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SYNERGIC REGIMES OPTIMISATION OF PULSED MIG ARC WELDING

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ABSTRACT

Because of the advantages offered, Pulsed MIG arc welding is used in recently years with an increasing frequency, for a large number of welded products in the Romanian industry. Welding sources parks were replaced gradually with new modern sources during 2000-2009. To extend the domains of use and adaptation of the welding regimes for synergic pulsed MIG welding were required numerous experimental determinations. This paper aims to find and validate an optimal welding regime for "pulse-drop" welding transfer, other than those set by manufacturers, in order to flexible use of the sources from earlier generations. To carry out the experiments a complex computerized system for data acquisition and high-speed shooting system was used.

KEYWORDS: welding, pulsed MIG, optimization, HDRC camera.

1. INTRODUCTION

The MIG welding represents, nowadays, a process having wide application in industry. This is due to the advantages it offers: high productivity, improved quality of the joint, mechanization and robot welding possibilities.

In parallel with the extension of the application field new materials and technologies, digital welding sources developed continuously

The welding operation efficiency imposes the reduction of the welding time, man labour, energy consumption, filler materials when the welding seam has a good quality and aspects related to the labour conditions (smoke, noxes) are almost the best [1,2].

These are achieved by:

- selection a larger diameter d_e for the electrode wire. This leads to a higher deposition rate and a reduced cost for the filler material, reduced disturbances of the arc length and good uniformity of the feed speed;
- use of MAG-M pulsed welding which represents the known results, controlled transfer, HAZ reduced size etc.

"A single wire, a single gas, a single equipment", represents a concept that finds application in the condition of the Romanian industry rehabilitation, by developing small and middle enterprises. So, the accent is focused more and more on the development of welded structure production in small and middle enterprises. In this situation, it is advantageous, in order to reduce costs, to find a technical solution, to allow the achievement in a unitary way of all welded joints from non-alloyed steels, with low carbon content and low alloyed steels, having the thickness over 3mm. One of the solutions would by the use of a single wire, a single shielding gas and single welding equipment. This concept was developed in USA and showed to permit the costs reduction and investment depreciation in about 6 months [5].

In our country, following a market study, there appeared that the optimum variant to solve the above problem is represented by the use of the shielding gas with 82% Ar and 18% $C0_2$ (Corgon 18), 1.2 mm diameter plain wire or flux cored wire. The issue in this case is represented by the acquisition of a performant welding equipment to assure a large range of adjustment possibilities of the welding regime. When there are available a lot of synergic equipment from the 1995-2000 generation, the ideal is to extend the corresponding technological field of these sources, by developing new regimes and new welding synergic lines. This will allow the use of this equipment under the conditions the concept "a single wire, a single gas, single equipment" mentioned above is used.

2. PAPER OBJECTIVES

The paper presents the practical methodology to optimise synergic regimes under the condition the above mentioned concept is applied. The welding process for which the exemplification is made is pulsed MAG-M welding, using an Aristo 2000 installation.

When the development of new synergic lines, others than those implemented by the producer, a considerable number of experimental determinations are considered. These determinations aim to achieve the following objectives:

- an adequate geometry of the seam, as uniform as possible in aspect, increased mechanical properties;
- still arc, without irregularities, spatter provided that the arc length is constant;
- higher welding speed arc ;
- minimum filler material consumption, shielding gas;
- corresponding price /quality ratio;
- minimum quantity of smoke, noxes.

If a part of the imposed requirements to obtain a quality weld are solved by using performant sources, optimizing the parameters couples U_a, I_s, v_a, v_s, d_{cp} represents the welding technologists task.

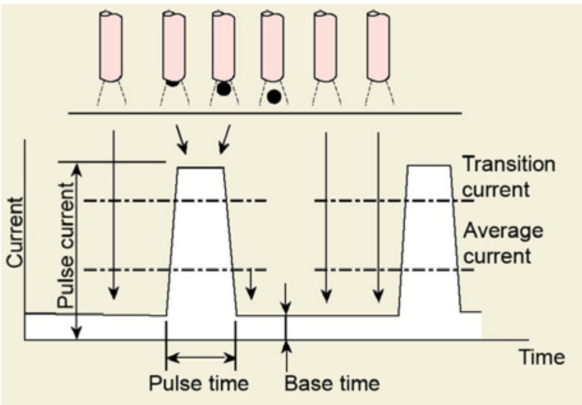


Figure 1. Pulsed current parameters

Classically, the establishment of synergic regimes in MAG-P welding is made only experimentally, following all above aspects. Apparently, for a performant source, provided there is an experience in pulsed welding, the modification of these regimes should be easy. To support this laborious activity, there are available a diversity of documentary materials which present indications regarding the selection of technological parameters in pulsed arc MAG-M welding. Several conclusions can be drawn out such as:

- each is specific for the used type of source;
- regimes present large variations from one producer to the other depending on the adjustment modality and adjustment characteristic types for I_p and I_b (CV-CC, CC-CC);
- for the same type of source, there is available a large range for adjusting the parameters of the pulsed arc, but in fact this is limited to maximum 20%, parameters are independent.

So, the smallest variations, (for certain sources are maintained constant), are those of the pulse parameters I_p, t_p, due to the fact that they are directly responsible for the pulse-drop transfer - TRPP.

Variations for parameters I_b, t_b and are up to 30% between minimum and maximum values. It is important to underline that even under the conditions a corresponding seam is obtained, it can happen that the transfer is not the TRPP.

The transfer depends directly (shielding gas corgon 18) on the pulse parameters and the distance contact nozzle -welding part d_{cp}, the feed speed v_a. Once the values for v_a and U_a are selected the imposed regime for the other parameters gives very few adjustment possibilities.

3. EQUIPMENT DESCRIPTION

The investigation methods allow the visualization of the electric arc and of the mass transfer.

This is achieved by high speed filming of the arc zone, associated with the synchronous measurement of the regime parameters involved in the process: arc voltages, current intensity, wire feed speed and welding speed.

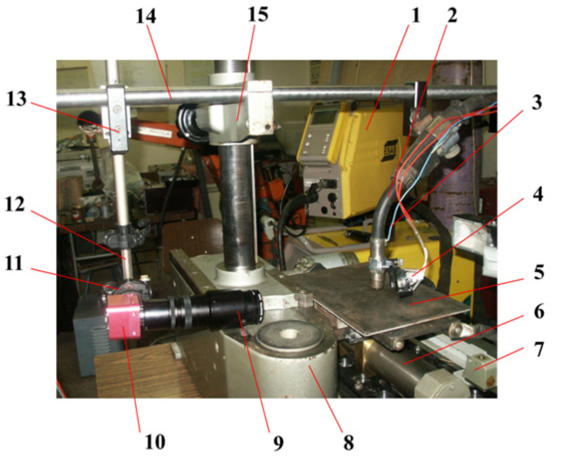
The team of the Robotics and Welding Department within "Dunarea de Jos" University of Galati developed a performant system to investigate the electric arc by direct filming and synchronous measurement of the electrical parameters with application in the first phase, of the pulsed current MIG process.

The system (figure 2) consists in an digital high speed camera with high optical dynamics and sensor C-MOS and synchronous measurement equipment of the welding regime parameters [1,2,3].

Figure 2. Research stand

The filming equipment comprises the filtering system, the MACRO optical system, the camera, the capture camera and the synchronization block (figure 3).

The camera is endowed with a CMOS type sensor active pixel LINLOG 2, high resolution (1024 x 1024 pixels), dynamic answer 120dB, spectral sensibility 400-900mm, 8 bites, monochrome and with a global type shutter and different trigger possibilities. The PF Remote software makes the camera control. The C-MOS camera has a high filming speed (150 frames/sec at the maximum resolution of 128 x 128 pixels), multiple synchronization possibilities, high speed data transfer on the C-link type main line. The capture plate used is completely programmable, of the microEnable III type with 96MB memory RAM and is used in the real time image processing systems.



1 - welding source
2 - welding head
3 - TT connection
4 - quartz lamp
5 - base metal
6 - Vs carriage
7 - course limiter
8 - bed
9 - MACRO/ MACRO objective
10 - high speed camera
11 - support camera
12 - toothed bar
13 - couple support camera
14 - fixing support
15 - adjustable column

Figure 3. System components

The measurement subsystem of analogical magnitudes consists in the following subassemblies:

- transducers to measure the values of the welding current, I_s, arc voltage U_a, feed speed v_a and welding speed v_s; [3]
- data acquisition plate of the PCI-6070E type;
- connector block which links the sensor elements and the acquisition plate. Data cables. Central computation unit.

To measure the welding current and voltage values performant transducers were used. They are of LEM production, in the range of Hall effect transducers in closed loop with opto-electronic separation between the primary and the secondary circuit. These transducers have dynamic performances and high accuracy for measurement (microseconds order answering time, very good limitation, residual current and very reduced thermal deviation) [3].

4. DETERMINATIONS

The development of the concept "a single wire, a single gas, a single equipment" when using the ARISTO 2000 source and the pulsed MAG-M welding process supposes the solving of more problems. One of them is represented by the welding regime optimization for single pass welding of thin plates. Ideal would be to make it at a high speed resulting a high deposition rate. Of course, when welding thin plates, usually small diameter wires are selected, 0.8-lmm, eventually the MAG-CO_2 with short arc transfer. Both versions presents disadvantages.

In order to weld thin plates, using the pulsed current, with a view to obtain one pass with an as reduced as possible aria, an increased welding speed is be used as well as reduced currents values I_p, I_b.

In mechanized welding, the use of these high welding speeds represents an easy condition to meet. In semi-mechanized welding, the increase of the welding speed v_s over a certain limit rises problems. The solution would be to modify the couple I_p,t_p, I_b, t_b so that the resulted regime was "soft" (soft arc - figure 4), the dynamic pressure of the arc, and the smaller droplet speed, reduced penetration, width of the bigger weld, less noisy arc [2,7,8].

The solution consists in finding the pulsed current regime, by classical methods, which meet the mentioned above quality objectives and then their validation when the mass transfer is corresponding, the TRPP type. Essentially, this represents the optimization of the pulsed current welding regimes.

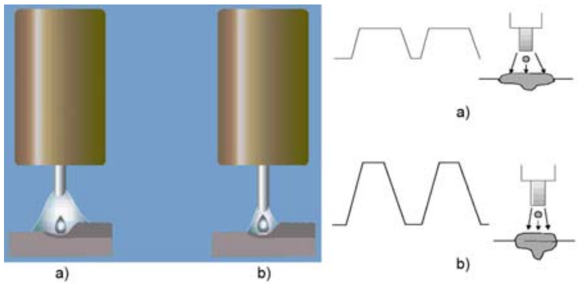


Figure 4. Arc welding shapes for hard and soft pulsed current

Finally, corresponding geometry and aspect welds are obtained (figure 5b), with increased quality conditions and minimum costs.

Experiments were made by depositing welds on common steel plates 200x300mm, in horizontal position using solid wire d_e = 1.2mm. The used welding process is the pulsed MAG-M one, the composition of the shielding gas 82%Ar and 18% CO_2 (Corgon 18). Experiments followed:

- if the mass transfer was pulse-droplet regime - TRPP;
- diameter, volume, shape, droplet speed and their path;
- weld dimensions (width, reinforcement);
- weld aspect (uniformity, crater type defects, edge channels);
- quantity of spatter and smoke.

In order to solve the above-mentioned aspects, the problem is reduced to the finding of the optimum synergic regimes, specific for the base material thickness. Concretely for an ESAB ARISTO 2000 installation, the synergic welding regimes, implemented by the producer, are partially presented in table 1, 2 and 3. The selection was made for different values of the feed speed retaining only the range 4-10 m/min. Table 1 and 2 present regimes using different types of shielding gases (Ar + 8%CO_2, Ar + 16%CO_2, respectively Ar + 20%CO_2, Ar + 2%CO_2, Ar + 5%CO_2 + 5%O_2).

Table 3 presents values of the pulsed current for different diameters: d_e = 0.8; 1.2; 1.6 mm, and the same shielding gas (Corgon 18).

Analyzing these data the following conclusions came out:

- for the same feed speed v_s = 6m/min (optimum value in welding plates of 4-8mm) the parameters variation was:
  - U_a = 29.7 - 36.5 V
  - I_p = 400-489A
  - t_p = 2.2 -2.7 ms
  - I_s = 56 - 88 A
  - f = 108-126 Hz
  - U_s = 33.3-36.5 V
  - I_p=292-484 A
  - t_p = 1.2 -2.2 ms
  - I_b = 48-60 A
  - f = 82-172Hz.

All these regimes should realize a TRPP type transfer. In reality this strongly depends on the distance nozzle - welding part d_{cp}.

The paper analyses the variations of the pulsed current parameters corresponding to the implemented synergic lines in the welding installation ESAB ARISTO 2000 as well as the way the synergic parameters are adjusted [8,9,2].

During the experiments the up and down slopes of the pulse current were maintained to the standard value UP SLOPE = DOWN SLOPE = 9. Also, considering that the welding source is provided with a regulator to maintain the arc length constant, without variations (it was mechanized welded, the gun being fixed) the action of the regulator was annihilated by setting constants k_s and k_i having the zero value.

To establish the optimum welding regimes, specific for the TRPP transfer, other than those existing in the source software, the following steps were made:

1. All possible synergic combinations, recorded in the source programme, were selected for the usual range of the feed speed v_a = 4-10 m/min;
2. The minimum and maximum values of the pulsed current parameters were established;
3. Their correlation was followed;
4. Depending on the plate thickness the value of the welding current was established I_{ef}. For the anterior selected value, the synergic values closest to those in the table 1,2 and 3 were chosen. For the base current the minimum value was selected, so that to assure the maintenance of the arc ignition, and for the pulse current, it was considered that its value should be under the level of the transition current I_{tr} [2].

Table 1. Regimes using different shielding gases

	t_p=2,2 ms				t_p=2,4 ms				t_p=2,4 ms			
	Ar+20%CO_2				Ar+2%CO_2				Ar+5%CO_2+5%O_2			
v_a	U_a	I_p	f	I_b	U_a	I_p	f	I_b	U_a	I_p	f	I_b
m/min	V	A	Hz	A	V	A	Hz	A	V	A	Hz	A
4,0	35,3	472	80	44	28,3	380	84	56	29,3	380	96	60
6,0	36,5	484	114	60	29,7	400	114	76	30,8	400	126	88
8,0	38,0	496	148	76	31,5	424	146	100	32,2	424	156	116
10,0	39,5	508	182	96	33,3	444	176	120	33,8	444	186	144

Table 2. Regimes using different shielding gases

	t_p=2,2 ms				t_p=2,2 ms				t_p=2,7 ms			
	Ar+8%CO_2				Ar+16%CO_2				Ar+23%CO_2			
v_a	U_a	I_p	f	I_b	U_a	I_p	f	I_b	U_a	I_p	f	I_b
m/min	V	A	Hz	A	V	A	Hz	A	V	A	Hz	A
4,0	31,5	448	78	56	35,0	472	74	60	33,3	436	80	40
6,0	33,0	464	112	68	36,0	480	108	72	35,0	456	108	56
8,0	34,2	480	146	88	37,2	488	144	92	36,7	480	136	80
10,0	35,8	496	180	100	38,5	496	178	112	38,5	500	164	92

Table 3. Values of the pulsed current for different diameters

d_e=0,8mm t_p=2 ms					d_e=1,2mm t_p=2,2 ms				d_e=1mm t_p=1,9 ms				d_e=1,6mm t_p=2,2 ms			
v_a	U_a	I_p	f	I_b	U_a	I_p	f	I_b	U_a	I_p	f	I_b	U_a	I_p	f	I_b
m/min	V	A	Hz	A	V	A	Hz	A	V	A	Hz	A	V	A	Hz	A
4,0	33,0	284	58	44	35,3	472	80	44	32,0	360	76	36	34,0	544	114	108
6,0	33,3	292	82	60	36,5	484	114	60	33,5	376	106	48	36,7	560	172	156
8,0	33,8	304	108	76	38,0	496	148	76	35,3	392	136	64	39,5	576	230	220
10,0	34,2	312	132	96	39,5	508	182	96	37,0	408	166	80	42,2	592	250	300

5. More samples were made, with a view to obtain welds having corresponding geometry and an as uniform as possible aspect (figure 5 a,b) as well as reduced variations of the pulsed current parameters (figure 6 a,b).

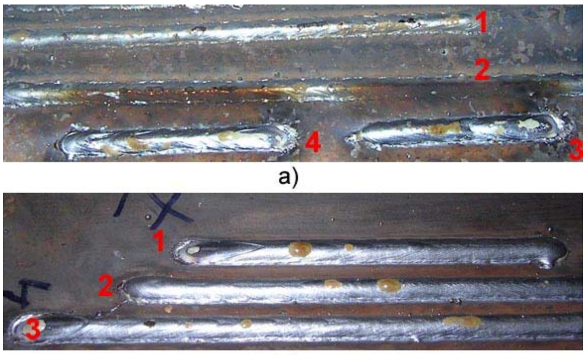


Figure 5. a) Faulty and nonuniform beads; b) Correct beads obtained by using synergic pulse parameters

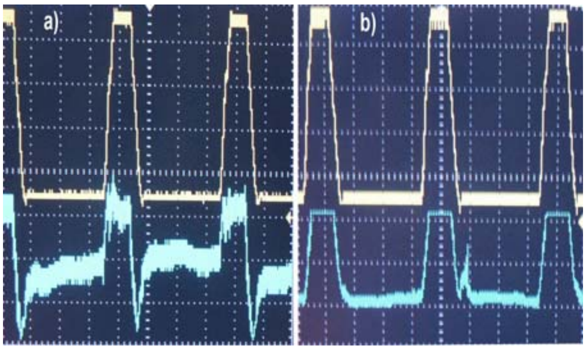


Figure 6. a) relatively high variations for the non-synergic regime; b) minimum variations for the synergic regime

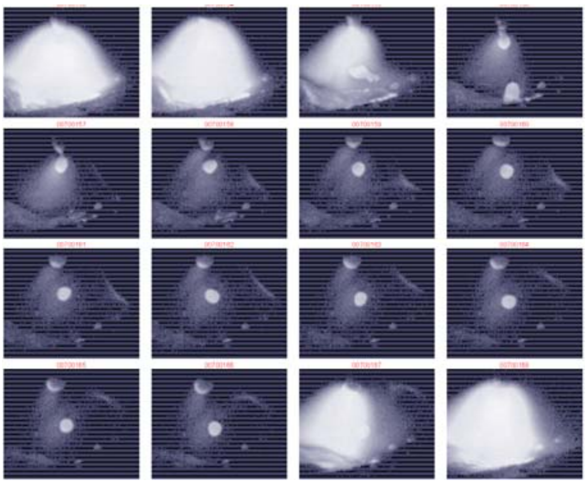


Figure 7. The cycle of the mass transfer in the TRPP regime visualized by high speed filming, with a speed of 2000 frame/sec

6. In the case of regimes that led to the achievement of the best welds the transfer type was verified, by high speed filming and the necessary adjustments were made, so that they are maintained at the TRPP level (figure 7).

5. CONCLUSIONS

Using the presented methodology we can establish "soft" synergic regimes, which can increase the applicability of the welding system. Such as welding equipment approaches to those of the last generation, which have increased flexibility. Even if the equipments and research techniques are relatively expensive, for developing new synergic lines, increased quality and reduced number of experiments is obvious. Important justifications occur when we want to weld performed welding materials: special steel (resistant, duplex, used in the petrochemical industry), titanium, aluminium alloys (used in manufacturing industry) where quality standards are very demanding.

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