TECHNOLOGICAL PARTICULARITIES REGARDING MANUAL METAL ARC WELDING USING PULSED CURRENT FOR BUTT JOINTS

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Abstract

Using pulsed current at manual metal arc welding represents a new research idea perspective and provocative for major manufacturers of welding equipment. The concept is based on the ability to control the volume of welding pool at low frequencies of the pulses, below 5 Hz.

Experimental research underlines the beneficial influence of pulsed current welding on weld geometry for butt joints. Also the technological particularities of the process are highlighted and the use of two welding techniques depending on the frequency of pulses in terms of how the welding of the root layer is done compared with standard welding:

- at low frequencies below 2 Hz welding is performed intermittently, electrode oscillation frequency has the frequency of the pulses, during the pulse time the welding arc is of the flanks on the joint, and during the basic time of the pulsed the welding arc moving from one flank on the joint to other; This technique ensures safe melting of the flanks on one side, and on the other side avoid penetration root layer;
- at frequencies above 2 Hz welding root is done without oscillation electrode, with support the electrode on the flanks of the joint, root is safe and uniform without excessive penetration; but it requires the right choice of the opening joint.

The results confirm that manual metal arc welding with pulsed current is feasible and technological beneficial effects can be obtained. It requires the expansion and diversification of research for a more complete assessment.

Keywords: Pulsed TIG welding, pulsed MMA welding, operating mod, butt weld, pulsed equipment STEL

1. INTRODUCTION

The use of pulsed current in s*hielding gases* environment has been for a long time an attractive option for achieving technologically and qualitatively efficient welding due to the advantages the process offers, especially in terms of controlling the transfer mode and the energy input into the components [1]. However, the use of pulsed current in manual welding with a coated electrode has not been targeted by large welding equipment manufacturers because it has not been perceived to have potential technological advantages, given the major differences in process compared to welding in shielding gases

The idea of first-time use of low-frequency pulse current at manual welding with coated electrode belongs to the company STEL which implemented this technical solution on some of its welding sources for manual welding with coated electrode, the frequency variation of the welding current being limited at 5 Hz [2]. The idea is based on the theoretical aspects of controlling the volume of the welding pool at low frequencies. The company EWM has now expanded the idea, expanding the frequency range up to 500 Hz for the purpose of controlling pulse frequency and the way to transfer molten metal droplets [3].

The experimental researches have revealed the influence of the pulsed current welding and the impulse frequency influence on weld geometry for welded butt joints. At the same time, the technological features of the process and the use of two welding techniques according to pulse frequency are emphasized with regard to the operation mode when welding the root layer of the welded joint compared to standard welding. The application highlights the beneficial effect of the pulsed current on the making of welded butt joints, especially in terms of the control of penetration when welding root layer.

2. BASICS OF WELDING WITH COATED ELECTRODE IN PULSED CURRENT

The idea of using pulsed current for manual metal arc welding with a coated electrode starts from the observation of the influence of frequency, as shown by the TIG manual welding with addition material, on the volume of the welding pool by *partial solidification of the welding pool at base time, thus controlling its volume*. This leads us to the conclusion that the use of pulsed current in manual welding with coated electrode is feasible or interesting only in the low frequency range i.e. below 10 Hz, as we will be present below.

Viewed as a whole, due to the partial solidification of the welding pool, its volume is lower than that of the constant current welding and therefore the bath can be controlled more easily. However, thanks to the high impulse current, a sufficient penetration is ensured [4].

Meeting the aforementioned prerequisites is possible only if a sufficiently large temperature difference of the welding pool is obtained between the pulsed current phase and base current phase. This is only possible if the pulse frequency is less than 6 Hz, see **Figure 1** below [5].

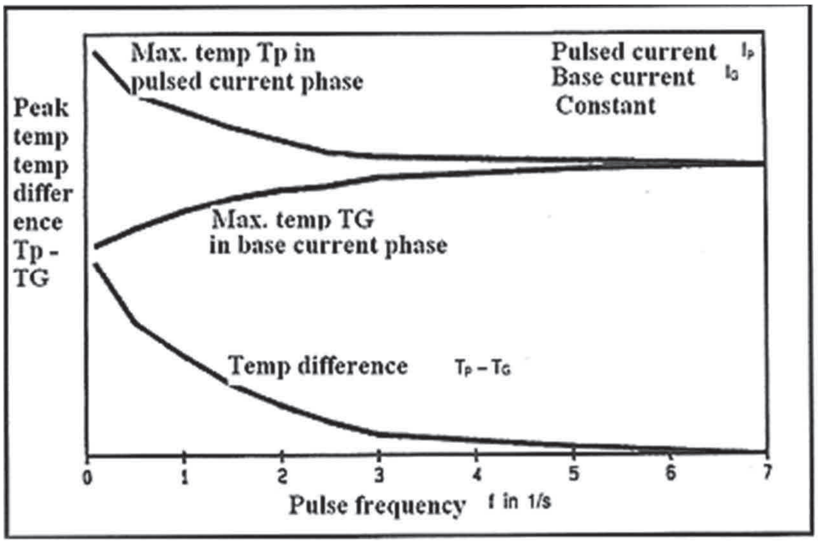


Figure 1 Influence of the frequency on the temperature of the welding pool

Among the main advantages of pulsed welding with coated electrode it is worth mentioning the following [6]: a better stability of the electric arc (especially for small welding currents), the possibility of using larger electrode diameters for the welding of thin sheets, respectively the use of lower average welding currents at the same electrode diameter while maintaining electric arc stability as in conventional welding, reducing the risk of breakage in welding of thin plates (low current densities), a better control of arc transfer at certain frequencies, a control of the linear energy input into the welded parts, a friendly operation by the welder, obtaining an outer surface of the welded part with smooth and regular layers of bed (finer or thicker depending on the pulse frequency) similar to the TIG welding; especially in the case of “high-frequency” welding i.e. 4 - 5 Hz, the welding becomes aesthetic with smooth and regular layers of bed and provides a better and secure bonding bridge for variable or joints with variable opening (see circumferential welding of large diameters), reliable and easier penetration in the case of welded butt joints with one side penetration, and an ideally suited to vertical downward welding of pipes using cellulosic electrodes.

3. PRESENTATION OF THE PULSED CURRENT WELDING SOURCE

The MAX dp-201C (STEL) inverter source allows both welding with coated electrode (MMA) and the TIG welding, and is also suitable for manual welding with cellulosic electrodes. As regards the characteristics of the pulsed current in manual welding with coated electrode (MMA) we mention as follows [2]:

- Pulse frequency: 0.4 - 5 Hz, continuously adjustable,
- Maximum pulsed current: 200 A, continuously adjustable,
- Base current: 50 % of the pulsed current (it results from the pulsed current - and it cannot be adjusted independently; for instance: for I_p = 100 A it results I_b = 50 A);
- Cycle time $t_c = 1 / f = 2 ... 0.2$ s (it changes as frequency alters);
- Pulse time t_p equal to the base time t_b: $t_p = t_b = (1/2) \cdot f$: f = 0.5 Hz: $t_p = t_b$ = 1s; f = 5 Hz: $t_p = t_b$ = 0.1s;
- Average welding current: $I_m = (I_p \cdot t_p + I_b \cdot x t_b / f = (I_p + I_b) / 2$; (See example above I_m = 75 A)

4. INFLUENCE OF PULSED CURRENT WELDING ON WELDING GEOMETRY AT WELDED BUTT JOINTS

Experimental research aimed at highlighting pulsed current welding and impulse frequency over the external appearance and welding geometry for welded butt joints respectively, and mainly on root penetration.

Research was performed under the following welding conditions:

- Base material: S235J2 - SR EN 10025/2009;
- Thickness of material: 6 mm; 10 mm;
- Type of joint: butt welded with Y joint;
- Electrode type: AWS: E7018;
- Diameter of electrode: 3.25 mm;
- Welding mode:
    - Standard: welding current: Is = 100A
    - using pulsed current:
        - **medium welding current: Ism = 100A**: (Ip = 134 A;: Ib = 67 A);
        - **pulse frequency: 1 Hz; 2 Hz; 3 Hz; 4 Hz; 5 Hz;**
        - Welding speed: v_s = 15 - 16 cm / min = const.

Also, one aims for keeping the main welding parameters constant i.e. the welding current and speed, in all cases for the most accurate and objective indication of the influence of the frequency of welding pulses as against standard welding.

4.1. Influence of the pulse frequency on the root penetration

The research was performed on butt welds with component thickness of 6 mm, respectively with a joint in Y: α = 60°; b = 3 mm; c = 2 mm. See **Figure 2** below.

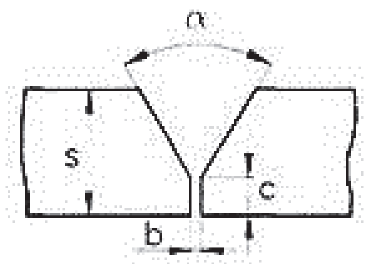
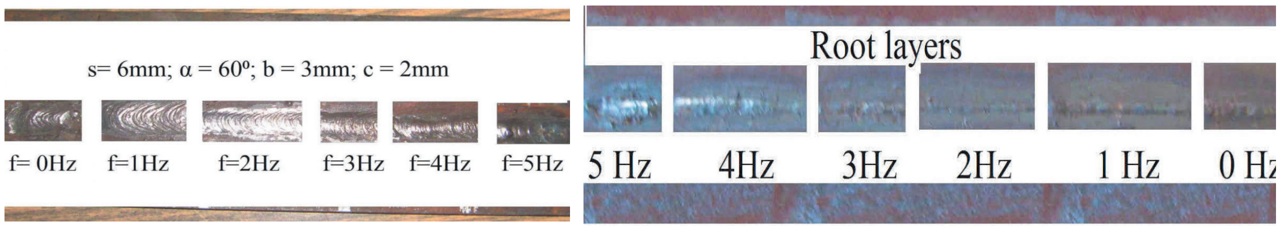


Figure 2 Shape and joint dimensions

The appearance of the outer surface of the welds, respectively the appearance at the root for the 6 butt welds (1 standard weld with Is = ct., respectively 5 welds with variable frequencies and Ism = ct.) are shown in **Figures 3a** and **3b** below



a. b.

Figure 3 Appearance of the welding surface: a. on the outside; b. to the root

From the analysis carried out on welds some interesting issues emerge and they are synthesized as follows: the welding using the frequency of 0 Hz and 1 Hz respectively was done with the swinging electrode. The way of swinging differed in the two welding modes, namely: for the standard welding (f = 0 Hz) the swinging was continuously carried out with a certain frequency imposed by the welding pool control and the penetration, while for the pulsed current welding with f = 1 Hz, the winging was intermittent due to the periodic variation of the current between the two limits i.e. pulsed current - basis current. On the pulsed current phase, the electric arc was maintained on the flanks of the joint for their safe melting, and on the phase of base current the swinging of the electrode was from one flank to the other, which prevented danger of breakage. At frequencies of 2 Hz, 3 Hz, 4 Hz, and 5 Hz respectively, the welding was done without swinging, keeping the electrode in the joint axis in contact with its flanks. It is therefore proposed a second pulse welding technique at frequencies > 2 Hz, namely non-swinging welding with the electrode support on the so-called sink arc. This technique requires the choice of the welding joint opening with great care, which should be narrower than in the case of standard welding with swinging, and the choice of some technological measures to avoid welding joint closure. The root thus obtained is good, safe and uniform. Moreover, sink arc welding ensures a very good protection of droplets transfer through the arc column, and reduces welding splashes very much.

Therefore, pulsed current welding determines two welding techniques in the joint, and the root, namely:

- At low frequencies range i.e. < 2 Hz, the welding is intermittent, with the swinging electrode at a frequency equal to the pulse frequency, and during pulse phase the arc is supported on the flanks of the joint, while during the base time it moves from one flank to another; this technique ensures, on the one hand, the safe melting of the joint flanks and on the other hand the avoidance of root penetration;
- At higher frequencies range i.e. > 2 Hz, the welding at the root is done without the electrode swinging by supporting the electrode on the flanks of the joint, the so-called sink arc; the root is very good, secure, uniform and undamaged; it requires though a correct choice of the opening of the joint and avoiding its change during welding.

4.2. Influence of joint geometry on pulsed current welding

Based on the interesting results obtained so far, the research continued with the making of some welded butt joints with different joint dimensions at the root layer.

In this sense, two samples with different dimensions of the joint were prepared and welded as follows:

a) Butt welding with joint in Y: α = 60º; b = 2 mm; c = 1.5 mm; s = 10 mm; ***f = 5Hz***;

b) Butt welding with joint in Y: α = 60º; b = 3mm; c = 2.0mm; s = 10mm; ***f= 1Hz***.

The pulse current parameters in the two situations were as follows: Pulsed current: Ip = 134 A; Base current: Ib = 67 A; Average current: Ism = 100 A.

Figure 4 below shows the appearance of the welding on the outer surface and at the root level for case "a" at a pulse frequency f = 5 Hz;

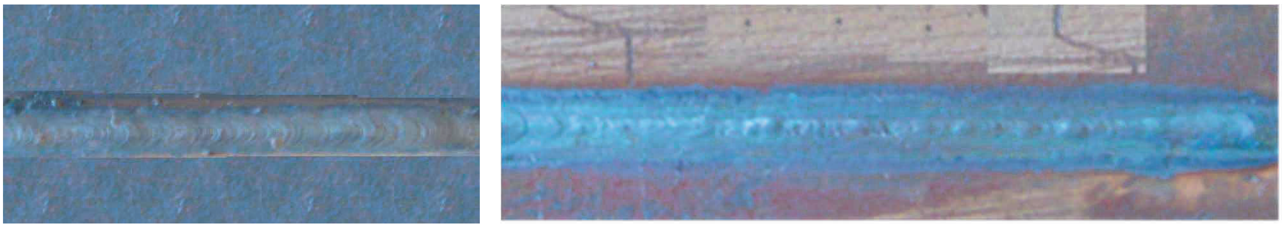


Figure 4 Aspect of welding for Ism = 100 A and f = 5 Hz

In this case it is obvious that the technique used as welding operation method the root layer was one without swinging the electrode, with its support on the flanks of the joint. The surface of the weld is uniform and smooth, with a low level of splashes and small splashes. It is worth noting the good and uniform penetration of the weld to the root using this welding technique and the effect of using 5 Hz pulse current which gives the welder a good control of the welding pool. This is also confirmed by the macroscopic appearance of the weld, see **Figure 5** below.

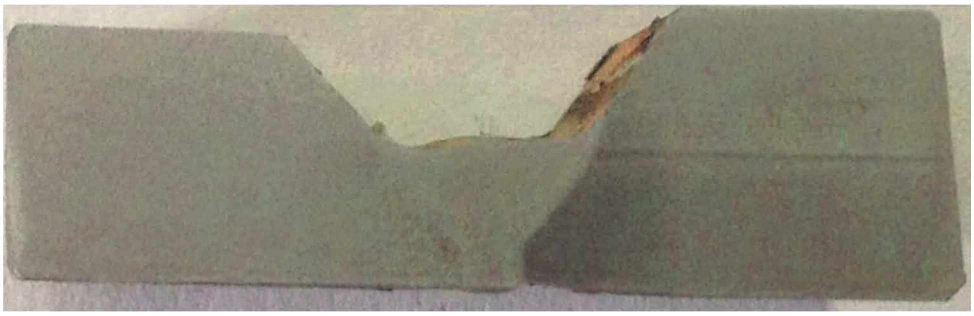


Figure 5 Macroscopic appearance of welding

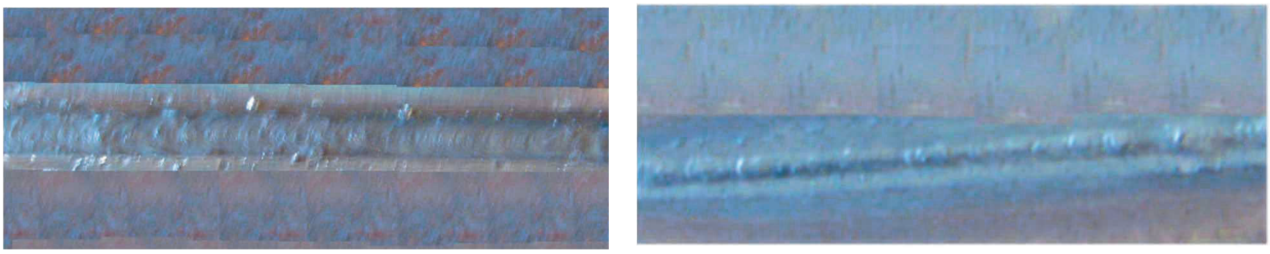


Figure 6 Aspect of welding for Ism = 100 A and f = 1 Hz

Figure 6 below shows the appearance of the weld at the outer surface, respectively at the root, for the case "b", at a pulse frequency f = 1 Hz. This time, from the analysis of the joint dimensions used, it is obvious that the operational welding technique used for welding the root layer was the continuous swinging of the electrode without supporting the electrode on the flanks of the joint, as in the previous case. The surface of the weld is uniform and smooth, with a higher level of splashes and larger sprays. It is noteworthy a better and uniform penetration of the weld at the root using this welding technique, mainly as a result of greater joint opening and electrode swinging. Penetration of the electrode favours greater and safer penetration at the root. This is also confirmed by the macroscopic aspect of the weld, see **Figure 7** below.

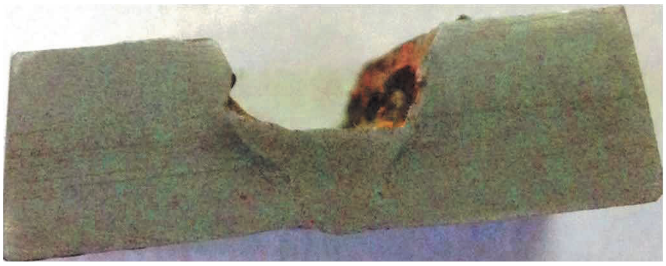


Figure 7 Macroscopic appearance of welding

The weld is slightly concave and a tendency of the left-side flange slotting is seen as a result of a longer arc used for welding.

5. CONCLUSIONS

- Control of the metal bath in pulsed low-frequency current welding is obvious;
- Partial solidification of the metal bath during the base current is manifested by the formation on the outer surface of welds of symmetrical and regular layers of bed;
- Pulsed current welding determines two welding techniques in the joint, respectively for the root layer: at low frequencies i.e. < 2Hz the welding is intermittently made by swinging the electrode at a frequency equal to the frequency of pulses and stopping on the flanks of the joint; at higher frequencies i.e. < 2Hz, root welding is done without swinging the electrode by supporting the electrode on the flanks of the joint i.e. the so-called sink arc;
- At the same average welding current there is a penetration improvement as a result of pulsed current;
- Welding penetration is safer and better for welding in pulsed current and is explicable by the high level of pulsed current;
- Psychological effect on welder is positive in terms of feeling of better control over the metal bath confers comfort and greater confidence of the welder;
- Manual welding with coated electrode in pulsed current is feasible and beneficial effects can be obtained.

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