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Technology Of MIG-MAG Welds Strength Enhancement

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Abstract. A new technology of MIG MAG welding control is developed. Authors introduce use of power AC and pulse feed of welding wire in the arc zone, that downsizes the heat affected zone, stabilizes formation of electrode metal droplets, as external magnetic field's effect on the arc is reduced. Principal criteria for electrode metal transfer control, when powered by AC sources, are specified.

Introduction

Conditions of the arc, if power AC supply, differ from conditions of the arc, if DC power supply. The active spot on the cathode changes voltage hundred times per second when a sinusoidal voltage frequency is 50 Hz. At the end of each half-cycle, sinusoidal voltage drops to zero; this diminishes the intensity of arc distance's electrical field. Consequently the gas ionization in the arc column diminishes and near-electrode spatial charge diffuses; that does not comply with the terms of arc stability [1]. However, alternating current arc welding has several advantages, i.e. absence of external magnetic field effect on the arc ensures its spatial stability; cathode's sputtering degrades the oxide layer during half-cycles when a product becomes the cathode. AC arc gives the best temperature fields distribution, which affects quality of microstructure and residual stresses of welded joints. In world practice, AC is used only when non-consumable electrode welding of aluminum metals and alloys, as well as arc welding with special purpose electrodes. The authors present a new technology of mechanized gas metal arc AC welding with a pulse wire feed for welding of steel structures in different spatial positions. This problem was considered by Paton B.E., Lebedev V.A., Mikitin Ya.I.

Implementation

As mentioned above, MIG MAG AC welding has several key advantages if compared with DC welding [2]. However, MIG MAG welding is limited in use because of disadvantages, caused by alternation of current itself. Regular charge recovery, if AC, is a precondition for arc stability while gas shield welding; consequently source of power with high open-circuit voltage is required for agitation of AC arc. Arc current curve becomes distorted; and DC component occurs in the welding circuit.

DC component, in its turn, creates a constant magnetic field the transformer core and the welding choke coil; that diminishes power and stability of the arc. One of the major limitations of AC welding use is arc distance short circuit while of electrode metal transition into the weld pool. Elimination of disadvantages would create an energy-efficient weld technology and increase quality of welding joints due to better thermal cycle and more intense deoxidation and refining of metal. [3]

The proposed welding technology is as follows. Welding is performed in shielding gas, powered by alternating current, with simultaneous use of two pulse sources: mechanical and electrical. Power AC is used synchronized with cycles of pulsed wire feed; procedure is controlled through the feedback paths (Figure 1). Wire melting occurs in alternating (sinusoidal) cycle of T1 current increase, correlated with wire feed cycle pause. Electrode metal transfer occurs when arc distance short circuit, in the cycle of decrease and alter of T2 current polarity due to wire feed pulse. Arc initiation is forced by wire move from the weld in the cycle of arc current increase. To do this, a pulse wire feeder is used (Figure 2) [4].

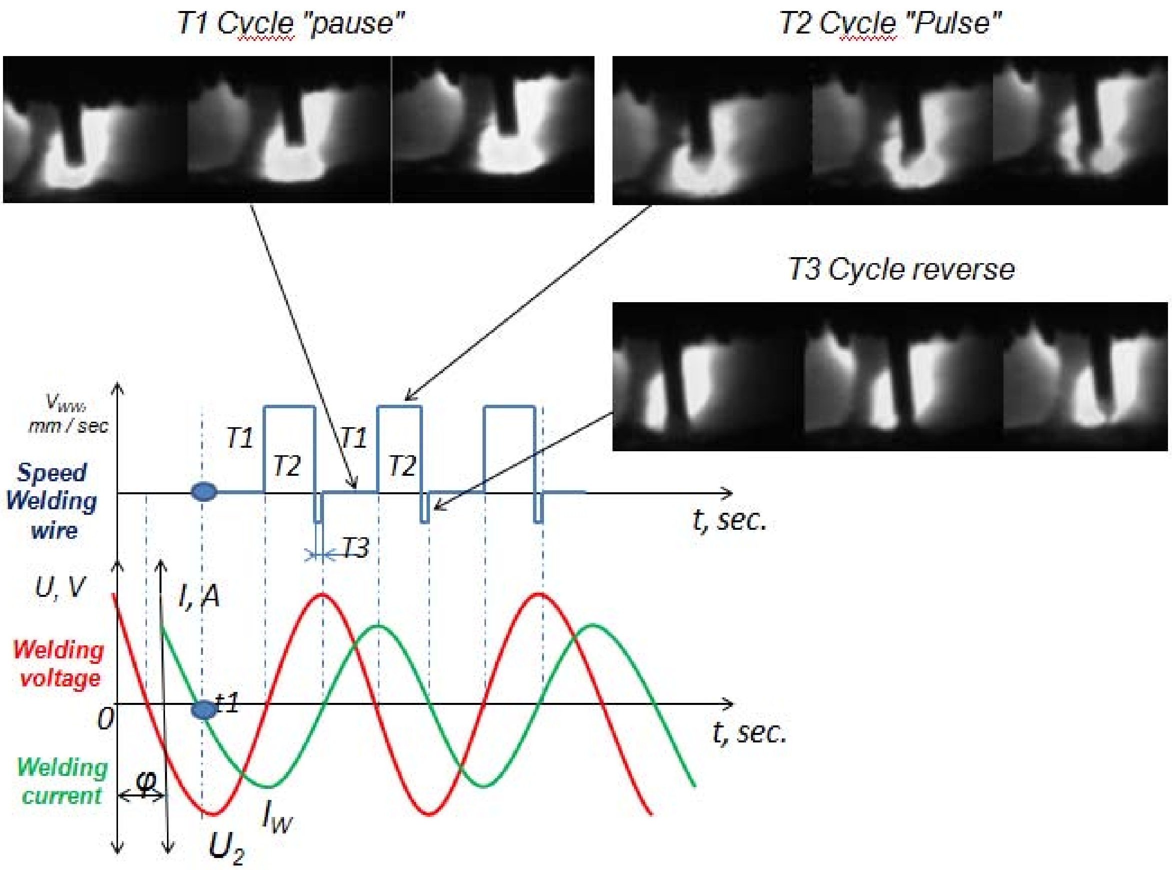

Figure 1 - Sequence diagram of welding process

Technology features. Melting of welding wire and initial formation of electrode metal droplets occur in the moment of no wire feed when arc polarity is reversed. When arc polarity reverses, the anode is hotter than the cathode. Melting rate increases during a pause in welding wire supply; thus a drop of electrode metal is formed. Further, impulse of welding wire feed occurs at time T1, when the arc voltage sinusoid drops to zero, and phase-shifted arc current gradually tends to zero. Accordingly, liquid metal drops transfer through the electrode arc distance occurs with minimum impact of arc forces. Droplet transfer to the weld pool occurs in the moment of short-circuit of arc distance, while the arc current alters from reverse polarity to direct, and at the end of wire feed pulse cycle T2. Thus, arc current has a low value; that diminishes gas dynamic force while droplet detachment, and facilitates smooth transition of electrode metal into the product. Arc initiation is improved and time of liquid wire metal attachment from the weld pool is diminished by controlled wire move upward the product [5].

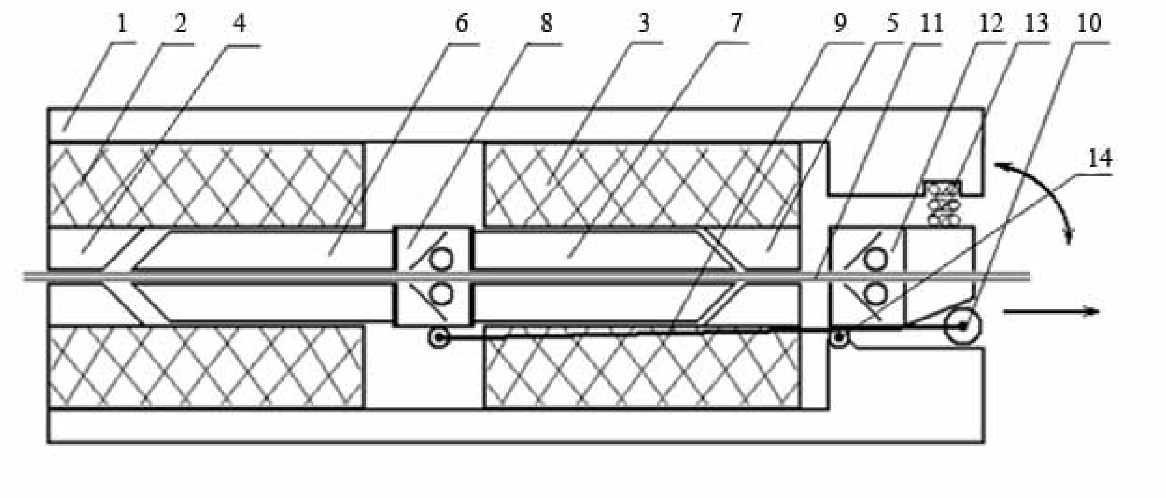

Figure 2 - Design of pulse feeder: 1 - body, 2, 3 - electromagnetic coil; 4, 5 - core; 6 - armature; 7, 8, 12 - ball-bearing guide; 9 - rod; 10 - roller; 11 - welding wire; 13 - compression spring.

Mechanism of pulse wire feed operates as follows. The armature (7) is pulled into of the electromagnetic coil (3) and pulls the armature (6) when electricity is supplied to the coil (3). At the same time the guide (8) is jammed and pulls the wire (11), which is sliding through the guide (12). After switching to the coil (2) reverse action occurs, i.e. the armature (6) is pulled into the coil (2) and pulls the armature (7); the guide (12) is jammed, and the guide (7) is sliding along the wire (11). While return of the armature (6) through the rod (9), roller (10) displacement occurs, which, while moving, ups the front guide edge (13) fixed in the hinge (14). Reverse of the guide (12) drives the wire (11) back from the welding zone, which leads to forced attachment of liquid metal between the wire and the weld pool. The spring (13) holds the guide (12) relative to the roller (10). In this way, alternate switching of coils provides wire movement into the weld zone (11) (shown by arrow), wherein the guide (12), vibrates relative the axis (14) (shown by arrow) and breaks liquid metal contact between the wire and the weld pool while reverse movement of the armature (7).

Besides, to produce high-quality welds, power circuit, controlling feeder's operation, should involve inductive nature of load (electromagnet or motor). Based on the foregoing, mechanism of pulse wire feed together with electric circuit and arc is to be an automated control system with feedback being the key element. Such a control circuit (Fig.5.6) can work with any actuator (electromagnet or motor) of pulse wire feed.

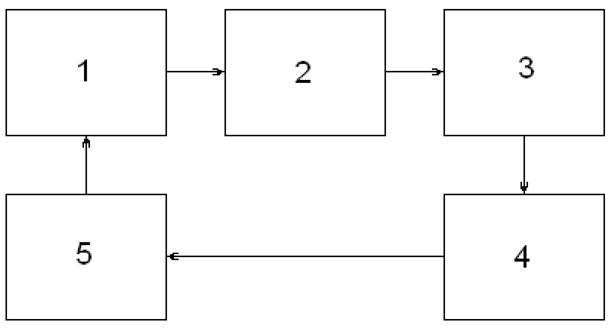

Figure 3 Diagram of pulse feeder control: 1 - correction block; 2 - pulse generator, 3 - power circuit; 4 - pulse feeder; 5 - welding arc;

The control unit monitors variations of arc parameters and corrects welding wire track adequately, at the stage of metal droplet formation and transfer to the weld pool. The unit has voltage or current feedback; the circuit diagram is shown in Figure 4.

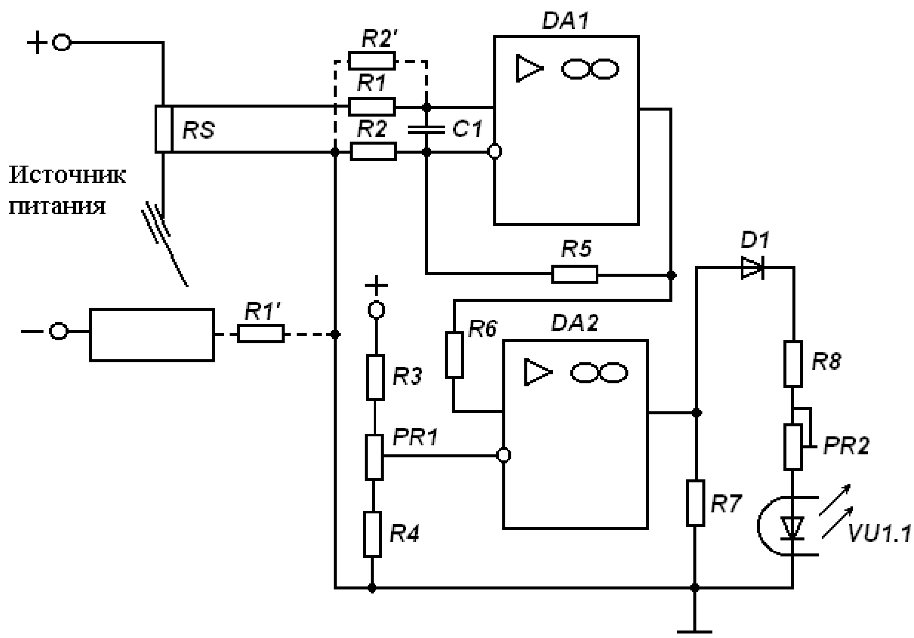

Figure 4 Welding wire pulse feed control unit

The device unit comprises: welding current or arc voltage sensor *(DA1)* and controller for synchronization of welding parameters and control unit input impedance; feedback is a current or voltage (voltage feedback is dotted). The device compares predetermined voltage with a feedback signal (DA2) and, depending on potentiometer's indications (PR1), gives a correction signal to the pulser. To synchronize operation of the correction unit and the pulser, as well as exclude their electrical interconnection, galvanic isolation (transformer or optoisolator) *(VU1)* is to be implemented.

Materials and Methods

Laboratory tests confirmed industrial applicability of the proposed technology. Mechanical properties of welded joints, made of 30ХГСА steel with Св-08Г2С welding wire in carbonic gas environment, were tested. It has been found that if using the proposed technology, impact toughness enhances [6].Results of mechanical tests of welded steel samples (multi-layer weld of articulated pipe joint) [7, 8]

Welding technique	Tensile strength, MPa	KCV Impact toughness, J/cm^2 at 20°C	Weld hardness, HB	Hardness 3TB, HRC (HB)
Conventional DC	635	141	167	22(198)
Recommended technique	634	167	153	23(207)

Metallographic examination of welded joints (Figure 3) showed a decrease in heat-affected zone to 15% due to cyclic rise and decline of arc current with alternation of polarity; if compared with mechanized DC welding in shielded gases. Videography and oscillography showed that electrode metal transfer was more stable, since no axial deviation of the arc; electrode metal scattering diminished to 4%.

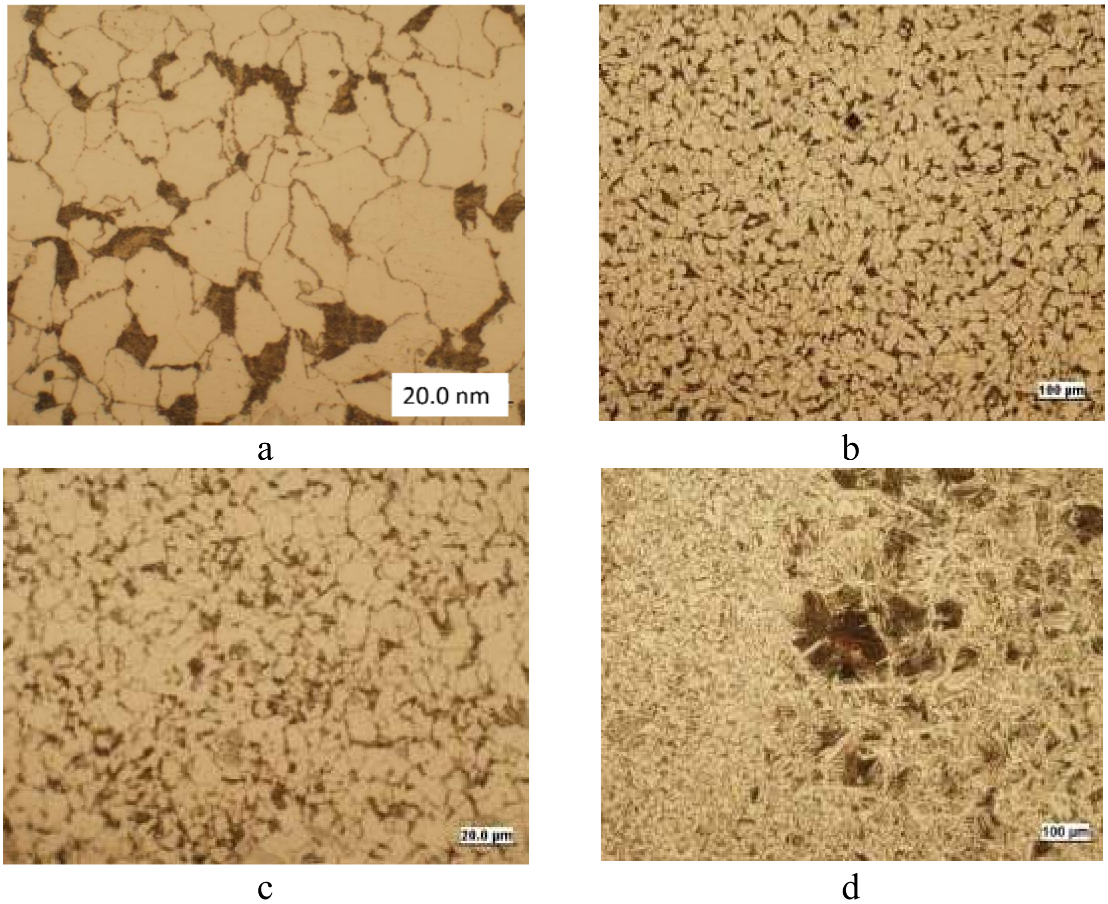

Fig. 3 Weld microstructure: a, b - 09G2S steel microstructure; c - HAZ microstructure (AC arc welding); d - HAZ microstructure (conventional DC welding).

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Conclusions

The technology developed has advantages as follows:

a) Electrode metal transfer is synchronized with polarity alternation of power AC by pulse wire feed, when voltage sine wave decreases and approaches to zero and arc pressure forces are minimal. Stabilization of electrode metal transfer to the weld pool occurs by the aid of automated control system feedback. Transfer is performed on power current of 50 Hz.

b) Volume of the transferred metal droplet is diminished because of lower arc current and no arc pressure during the transfer, thereby reducing both electrode metal heat capacity and alloying elements burnout; impact toughness of weld joints enhances.

c) Transfer rate of the droplet into the weld pool enhances, as short circuit and transfer occur simultaneously in the moment of current zero and polarity alternation from reverse to direct. This minimizes gas-dynamic impact; spattering losses are reduced to 4%

d) Width of HAZ is reduced to 15% as resulted by sinusoidal variations of current intensity and polarity; cyclic electron emission from the cathode provides equilibrium fine-grained microstructure of weld joints.

e) Power consumption is diminished by use of welding AC transformers.

f) HAZ downsize and weld metal dilution occur without use of costly high-tech SMPS.

References:

[1] Saraev Y. Adaptiv pulse-arc welding methods for construction and repair of the main pipelines.

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Proceedings of The 2nd South-East European IIW International Congress “Welding – HIGH-TECH Technology in 21st century”. Sofia, Bulgaria, October 21st-24th 2010, p. 174 – 177.

[2] Lebedev V.A. Creating mechanized arc-welding equipment with pulsed electrode supply. Russian engineering research. 2009. т. 29. № 2. с. 131-135.

[3] Chinakhov D.A., Agrenich E.P. Computer simulation of thermo-mechanical processes at fusion welding of alloyed steels // Materials Science Forum. – Vols. 575-578 (2008). – Pp. 833-836.

[4] Brunov, O.G., Solodskii, S.A. Physico-mathematical modelling of the transfer of electrode metal droplets into the weld pool. Welding International. 2009. 23 (12), pp. 930-933

[5] Paton B.E, Lebedev V.A, Pichak B.G, S.I Poloskov Evolution pulsing systems electrode wire length welding and surfacing. Welding and diagnostics. Number 3. 2009. p. 46-50.

[6] Brunov, O.G.,Solodskii, S.A.,Zelenkovskii, A.A. Conditions of arc ignition in welding in shielding gases/Welding International 2012 26 (9), pp. 710-712

[7] 7.Chinakhov D. A. Study of thermal cycle and cooling rate of steel 30ХГСА single-pass weld joints // Applied Mechanics and Materials. – Vols. 52-54. – 2011. – p. 442-447. - Mode of access: http://www.scientific.net/AMM.52-54.442

[8] Valuev D. V. , Danilov V. I. Reasons for Negative Formation of Structures in Carbon Steel Processing of Pressure // 7th International Forum on Strategic Technology (IFOST - 2012): Proceedings: in 2 vol., Tomsk, September 18-21, 2012. - Tomsk: TPU Press, 2012 - Vol. 2 - p. 151-154.