STUDY OF INFRARED SENSING AS WELD PENETRATION TIG PROCESS

Cláudio F. Benício Araújo
Companhia do Metropolitano do Distrito Federal - Departamento de Manutenção - OMT
Brasília - DF
claudiofba@gmail.com

Filinto E. C. Cutrim
Universidade de Brasilia Departamento de Engenharia Mecânica/Mecatrônica, Grupo de Automação e Controle(GRACO), CEP 70910-900, Brasilia, DF
cutrim@enm.unb.br

Guilherme C. Carvalho
Universidade de Brasilia Departamento de Engenharia Mecânica/Mecatrônica, Grupo de Automação e Controle(GRACO), CEP 70910-900, Brasilia, DF
caribe@enm.unb.br

S. C. Absi Alfaro
Universidade de Brasilia Departamento de Engenharia Mecânica/Mecatrônica, Grupo de Automação e Controle(GRACO), CEP 70910-900, Brasilia, DF
sadek@unb.br

Abstract. *This paper present a qualitative approach to use infrared emissions intensity produced by the arc-welding pool as monitoring parameters to welding procedures specifications with the objective of developing one real time control system. Welding samples TIG welded on SAE 1020, which present variations in dimensions (width and thickness) were obtained. In each test one collect data treated as timing series relating CC voltage produced by infrared thermometer and the dimensional variations of the sample. Data were registered from an A/D converter 16 channels. A thermometer linked to a robot was monitoring the infrared emissions of the welding pool at the time of bead depositions. The timing series were analyzed from graphics and statistics methods looking for identification of width and thickness variations appeared in the samples under infrared emissions. This chooses technique demonstrates the potential for infrared emissions as welding monitoring parameter sensor.*
Keywords*: Infrared sensor, monitoring welding, welding processes.*

1. Introduction

The welding process control system could be classified in two main categories: opened control system and closed control system. The opened control system has as goal to establishment the relationships between processes parameters and welding bead geometry leading to a selection of better settings parameters which could result in the best output characteristics of weld bead geometry (Wikle III, H. C *et al.* 1999, 2001). The closed control system are related to informations obtained during the welding process, with the objective of the welding parameters adjustment in a way to keep welding beads final characteristics within desirable values.

The basic differences between these approaches are related to the fact that the closed control systems has the capacity to provide accommodation of factors that affect the process such as: no uniform plate, joint misalignment, thickness variations, welding geometry, shielding gas composition (Wikle III, H. C. *et al.* 2001), looking for a dynamic compensation of these disturbances. Therefore, it can be said that these approaches are complemented, once the opened system aim at the parameters optimization and the closed system look for dynamic control of them.

The techniques related to welding process optimization are based in experimental methodologies, being the most important: Factorial design and neural network (Hartman, D. A. *et al.* 2002). These techniques are strongly related to experimental tests and look to establish relations between welding parameters and welding bead geometry. The introduction of closed or adaptative control to welding processes must be done by monitoring variable or set of variables witch can identify a process disturbance. For each practical implementation of an adaptative system to a welding process should identify the "envelop" or the set of monitoring variables. These variables must be used as a reference value in the process control, producing system control start of parameter adjustment (welding current, voltage, etc) looking to guarantee bead characteristics close to desirable values. Once the welding parameters varies in accordance to base material, type of chosen process, plate dimensions and welding bead geometry, the adjustment of the reference value of the monitoring variable will depend on the establishment of a set of optimized parameters, witch gives a welding bead with the desirable specifications. Therefore, it can be observed that techniques related to the open systems are important in adaptative control implementation for a specific welding process.

The researches related to adaptative system for welding look for the improvement of welding bead geometry with direct or indirect monitoring techniques. The indirect monitoring systems are the more used looking to link elements as welding pool vibrations, superficial temperature distribution and acoustic emissions to size, geometry or welding pool deep (Kerr, H. W. *et al.* 2001). According to Hong (Hong, L.; Kee *et al.* 2000) the more used approaches in the welding control are: infrared monitoring, acoustic monitoring, welding pool vibrations and welding pool depression monitoring.

2. Infrared Monitoring

Recently, the welding research in adaptative control has leading some researchers to identify infrared monitoring as a valuable tool in detecting the variations occurred in welding condition. The concept of penetration control by infrared base on monitoring the welded plate temperature distribution The radiation and convection heat changing with the environment and the heat transfer between welding pool metal liquid and solid part of base material determine the temperature distribution profile in both, the internal region and the welding plate surface (Nagesh D. S. *et al.* 2002). When infrared sensors are used in monitoring the surface temperature distribution, it is studied the relations between temperature distributions characteristics and bead geometry with the objective of developing an efficient control system (Nagarajan, S. *et al.* 1989).

The superficial temperature distribution can be used as indication of defects formations, distortions appearance and welding joint misalignment besides disturbances identifications in welding penetration. The welding penetration variation control can be possible once the welding pool radial convection pattern, witch are responsible by the variation of the penetration in welding joints, can be identify through welding pool temperature distribution. To produce a good quality welding, it should be obtained welding without variations in the processes conditions, maintaining a regular and repeated pattern in distribution of superficial temperature (Chen, W. *et al.* 1990).

3. Experimental Procedure

Welding beads were deposited in specimens (SAE 1020) within 4 different shapes (fig. 1). Fig. 2 shows a set of welding parameters data collection equipments. The experiments were carried out in a robotic cell composed by: Migatronic TIG BDH 320 tipple welding machine, ABB IRB 2000 robot. Tab. 1 show the welding parameters used in all experiment.

Table 1 – Welding Parameters

TIG Welding	
Welding Position	Bead on plate
Gas	Argon
Current (Amp)	150
Voltage (volts)	12
Welding speed (mm/s)	2,5
Gas Flow (l/min)	10
Electrode Ewth-2	2%

The welding pool monitoring system were composed by infrared thermometer, acquisition system and analyses data composed by A/D converter with 16 channels and software. The infrared thermometer and the TIG welding torch were fixed to robot clamp through an aluminum device, which permits monitoring the welding pool during the welding. The infrared thermometer generated one analogical signal of 1 mVcc/C collected by the acquisition system in a rate of 350 samples/sec. The tests were identified by the legend CPxy, where x indicates the type of test specimen and y the number of the test. All tests specimens were marked with two points indicated beginning and the end of the welding bead (“O” and “F”). The test specimens type 1 and 3 look for simulate one step signal through width and thickness respectively, and P1, P2 and P3 the location of the alteration places. Test specimens 2 and 4 look for simulate ramp signal through width and thickness respectively, being the point P1, the location point situated in the beginning of the alteration place.

4. Results

The graphics (direct voltage temporal series produced by thermometer vs. samples) were analyzed by statistics techniques (correlation and linear regression). Figs. 3, 4 and 5 show graphics obtained from run test in specimens types 1, 3 and 4, respectively. The location, within temporal series, of the alterations in test specimens geometry were marked with “O”, P1, P2, P3 and “F” as observed in the figures. The calculations to identify the position of each point within temporal series were realized from welding speed, sample rate and distance between the points P1, P2, P3 and F and the reference point “O”. Before running the tests, all the specimens were measured and the distances between geometric alterations were registered.

5. Discussion

The test graphics analysis type 1 showed one reduction of the analogical signal (direct voltage) produced by the thermometer during welding, indicating one temperature reduction of the welding pool as the test specimens width grows. These results were confirmed by statistics analysis done for each data interval between alterations, where the negative linear relations has been registered within the variables: voltage (analogical signal) vs. length (welding bead).

The test graphic analysis, type 3 and 4, also present an analogical signal reduction produced by the thermometer during welding bead deposition, with good performance of the test type 4, indicating a welding pool temperature reduction facing the test specimen width growth. These results were confirmed by statistics analysis and negative linear were registered within the "variables voltage (analogical signal) vs. length (welding bead)" to tests type 3 and "voltage (analogical signal) vs. thickness" to type 4 tests.

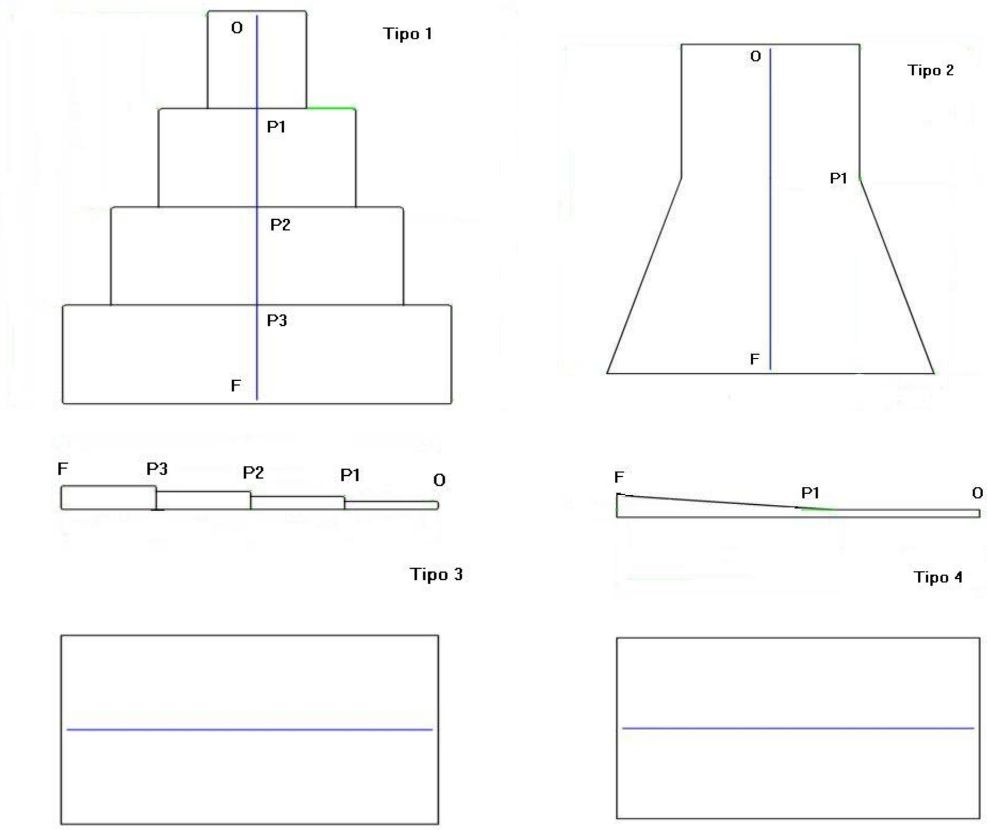

Figure 1 – Test Specimens

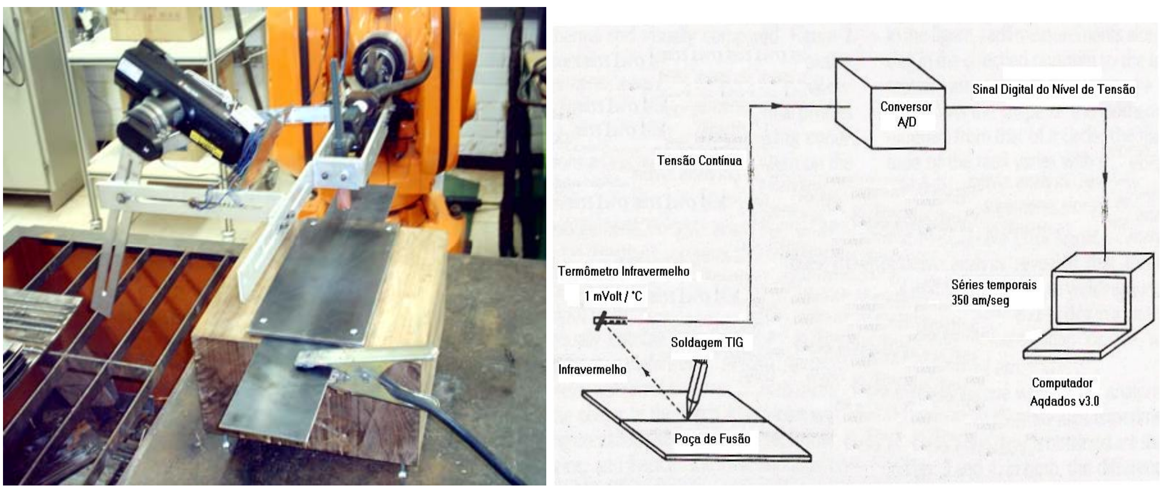

Figure 2 – Equipment setup

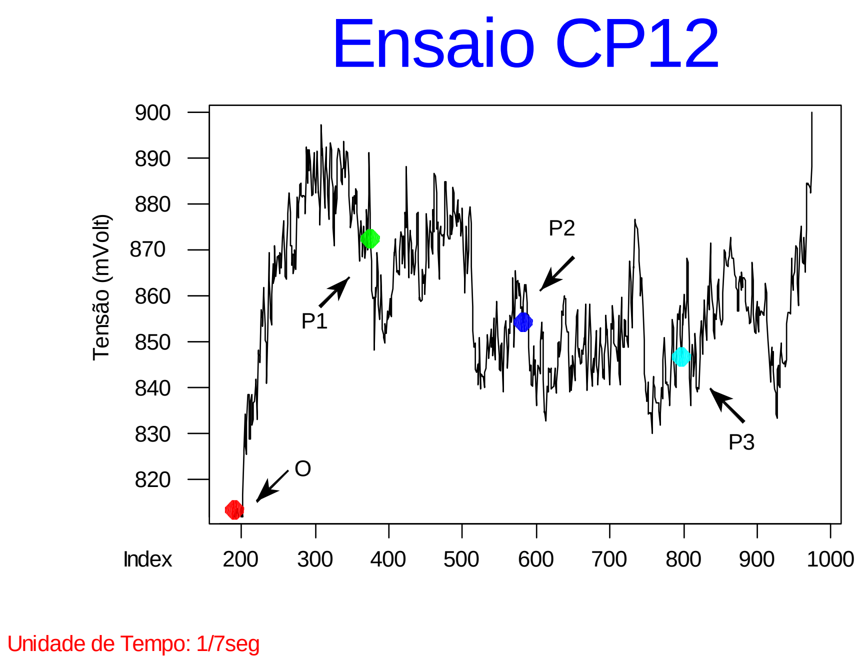

Figure 3 – Temporal Series of the CP12 Test

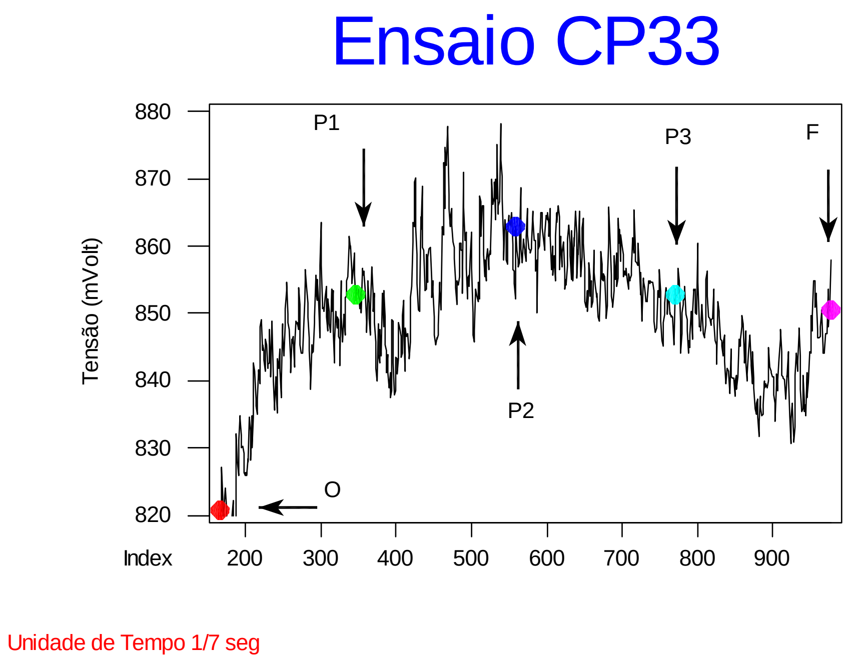

Figure 4 – Temporal Series of the CP33 Test

6. Conclusion

In the type 1 tests, it was verify that the geometry has influences on heat transfer during welding, acting over welding bead formation. This result gives indicating related to the necessity one control system that attenuates this effect during the process.

The weak results presented by type 2 tests can be explained by the ramp shape applied to the width. Observing the results of tests type 1 and 2, it was concluded that the width alteration has minor influence over the heat transfer process than thickness alterations. Consequently, the perception of his effect in welding process needs a monitoring system more accurate. The best results showed by type 1 tests can be explained by the abrupt changing in width. The soft width variation of the type 2 test specimen in a ramp shape associated to the equipment technical limitations which are used, probably are the causes of the weak results present by the tests carry out with these specimens.

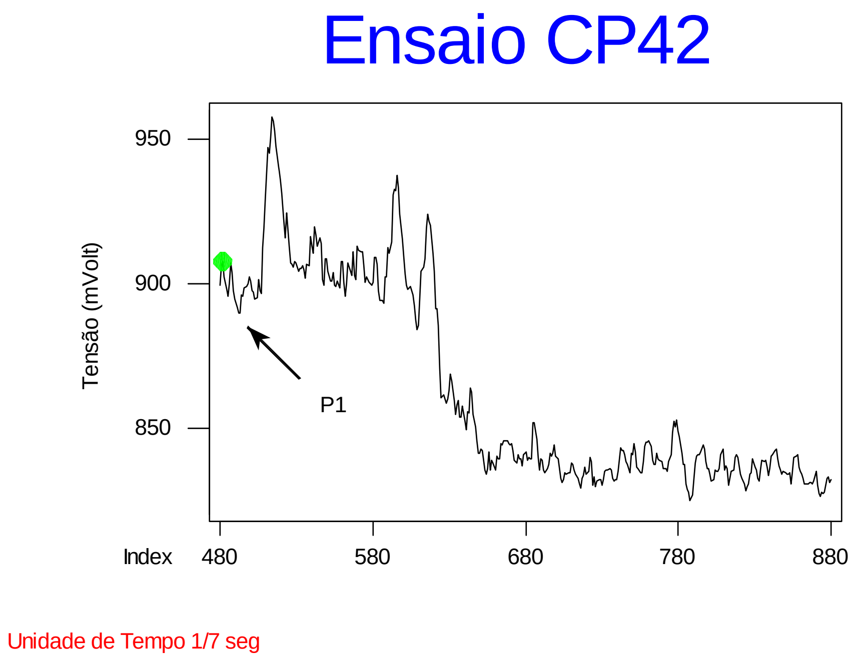

Figure 5 – Temporal Series of the CP42 Test

The tests width type 3 test specimens showed the possibility of penetration monitoring through infrared. In spite of the impossible to analyze the delay between disturbance occurrences and its records, due to technical limitations of the used equipment, the results showed the possibility of use the welding pool infrared emissions as penetration monitoring parameter during welding.

The good results obtained in the specimens type 4, confirm the observations verified in type 3 test, related to infrared as penetration indicator. Significant alterations were observed in infrared emissions which could be registered by monitoring system even though the geometry were in ramp form, which softens the width variation in the length of the test specimens.

7. Acknowledgements

This work was performed under the auspices of Brazilian Research Council (CNPq) and the sponsor of Technology Foundation FINATEC.

8. References

Chen, W.; Chin, B. A.; “Monitoring Joint Penetration Using Infrared Sensing Techniques”, Welding Journal, abr. 1990, 181s-185s.

Hartman, D. A.; De Lapp, D. R.; Barnett, R. J.; Cook, G. E., “A Neural Network/Fuzzy Logic System for Penetration Control”, Vanderbilt University, 2002, p. 1096-1101.

Hong, L.; Kee, L. F. M.; Mohanamurthy, P. H.; Devanathan, R.; Xiaoqi, C.; Piu, C. S; “Vision Based GTA Weld Pool Sensing and Control Using Neurofuzzy Logic”, SIMTech Technical Report (AT/00/011/AMP), 2000, p. 1-7.

Kerr, H. W.; Hellina, M. C.; Huissoon, J. P.; “Identifying Weld Pool Dynamics for GMA Fillet Welds”, University of Waterloo, 2001.

Nagarajan, S.; Chen, W. H.; Chin, B. A.; “Infrared Sensing for Adaptive Arc Welding”, Welding Journal, nov. 1989, p. 462s-466s.

Nagesh D. S.; Datta, G. L., “Prediction of Weld Bead Geometry and Penetration in Shielded Metal-Arc Welding Using Neural Networks”, Journal of Materials Processing Technology, Vol. 123 issue 2, abr. 2002, p. 303-312.

Wikle III, H. C.; Kottilingam, S.; Zee, R. H.; Chin, B. A., “Infrared Sensing Techniques for Penetration Depth Control of the Submerged Arc Welding Process”, Journal of Materials Processing Technology, Vol. 113 Issues 1-3, jun. 2001, p.228-233.

Wikle III, H. C.; Zee, R. H.; Chin, B. A, “A Sensing System for Weld Process Control”, Journal of Materials Processing Technology, Vol. 89-90, mai. 1999, p. 254-259.

9. Responsibility notice

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