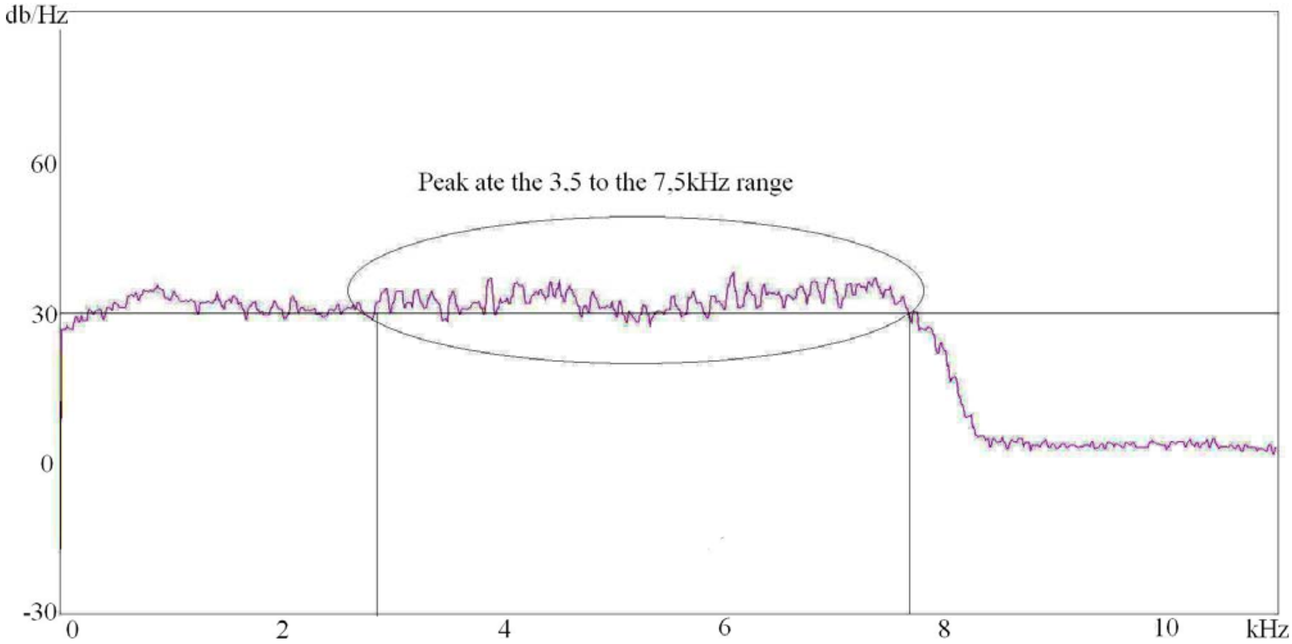

Figure 7. Signature of globular transfer

For the transfer through spray it was possible to obtain a very clear wave format, exactly as described in the literature and shown in Figure 8.

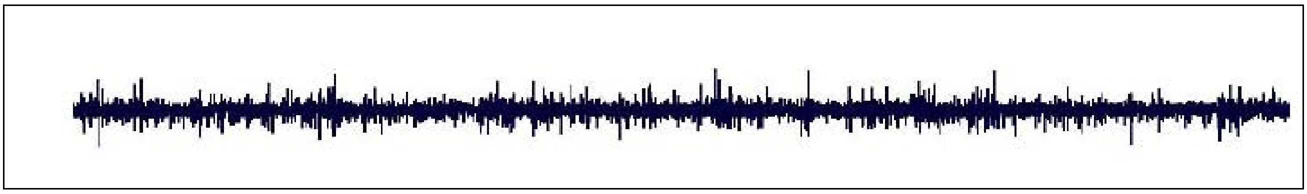

Figure 8. Metallic transference in spray mode displayed in power (volts at input) versus time.

However, it was more difficult to get a clear spectrum signature, because the sound has an peak amplitude of 67dB while the background has 60dB. When the spray transfer has been stabilized, the dominant environmental sound is that of the water recycler, and not of the arc, as demonstrated in Figure 9.

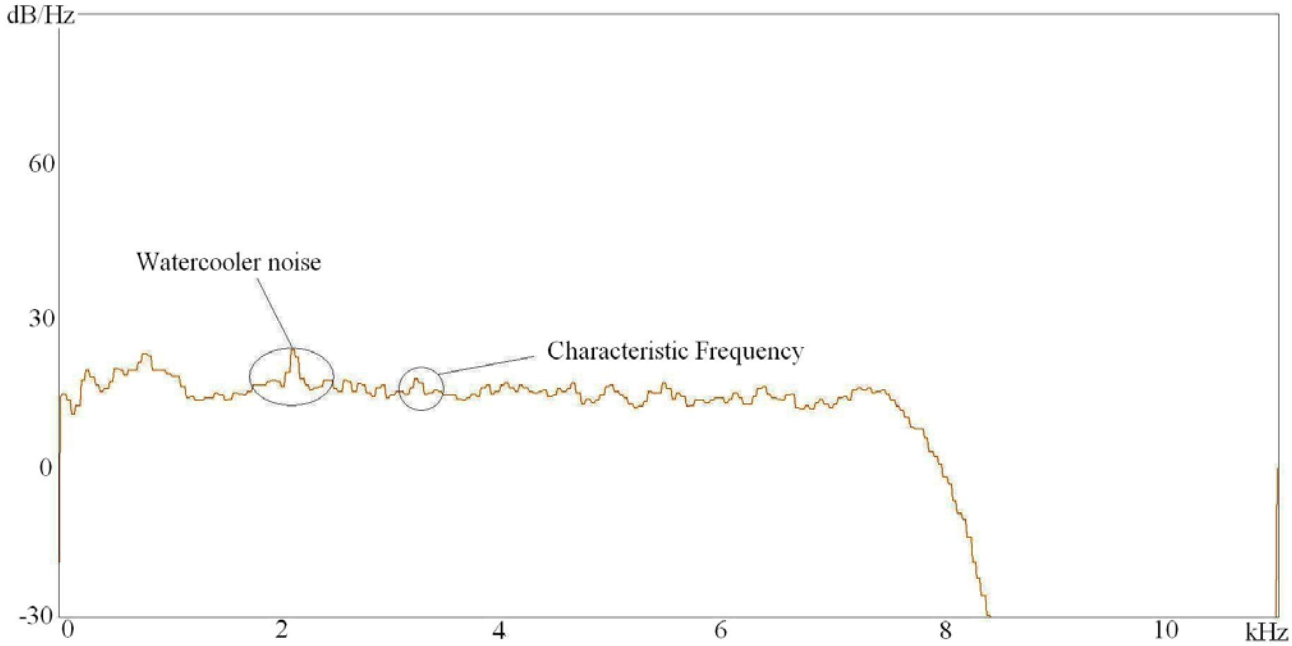

Figure 9. Transfer through spray signature

One of the defects clearly detected is the lack of the shielding gas, since when this happens, we have an immediate increase of up to 15dB SPL, and the complete change in the sound spectrum, as can be seen in Figure 10, where a welding in spray transfer mode with and without the shielding gas, and using the same parameters.

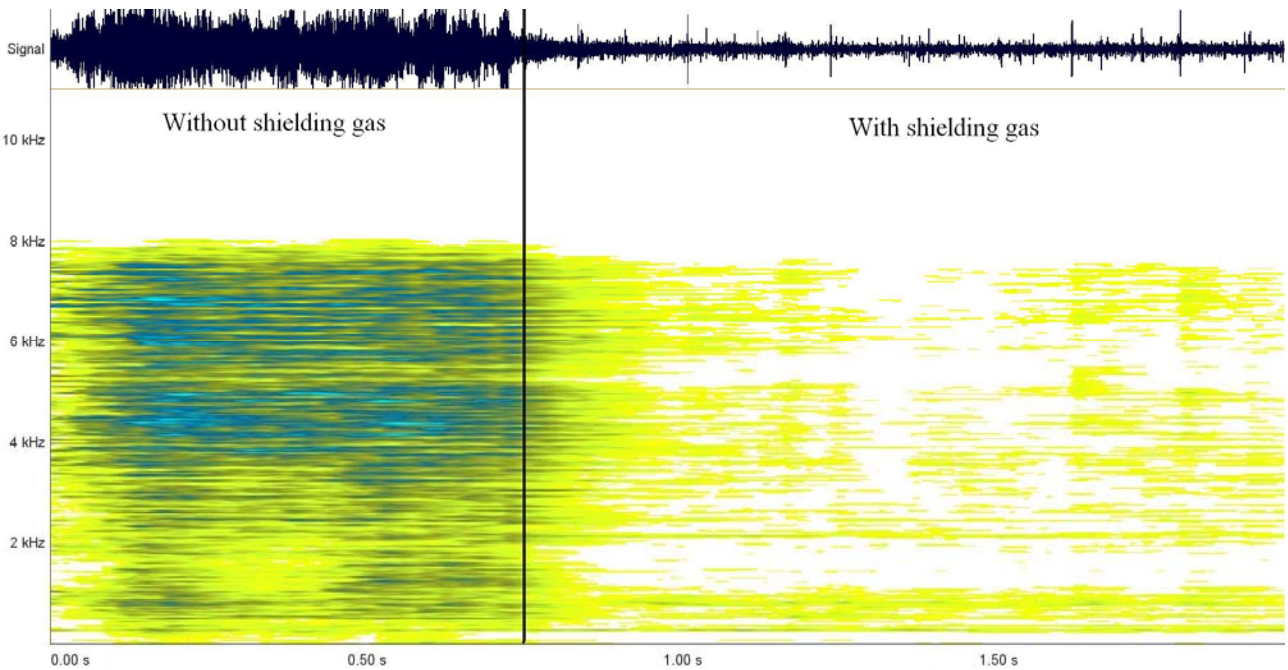

Figure 10. Spectrum in the time domain of welding without shielding gas (left) and with adequate flow (right)

It was also possible to detect the sound of the droplet. In the frequency spectrum shown on Figure 11 it is possible to compare the average sound pressure level per frequency during the welding in spray mode (blue), and the sound level during the droplet (green line). It is possible to notice an increase of the total SPL from 3 dB, up to 10dB per frequency and a remarkably large quantity of noise above 8 khz.

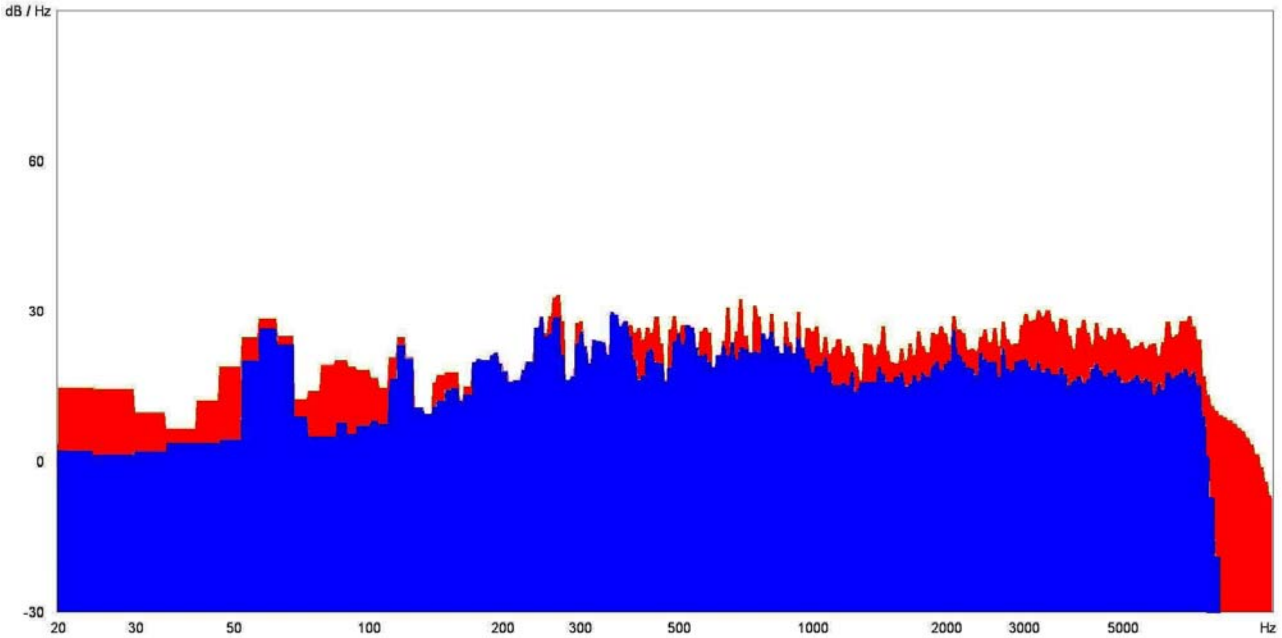

Figure 11. The sound spectrum of welding with spray transfer mode (blue) and during the spark (red)

During the domain of time and frequency-time (Figure 12), it is also clear that the presence of the drop and how it is propagated through the frequency spectrum.

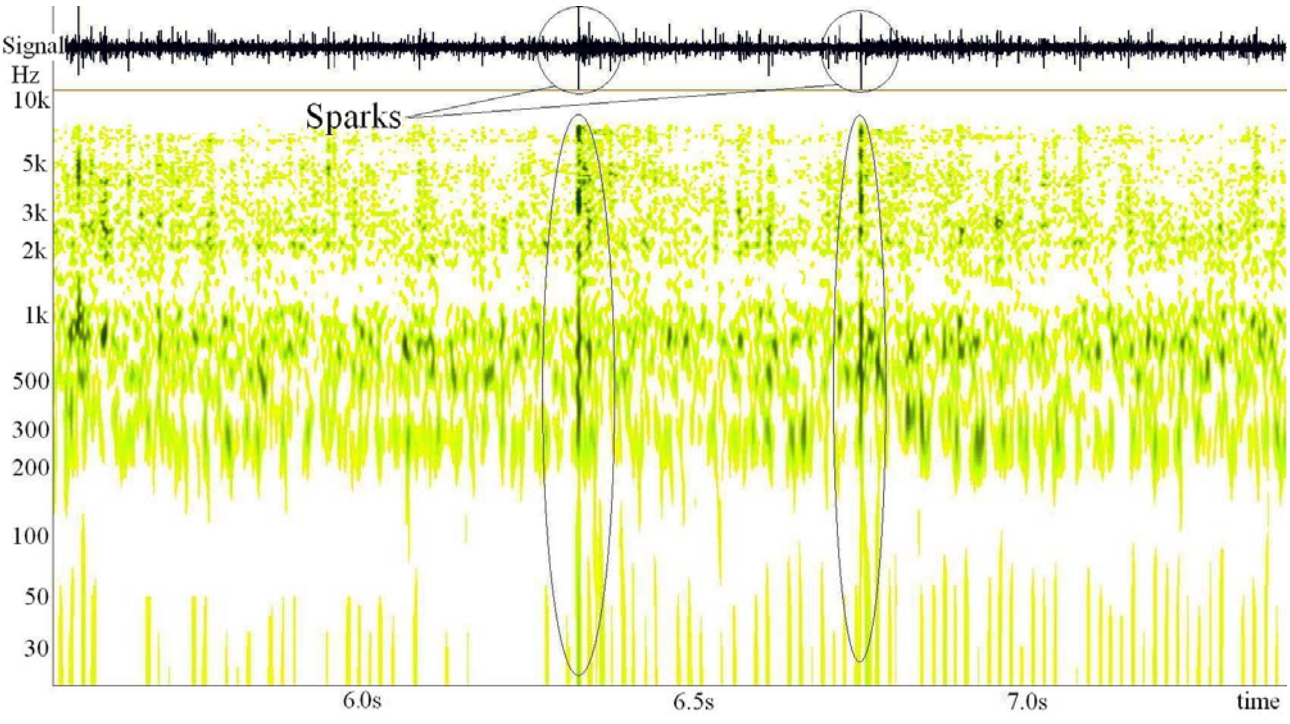

Figure 12: Welding through transference of spray and sparking noise

4. CONCLUSION

If the entire phenomenon's of the welding process can be detected through the sound of the arc or if the differentiation between them can be made possible in real time, is still a question for future study. The results of this paper and the available bibliography are unable to answer without any doubts that the sound is a reliable way of monitoring without occurring false positives or negatives.

The variability within the control group while studying the analysis of the spectrum demonstrated that it is still difficult to clearly characterize the process. However the differential monitoring, especially with the SPL monitoring x time, can easily pick up a serious defect, with relatively simple software. The identification of the signatures is possible with more advanced software.

Therefore, a system which describes a universal characterization process would be very hard to develop, and the strategies for monitoring should be planned according to the type of metallic transfer, and which type of defect should be detected.

Further studies should be done in highly automated welding processes to map small deviations and the consequent defect in the final piece. The purpose would be study the confidence of this feedback system in flaw detections.

5. ACKNOWLEDGEMENTS

The authors wish to thanks FAPEMIG for the support.

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