DAMPING OF WELDING CURRENT FLUCTUATIONS IN ROBOTIC ARC WELDING

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The possibility of damping undesirable current fluctuations in welding circuit was considered. A criterion was derived which allows assessment of damping properties of welding circuit directly by its parameters.

Keywords: *robotic arc welding, consumable electrode, stability of process, aperiodic modes, damping of welding current fluctuations*

The character of dynamic processes running in welding circuit in consumable electrode arc welding is defined, as is known, by parameters of the circuit itself. One of the fundamental requirements for the choice of these parameters is providing stable dynamics for a wide range of modes being applied. Therefore the issues of stability have always been of a proper attention. In particular, the conditions of stability for the case of fixed parameters were profoundly studied and corresponding criteria were obtained [1–4]. The results of further investigations [5–8] regarded issues of stability in mechanized and automatic arc welding. In the recent time the influence on stability of parametric disturbances, caused by electric current fluctuations in arc column [9] and non-controlled change of contact resistance in current conducting tip of a torch in welding process, was investigated [10]. The influence on stability of so-called small parameters, in particular, lag of arc discharge [11] was also investigated.

Therefore it is necessary to note that in manual arc welding the conditions of stability are practically fulfilled in the whole range of applied welding currents. It is predetermined, first of all, by the fact that steepness of external characteristics of welding current source is selected as a rule as steep falling, and welding electrodes are used of rather large diameter. Such combination of parameters, as is shown below, provides not only stable but also aperiodic mode, at which transition processes in welding circuit are running without free (natural) fluctuations, which favorably affects the quality of welding process itself.

Somewhat different characteristics are peculiar for robotic arc welding. Its distinctive feature is application of consumable electrode wire of small diameter and welding current sources with more rigid external characteristics. Namely in that case the so-called loss of aperiodicity can occur and, as a consequence, fluctuation processes can occur in welding circuit due to different disturbances (especially at the beginning of welding) not contributing to the quality of welding performance. To damp undesirable fluctuations of welding current one should know the conditions (criteria) first of all which result in running only aperiodic processes in welding circuit.

Thus, it turns out to be necessary to define the aperiodicity criterion itself which could be used at preparation of equipment for robotic arc welding. In the present work such criterion has been derived.

Let us examine welding circuit as a system with negative feedback by the rate of electrode melting. Due to this feedback the rate of electrode melting, arc length and welding current in welding process are automatically maintained at the specified level (in literature this effect is known as arc self-adjustment).

According to [12] the system under consideration can be introduced in dynamic relation by a one «folded» link with the operator transferring function

$$W(D) = \frac{\Delta v_m(t)}{\Delta v_e(t)} = \frac{1}{T_e T_s D^2 + T_s D + 1}, \qquad (1)$$

where $D = d/dt$ is the operator of differentiating; t is the current time; $\Delta v_m(t)$, $\Delta v_e(t)$ are the deviations of rate of melting and feed of electrode from nominal values, respectively; T_e, T_s are the constants of time, defined by relations

$$T_e = \frac{L}{R_*}, \qquad (2)$$

$$T_s = \frac{R_*}{EM}. \qquad (3)$$

Here L is the inductance of welding circuit; E is the intensity of electric field in arc column; $M \equiv \partial v_m / \partial i$ is the steepness of characteristics of electrode melting at nominal value of welding current i; R_* is the total resistance of a circuit, calculated according to the formula

$$R_* = R + S_a - S_s, \qquad (4)$$

where R is the summed resistance of current-carrying wires, electrode stickout and sliding contact in the torch nozzle; $S_a \equiv \partial u_a / \partial i$, $S_s \equiv \partial u_s / \partial i$ is the steepness of volt-ampere characteristics of arc and source of welding current, respectively, at nominal value of a current i; u_a, u_s is the arc voltage and output terminals of welding current source, respectively.

Having used the following relation from the work [13]:

$$M = P/d^2,$$

where P is the parameter characterizing thermal physical properties of electrode material (density, temperature of melting and boiling, specific heat capacity and work of electron outlet); d is the diameter of consumable electrode, let us write the expression (3) as a function of R_* and d:

$$T_s = \frac{R_* d^2}{EP}. \quad (5)$$

Now disposing the dependencies (2) and (5) as a criterion of aperiodicity one can accept the relation

$$T_s > 4T_e, \quad (6)$$

at the performance of which the both roots of distinguishing equation corresponding to denominator of transfer function (1) are substantial, different and negative [14, 15]. Consequently, in this case welding circuit represents aperiodic link in structural relation. Violation of the condition (6) transfers this link to the fluctuating one. Therefore, the constant of time T_s defining lag of welding circuit is at the same time a damping factor, as with increase of T_s the decrease of natural fluctuations in welding circuit until their complete disappearance occurs.

Substituting the (2), (5) into inequality (6), we shall obtain the expression

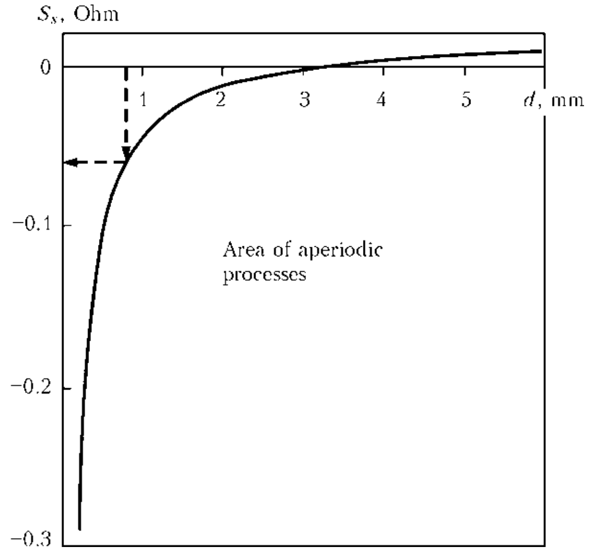
$$R_* d > 2\sqrt{PLE}, \quad (7)$$

which is the criterion of aperiodicity for the processes running in welding circuit. The criterion (7) considering the expression (4) can be presented in the form of

$$S_s < -\frac{2\sqrt{PLE}}{d} + (R + S_a). \quad (8)$$

On the right side of the inequality (8) all values of parameters, except d, are constant and known beforehand. Consequently, to define the field of aperiodicity of processes in welding circuit it is enough to plot a diagram of dependencies $S_s = S_s(d)$ at preset values of the rest parameters.

In the Figure, a curve $S_s(d) = -\frac{2\sqrt{PLE}}{d} + (R + S_a)$ at $P = 0.53$ mm^3/(A·s), $L = 10^{-3}$ H, $E = 2$ V/mm, $R = 0.015$ Ohm, $S_a = 0.005$ Ohm, $d = 0.2$–6.0 mm is presented. It represents a boundary between regions of aperiodicity and damping fluctuating processes. It is seen form the Figure that for electrodes of large diameters the aperiodic character is preserved practically at any slope of falling external characteristic of welding current source. With the decrease of the value d the margin of aperiodicity is sharply decreased. Therefore, at small values of d, which are used as a rule in robotic arc welding, the appropriate value of steepness S_s applied for welding current source should be preliminary calculated according to the formula (8) for damping of undesired fluctuations. For example, if the steepness S_s is selected larger (according to the absolute value) than $|S_s| = 0.07$ Ohm at $d = 0.8$ mm and mentioned values of other parameters (see the Figure) are considered, only aperiodic processes will run in welding circuit.



Boundary between areas of aperiodic and fluctuating processes

Thus using criterion of aperiodicity (8) one can easily calculate the necessary slope of external characteristics of welding current source for any diameter of consumable electrode, at which the welding circuit itself will provide damping of undesired fluctuations in robotic arc welding.

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