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Systems to Control Molten Metal Transfer in Arc Welding

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Abstract. The paper analyzes the systems used for controlling molten wire metal droplets during the arc welding process in shielding gases. The variations for implementing the relevant systems are given, with the positive and negative aspects of such implementation taken into account. Electrical systems are currently investigated to the fullest extent possible and implemented in different power sources for pulsed welding arc. Mechanical systems are represented by different types of feeders that provide the pulsed wire feeding process. The feed mechanisms driven by electric motors and electromagnets are analyzed. In addition to the mechanical and electrical systems, the examples of combined control systems are given.

1. Introduction

Mechanized and automatic consumable electrode arc welding is the basic technology to have a permanent joint. Gas-shielded metal arc welding is the most widely used in industries over the world.

The developed and offered on the market consumable electrode welding techniques are constantly improved with the purpose to obtain joints having an optimal balance between geometry and metal quality, reduce the costs of further processing works, and reduce the consumption of material and energy resources. A number of features pertaining to the gas-shielded welding process depend on a type of electrode metal transfer.

The transfer of wire electrode metal to a weld pool can normally be divided into three main stages. During the first stage a droplet of a specified size is formed at the electrode tip. Within the second stage the droplet's growth stops, and this droplet together with the electrode contact tip approaches to the weld pool. The third stage completes with the metal transfer to the pool when the bridge between the electrode tip and molten metal drop is destroyed.

There are several variations of metal transfer in the AW process using gas shields; the basic types are featured as follows:

- with naturally occurring short circuits;
- with continuous arcing and droplets or globs of metal transfer;
- with continuous arcing and spray or rotating spray transfer of metal.

The types of metal transfer as well as forces acting on a wire electrode metal while arcing are described in [1, 2]. Each type of metal transfer has both advantages and disadvantages.

2. Analysis

The droplet of a specified mass can be obtained using several possible processes. One of the promising trends in techniques to solve problems in terms of controlling droplets of molten wire metal is to apply power pulse cycles to affect the welding process [3]. Currently, three systems have been developed to control the metal transfer:

- Electrical systems, where power sources generate energy pulses to act on the transfer process (Pulsed Power Welding);
- Mechanical systems, where pulsed wire feeding devices are used;
- Combined systems, where the combined effect of electrical and mechanical systems is received.

The first technique, when using an electrical system, is mostly fully investigated and implemented in different pulsed power supplies [4]. A wide range of ways in implementing the first technique makes possible to program almost any algorithms to change the energy parameters of welding arc [5, 6]. The feedback processed in similar devices also enables the design and development of adaptive control systems.

Complexity in designs and difficulty in finding technical solutions may refer to the disadvantages of those devices, and as a consequence they are more expensive. Their operation is limited and sometimes impossible in difficult conditions of high electromagnetic disturbances.

The second group when using a mechanical arrangement, according to the classification proposed in [7], represents devices that can make an influence on a filler material feed system (figure 1).

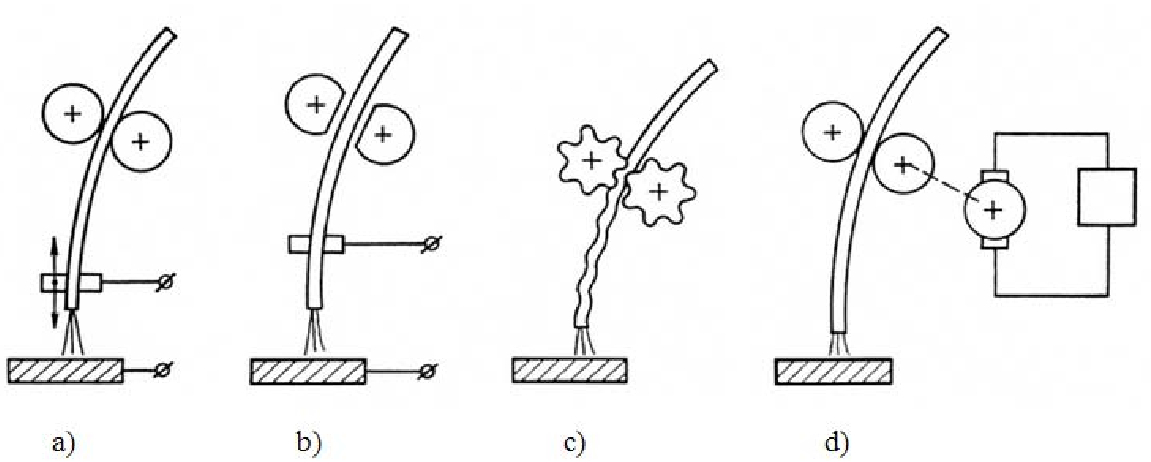

Figure 1. Devices to control the feeding process of filler material.

The devices acting on a feeding system of filler material are presented by mechanisms with the position of the current contact jaw be changeable (figure 1, a), mechanisms with non-circular (figure 1, b) and specifically profiled drive rollers (figure 1, c), and mechanisms fitted with a variable speed wire feed motor (figure 1, d). These mechanisms increase the stability of the welding process and improve the weld formation [8]. Describing this group, we can set the common shortcomings of these mechanisms are as follows: a narrow frequency range, complexity, and sometimes impossibility to correct operating modes during welding. On the other hand, such devices are less sensitive relating to utilized power sources and types of current, i.e. these techniques can be employed using standard power sources.

At the present time, the materials relating to this problem and presented in [7], have been further developed. Therefore, it seems necessary to update the information already available.

The currently available mechanisms of pulsed wire feed can be divided according to a number of features defining their characteristics.

One of the important criteria characterizing both continuous and pulsed feeders is a weld wire feed method. On the basis of this feature, the wire feed mechanisms can be divided into:

- a push-type feed system (a feeder is located in front of the drive rollers, its job is to push the electrode wire through the insulated conductor tube to a welding zone);
- a pull-type feed system (a feeder is located behind the drive rollers, its job is to pull the electrode wire from the insulated conductor tube).

Another classifying criterion is a type of electrode wire feed drive. According to this criterion, there are two main tendencies for designing and developing devices being used for pulsed wire feed:

- Devices driven by an electric motor (AC or DC, stepper motors);
- Devices driven by electromagnets.

We consider three conventional schemes used for feeding units based on electromagnets (figure 2) [9, 10].

One of the generalized variations for electromagnetic feeding units is shown in figure 2, a. A returnable member in these structures is made in the form of a spring [11] or in the form of elastic membranes [12, 13]. The disadvantage of these devices is irrational use of electromagnet power, which is used not only for wire feed but also for compressing the returnable member.

The device where the second electromagnet is used instead of the returnable member [12, 14] is shown in figure 2, b. Its disadvantages are a low rate of rise in the wire feed and instability of pulse intervals, hence, like the previous device, this mechanism requires the increased electromagnet power in order to overcome initial inertia, and the electromagnet used for the return action does not operates in full.

The device that does require much forces while returning a clamp and simultaneously compresses the spring (figure 2, c) [15] is accepted as the most successful technical solution, i.e. this device accumulates energy as long as the electromagnet armature retracts, and then this energy is translated into an initial point of wire feeding that leads to its rapid acceleration and enables the maximum use of the complete energy supplied to the feeder.

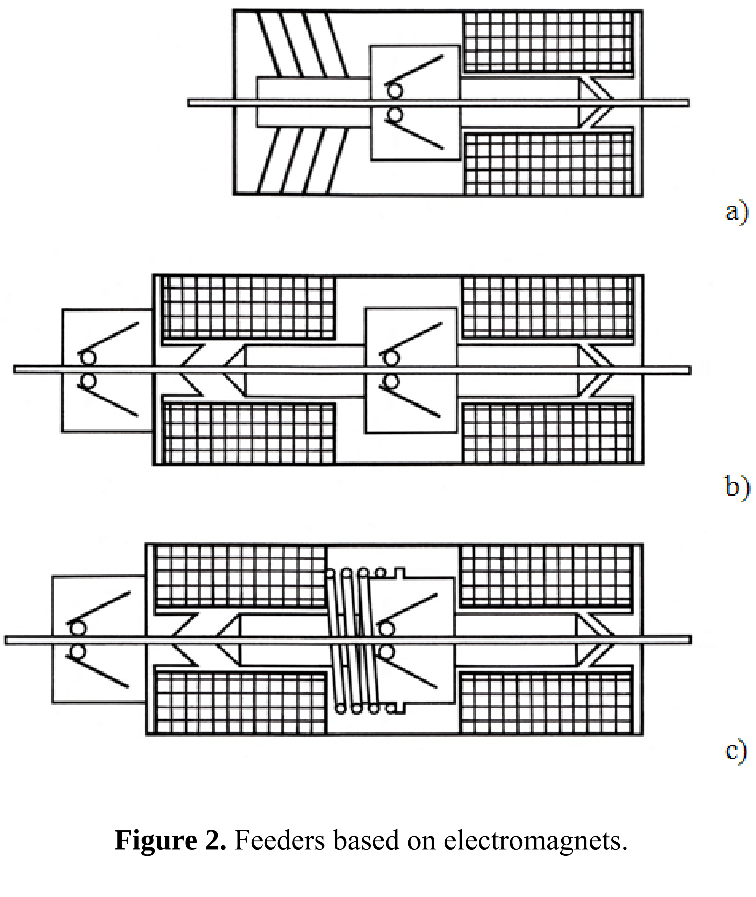

Figure 2. Feeders based on electromagnets.

The feeding mechanisms driven by an electromotor, except for those presented in [7], can additionally be divided into:

1. Direct-drive mechanisms driven by an electromotor [16];
2. Mechanisms with an eccentric roller or profiled jaw;
3. Mechanisms with a programmable voltage supply motor [17];
4. Mechanisms with a movable clamp on the basis of a quasi-wave inverter (QWI) [18, 19];
5. Feeders with a stepping electromotor;
6. Direct-drive mechanisms with a valve electric drive [20].

The E.O. Paton Electric Welding Institute in Ukraine and the Fronius Company are the leading designers of pulse wire feeders.

According to the Ukrainian experts' opinion, mechanisms with a quasi-wave inverter are the most sophisticated all-purpose devices, featuring the improved capability to adjust pulse parameters, in which the feed roller is mounted directly on a motor shaft, and a microprocessor control system enables the programmable pulse rotation of the shaft [3]. One of the solutions offered by Ukrainian designers is the pulsed wire feed system using a special valve electric drive fitted with a digitally controlled unit for adjusting the shaft rotation characteristics [21, 22].

Fronius developed a new technology for the controlled metal transfer process branded the CMT (Cold Metal Transfer) process. During the short circuit, the wire metal moves rearward, the current flow stops and the droplet transfers to the weld pool without spattering [23, 24]. In fact, this technology is the one of those representing the third type of wire transfer control systems – the combined system.

The pulsed wire feed devices driven by the electric motors enabling the direct-drive pulsed feeding are research developments; however, their price exceeding that of conventional systems 1.2-1.5 times needs to be taken into account [25].

The analysis of the systems described in this paper has proved that wire feeding units show a great potential for further development. The pulsed wire feeding process finds its successful implementation in the scheme shown in figure 3.

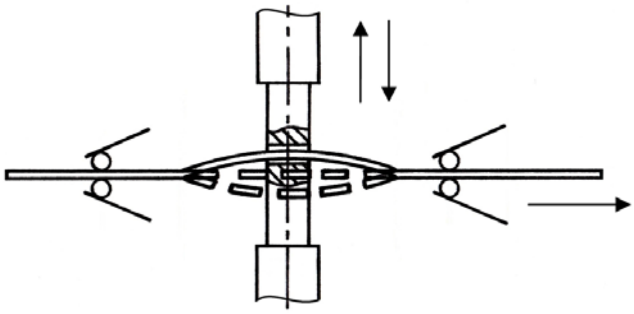

Figure 3. Schematic pulsed wire feed mechanism.

The operation of this mechanism can be described as follows: when moving “upward", the wire is pulled through the left clamp, at this time the right clamp is jammed, preventing the wire from passing. While moving to a "low position", the left clamp is jammed and the right clamp is open, enabling the wire feeding process. The reciprocating movement of the wire rod in the axial direction can be performed using one [26] or two [27] electromagnets, cams [28, 29, 30], or an electromotor driven crank-and-rod mechanism [31].

3. Conclusion

Thus, the wire metal transfer control process using various kinds of pulsed cycles is of great interest; this fact is evidenced by the development of modern welding technologies and machines, aiming at welds having specified properties. The most advanced types of feeders are electromagnetic devices with quasi-wave feeders and direct-drive devices with electric motors. The electromagnetic mechanisms have the advantages as they provide a wide range of control feed rates, relatively low feed forces, and high efficiency. The simple design, highly reliable mechanism and low mass-and-dimension parameters result in the advantages for the direct-drive devices. Therefore, these two types of mechanisms as well as their combination and the usage in combined systems are supposed as most promising relating to their further research and development.

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