CONTROL OF ARC IGNITION DURING EXCITATION OF ELECTROSLAG PROCESS

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Control of the electric arc ignition process for inducing the slag pool for ESW is described. Algorithm of contact ignition of the arc from the first touch of a workpiece by wire electrode is given. The sharpened electrode tip and feeding of voltage from the power source to the fixed-electrode short-circuited to the workpiece are decisive conditions for reliable ignition of the arc. To transfer to the steady-state process, the electrode feed should be switched on with a lag after the arc ignition. Experimental data on the arc ignition are given.

Keywords: *electroslag welding, ignition of welding arc, induction of slag pool, ignition control*

A slag pool of molten flux is necessary for beginning of the electroslag process. It can be obtained (induced) by several methods. The slag is preliminary melted in auxiliary crucible and then poured in a gap between the edges being welded [1] or a solid state conducting flux is used [2] during electroslag welding (ESW) with large section electrodes. The slag pool in most cases is induced with the help of arc in wire electrode welding. Arc ignition can be contact-free using high-voltage high-frequency generators [3, 4], but mostly it is performed with the help of contact methods. A layer of metal powder or chips of 10–12 mm thickness and then a flux layer 3–5 mm thick [5] are put into a welding zone for making arc ignition easier. A method based on break of live contact between the electrode and workpiece being welded [6, 7] became the most widespread for shielded-gas consumable electrode arc welding or submerged arc welding.

A range of papers, for example [8–11], is devoted to the theoretical issues of contact ignition of the arc. Based on them, the process of contact ignition of the arc can be shown in the following way. Short-circuit welding current (SC) starts flowing through the electrode during contact of the electrode tip with metal being welded. Heat of the electrode making it heated is released as a result of current flowing. The largest amount of heat is released in the high-resistance zones: in electrode–workpiece and electrode–current-conducting tip contacts.

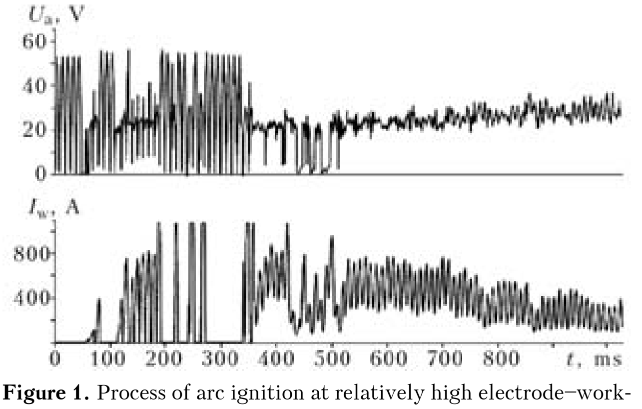

Figure 1. Process of arc ignition at relatively high electrode–workpiece contact resistance

If the contact resistances are relatively low than the electrode is heated up to the melting temperature closer to the middle of its extension due to intensive heat removing in the contact zones. After that the diameter of formed liquid bridge begins to reduce under the effect of surface tension forces and electromagnetic forces induced by flowing current. The bridge metal overheats up to evaporation and explodes. Significant part of the electrode, collapsed due to intensive heating, is removed out of the welding zone by explosion. The arc is not ignited due to large gap formed between the electrode. As a result of electrode feed the SC of arc gap is occured again but already with new temperature distribution along the electrode length. Initial temperature of the electrode tip will be every time higher due to heating at previous touch during repeated and following touches of the electrode to workpiece being welded. Electrode melting and bridge explosion will take place close to the electrode–workpiece contact after several SC. The electric arc is ignited [8] since formed ionized gap is sufficiently small. The SC for such a process of arc ignition is characterized by significant duration (Figure 1). Electrode wire of 3 mm diameter (feed rate of 42 m/h) and AN-8 flux were used in experiments.

A zone of electrode with workpiece contact appears to be the most heated at large electrode–workpiece contact resistance. Electrode melting and explosion of the liquid bridge take place exactly in this zone. The arc is ignited in a gap (electrode–workpiece) filled with ionized gas formed after the bridge explosion, i.e. the process of arc ignition occurs after the first touch of the workpiece by electrode.

Thus, a decisive condition of reliable ignition of the electrode from the first touch is increased resistance of the electric circuit in electrode tip–welded workpiece area and minimum resistance of the electrode–current-conducting tip contact.

A cross-section area of current conductor in the contact area is reduced in that or another way in order to increase the contact resistance of electrode–workpiece. Mentioned above metal chips or powder, electrode-welded metal plate of smaller cross-section than in electrode [7], vibrations of the electrode tip in the direction normal to its axis [12, 13] or sharpened electrode tip can be used for that. The latter can be obtained through reducing a size of drop remaining on the electrode tip using special algorithms for finishing of process of welding or snapping off the electrode tip with cutters better at acute angle to the axis. This method is the most simple and effective as experience shows.

The results of computer modeling of heating for sharpened and obtuse electrode tip at SC are given in study [11]. Heating conditions for these two cases have significant differences. Temperature maximum for the sharpened electrode is situated in the area very close to the tip. At the same time, the rest of the electrode is at room temperature. The area heated up to melting temperature in flat end electrode takes more extended area and situated at significant distance from the electrode tip.

If possible a form of the electrode should remain constant during the whole heating period for using advantages of the sharpened electrode to maximum. For that, initial rate of electrode feed up to arc ignition is set lower working one [6]. Otherwise, the area of electrode to workpiece contact is increased due to electrode feed at heating of sharpened electrode tip during SC up to ductility temperature and heat emission in this area is reduced. The best result is achieved at complete stopping of electrode feed for the period of arc ignition as this was done in work [14]. Process of submerged arc ignition at zero rate of electrode feed is given in Figure 2. A feed drive after touch of the welded workpiece by sharpened tip of the electrode is stopped, flux is put and welding power source is switched on. As can be seen from Figure 2, the process

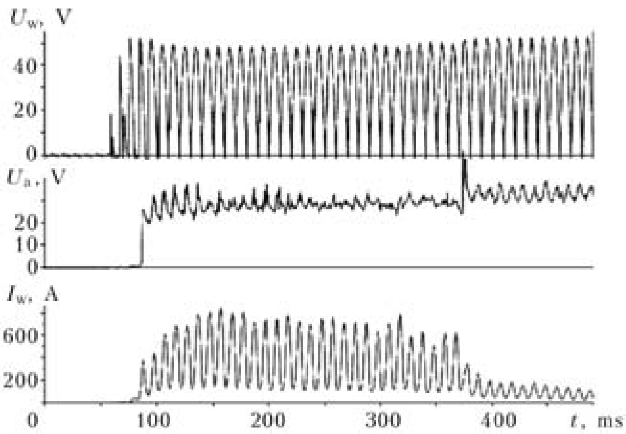

Figure 2. Electric arc ignition at zero rate of feed of sharpened tip electrode: U_w — voltage of welding source

of arc ignition is very flexible — SC current lower than 300 A, and duration is less than three half-circuits of supply-line voltage. Electrode melting by electric arc and discharge of formed drop result in increase of the arc gap up to threshold value of arcing at given voltage of power source and resultant arc extinction. The arc extinction takes place at 5 mm arc length for process parameters given in Figure 2. Duration of this process makes 350–600 ms. Therefore, electrode feed can be switched on after 150–250 ms for setting stable arc process. Further, the arcing stability depends only on parameters of power source, electrode feed rate and shielding medium, etc.

A sensor for the short-circuiting of electrode to workpiece and controller of driving of electrode feed motor and switching of welding power source were developed for automation of the algorithm of arc ignition mentioned above. The SC sensor is a low-voltage self-regulating voltage source with high internal resistance connected to the electrode in parallel to the welding power source.

A system of arc ignition is operated in the following way. START instruction switches on probing voltage of the SC sensor and electrode feed motor at low speed. Electrode voltage (Figure 3, *a*) sharply decreases at

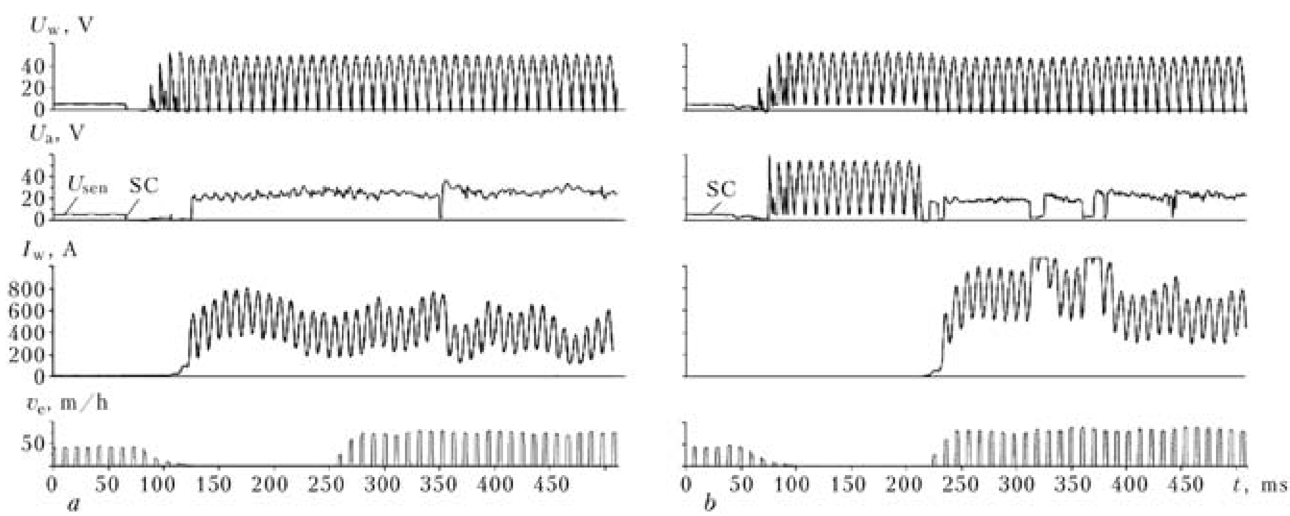

Figure 3. Automatic control of ignition of submerged arc using the electrode to workpiece touch sensor: *a* — ideal process of ignition; *b* — lag of arc ignition due to the flux film between the electrode tip and surface of workpiece being welded

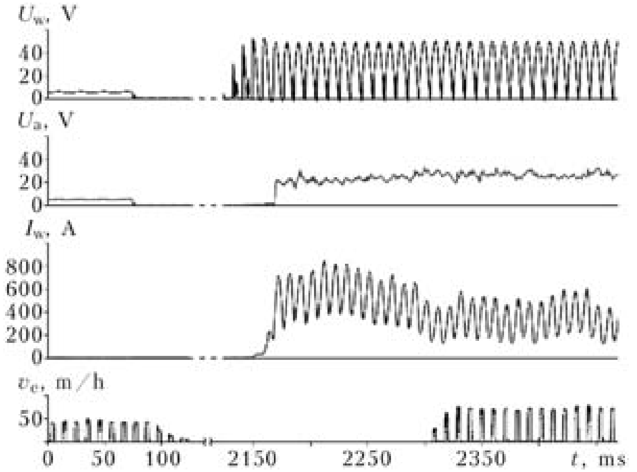

Figure 4. Automatic control of arc ignition at the flux filling after stop of electrode feed by touch sensor command

electrode SC to the workpiece. This signal stops the motor, welding power source is switched on and after around 200 ms of time lag the electrode feed motor is switched on again but already at working speed.

Unfortunately, the arc ignition occurs not as smooth as shown in Figure 3, *a* with flux preliminary filled in the welding zone. Sometimes, ultra thin flux film is formed between the electrode tip and surface of workpiece being welded. It makes worse a signal of the SC sensor and conditions of arc ignition (Figure 3, *b*) due to own low conductance. In this case the sensor acted accurately but arc was ignited not at once after welding source switching on but at significant lag. In principle, a situation is possible when the sensor can fail and motor does not stop or arc not ignite because of too low SC current (mainly it concerns only to ESW of vertical welds) due to high resistance of the flux film. Possibility of such a situation is significantly reduced in the process of relative movement of welding head and workpiece being welded during submerged arc welding.

Unreliable starting SC is eliminated when the flux filling is carried out after the SC sensor triggering (Figure 4). A difference from the processes, given in Figure 3, lies in significant increase of operation reliability of the SC sensor since its data are not influenced by the flux film on the surface of workpiece being welded. The peculiarity of the process is that the arc ignition current appears to be lower than the welding one. This is result of sharpened electrode tip. Besides, some current increase relative to its steady-state value is observed just after arc ignition. It seems that the relatively low resistance of still cold electrode extension and reduced arc voltage drop due to its small length provoked this.

Thus, ignition of the arc from the first touch of the workpiece by wire electrode for inducting the slag pool for ESW takes place in fulfillment of the following conditions:

- sharpened electrode tip;
- reliable contact of the electrode with current-conducting nozzle;
- stop of electrode feed after its short-circuited to the workpiece being welded;
- flux filling after electrode short-circuited to the workpiece;
- switching of power source only after this;
- electrode feed is switched on with 100–200 ms lag after power source switching to transfer to the steady-state process.

The SC sensor and controller of driving of the electrode feed motor and welding power source were developed for automation of performance of given algorithm.

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