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CORRELATIONS BETWEEN DROPS DYNAMICS AND THE GMAW-P ARC STABILITY

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ABSTRACT

In case of the pulsed gas metal arc welding process (GMAW-P), the metal transfer from the wire tip to weld pool is one of the most important phenomena. The paper presents a system designed by developing an appropriate weld quality model based on the optimum transfer and weld pool parameters and comparing it in real-time with the information provided by the monitoring system, becoming an effective quality assessment feedback loop. The drop transfer process in pulsed welding was investigated by a modern, discontinuous method, using high-speed video monitoring performed with High-Dynamic-Range-CMOS camera (HDRC), with an external trigger input and by current and voltage measurements. Real-time welding monitoring enables also the real time assessment of the welding quality, besides the usually envisaged process control. The metal transfer affects the arc stability, weld pool dynamics, joint penetration, weld bead geometry and spatter. The process of metal transfer is influenced by dynamic factors, thermal conditions and electromagnetic effects.

KEYWORDS: welding, GMAW-P, drop transfer dynamics, arc stability, HDRC camera, quality assessment.

1. INTRODUCTION

1.1. Classification of the mass transfer processes

The MAG welding is characterized by the mass transfer process of the melted metal drop from the contact point through the electric arc column. The filler metal transfer is depending on the welding procedure, the welding current value and the protection gas nature.

Even at present, MIG-MAG welding is the most used procedure in the developed countries from Europe, United States of America and Japan.

In the case of MIG-MAG welding, the study of physical phenomena which are developed in the plasma arc is necessary to perform the high quality welded joints. Also, it is necessary to analyse the forces which act in the electric arc and the metal transfer dynamics. The arc stability is depending on the forces developed in the electric arc column. In fact, the metal transfer is determined by the equilibrium of the forces which act, at once, on the melted metal drop.

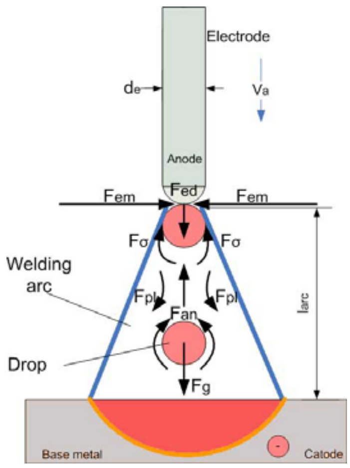

Figure 1. Arc force equilibrium

1.2. Modelling of the mass transfer phenomena

By modeling the metal transfer process, the correlations between the welding parameters were been established. These correlations are necessary to control the number, sizes and frequency of the metal drops. In the case of the synergic welding, the results of research are expressed by equations which command the metal transfer. This approach allows developing the "intelligent" welding sources, which can compute and control any welding process, starting from the minimum input data.

1.3. Forces acting in the welding arc

The melted drop is detached from the contact point through the electric arc column when the static equilibrium of the forces, acting in the arc, is broken, (figure 1), [1], [5], [7]:

F_g - gravitation force;
F_{pi} - dynamic transport force owing to the drop propulsion in the plasma jet;
F_{em} - electro-magnetic force or Lorentz force owing to the Pinch effect;
F_{an} - force owing to the vaporization, force of the anodal reaction;
F_σ - force owing to the surface tension of the liquid metal;

Mass transfer depends on the arc forces equilibrium. This is concretized by the table parameters of arc phenomena: form and arc geometry, dynamics, droplet speed, droplet acceleration and direction (trajectory), mean diameter, arc length, stick out and the inclination angles of electrode.

2. INVESTIGATION SYSTEM

The system is made up of an ultra-rapid camera with high optical dynamics and CMOS sensor, and synchronous equipment for measuring the welding regime parameters. [8]

The camera equipment comprises the following components: filtering system, MACRO optical system, camera proper, capture board and synchronizing module (Figure 2).

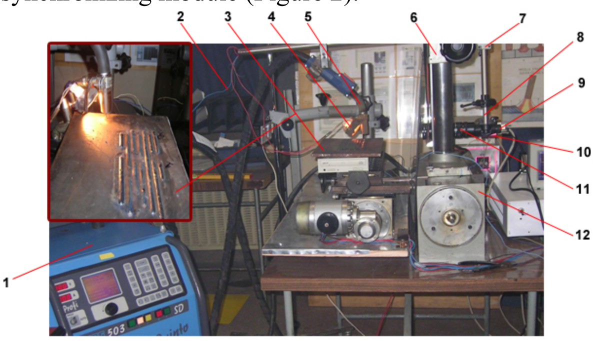

Figure 2. High speed synchronized System

1 – power supply	7 – Camera mounting pair
2 – TT connection	8 – Cremaillere
3 – Base metal	9 – Camera mounting
4 – Quartz lamp	10 – High spend camera
5 – Welding torch	11 – MACRO objective
6 – Control pedestal	12 – Holster

The subsystem for measuring analogical parameters is made up of the following parts:

- Transducers for measuring the values of the welding current, I, arc voltage, U, wire feed speed, w_{fs} and welding speed w_s;
- Data acquisition board of PCI-6070E;
- Connecting the tower linking sensors and the acquisition board. Data cables. Central processing unit.

3. MASS TRANSFER STABILITY

3.1. General aspects regarding GMAW-P transfer. Selection of the work parameters

In order to carry our experimental measurements, an Aristo 2000 welding equipment was used.

In what concerns the pulsed arc welding, the method of controlling the transfer of the droplets by current pulses (30 – 300 Hz) from the power source makes it possible to extend the spray arc range down to low welding data. The process provides a stable and spatter-free arc as a welcome alternative to short arc welding.

The principle of MAG-P welding is based on the transfer phenomena and melting pool development, which are not corresponding for the same duration. The first phenomenon depends on the instantaneous current value. In the same time, the second phenomenon is determined by the average current value, in fact by thermal inertia. The waveforms of the pulse current and the transfer mechanism are presented in figure 3**.** [4] In the diagram from figure 4**,** it is presented a correlation between pulse parameters, I_p t_p. It can be observed that the range to adjust the pulse current is large enough. So, the low values of I_p, must be balanced by the increasing of time, t_p, to maintain a high enough value of energy, able to detach the drops. It was proposed an equivalent low between different adjustable pulse cu-rrent, such as[7]:

$$I_p^n \times t_p = D \qquad (1)$$

where n and D are constant, depending on the nature and diameter of the electrode wire, also on the protection gas.

For example, in the case of wire from carbon steel, with 1.2 mm diameter, using Ar + 1.5 % O_2, as protection gas, it is obtained n = 2 and D = 400 A^2I.

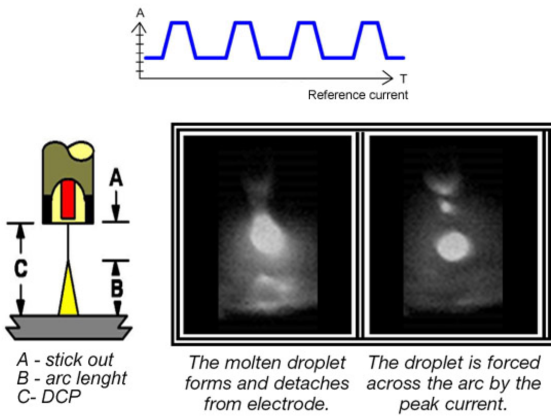

Figure 3. Droplets transfer only one pulse (ODPP)

Analyzing the I_p t_p, diagram we can see that in the A and B areas is realizes an non-synergic transfer, non ODPP and we have an instable transfer. In this domains we can’t control the moment of droplet detach and the modification of droplet speed may influence the arc stability and welding pool geometry. The variation of velocity with a unit can produce anomalous transfer, in other words, an unstable arc and process.

It is very important to know the main parameters and the correlations between them, also the independent sizes of the pulse waveforms. These informations are necessary to be sure that the established parameters are the best choice. If it's possible, the transfer conditions will be choose to assure a uniform drops transfer, following their shape during this process. The drops shape must be almost spherical, avoiding the drops „satelliation" (developing of small drops).

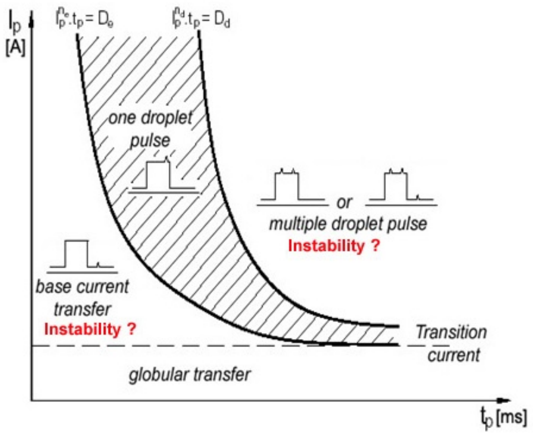

Figure 4. The domains of the droplet per irregular transfer of droplets

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The best choice of the pulse parameters must take into consideration the influence of I_p and t_p on the fume emission during the welding. The vapours quantity is depending on the developed heat in the arc column. The heat quantity is depending, in his turn, directly on the both values I_p, t_p. The optimal values which decrease the fume emission impose to choose a value for I_p at the upper limit of the range and lower values for t_p. So, the values for I_b and t_b must be increased to keep constant the current average value.

3.2. Analysis of mass transfer stability

Arc stability depends on physical parameters of:

- Filler metal - diameter, composition, form, uniformity
- Protector gas – purity, composition, debit
- Base metal – joint type, thickness, surface quality, rust, oxides, soot,
- Equipment – power source, quality of feed device, cable length, welding gun
- Modification of sheet position and variation of joint form

The identification of the optimal combinations of pulse parameters for MAG-P welding is a laborious work, which involves many tests and errors. The main parameters which must be identified are: the electrode feed rate, the pulse current, the base current and the frequency. There were established the correlations between the sizes to be measured (monitoring) by artificial view: drop size, drop speed (frequency) and process parameters, as:

$$T = \frac{240 \cdot V_d}{\pi \cdot d_e w_{fs}} \quad \text{where} \quad w_{fs} = \frac{\pi}{6} d_d^{\,3}, \ [m^3] \qquad (2)$$

d_d - drop diameter, mm
d_e - electrode diameter, mm
T -period, [ms]
W_{fs} - feed rate, [m/min].

Based on the experimental measurements, the correlations between the transfer parameters, I_p and t_p, were established. These parameters influence the drops transfer uniformity and ODPP assurance, (figure 5). [2]

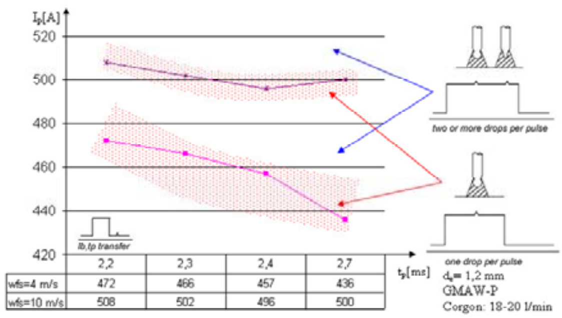

Figure 5. Parameters influence on the drops transfer uniformity and ODPP assurance

Along with the increasing of wire feed speed, is reducing the synergic domain of functioning. For high values of speed, for robotized welding is indicate to equip the welding power sources with supplementary feed-back controlling devices for maintaining the ODPP transfer.

Also, using the high-speed shooting system and work parameters measurement, there were drawn the curves, which indicate the relation between the drops volume and the pulse parameters, (figure 6). In these curves, there are determined the transition limit points, where the transfer is unstable. In this case, there is a multiple transfer or a lack of transfer, so the state is unstable, situation which must be avoided. Analyzing the transfer phenomena in the electric arc column, it was established the influence of the pulse parameters, the contact point-piece distance, the arc length and the gas nozzle-piece distance on the arc shape, the weld geometry and the melting pool.

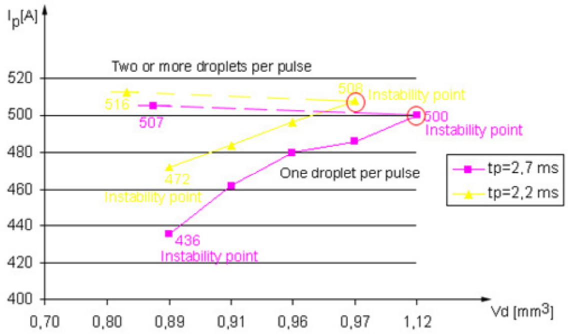

Figure 6. Relation between the drops volume and the pulse parameters

It's shown a reduced variation of the droplet volume for t_p 2,2ms respect of 2,7 ms. For this reason the modern power sources works with smaller values of t_p.

4. CONCLUSIONS

In the case of MAG-P welding, the experimental measurements were been made. Based on the experimental measurements, the correlations between the transfer parameters, I_p and t_p, were been established. These parameters influence the drops transfer uniformity and ODPP assurance.

The equipment used in the experimental research is based on high-speed shooting of the synchronized images of the drops transfer. In the same time, the work parameters are measured.

In the case of MIG-MAG welding, the mass transfer is decided by forces, acting in the electric arc column. These forces influence the arc stability, the dynamics and the metal drop geometry.

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