DEVICES FOR IMPACT TREATMENT OF A WELD IN THE PROCESS OF RESISTANCE SPOT WELDING

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Variants of suspensions of welding electrodes for thermomechanical treatment of the weld metal directly during the welding process are considered. Design of the welding head with impact application of the compression force and a variant of the cyclogram for practical implementation of the thin metal welding process are offered.

Keywords: *resistance spot welding, structural steels, weld metal, impact loading, compression force, peening device, welding process cyclogram*

The results of experiments on qualitative estimation of effect of thermomechanical treatment of a weld, carried out directly during welding process, on the strength of welded joint described in [1] show the challenging application of high-speed (impact) compression force at the stage of cooling the metal of a weld spot.

The metallographic analysis of welds shows that impact influence on the metal of a weld spot directly in the process of resistance spot welding results in considerable refinement of microstructure and increase of mechanical strength of welded joints. Especially noticeable is the increase of strength properties in case of multiple application of impact compression force, which is most probably connected with impact influence on weld metal within the certain temperature range. The latter is achieved in the certain period of time which is set with insufficient level of accuracy due to imperfection of applied equipment for measuring temperature of a weld spot in continuous heating of less than ten half-periods of alternating current.

The purpose of this work is to select the optimal variant of a device for impact treatment of weld metal in the process of resistance spot welding.

Basing on results of strength tests of welded and brazed joints produced in gas flame heating and heating using electric resistance, it was established that the method of heating is not a distinctive factor in increase of mechanical strength. The basic parameters influencing the formation of fine-crystalline structure of a weld spot are the temperature range of weld metal duration at the moment of application of impact compression force and quantity of impact pulses.

The topicality of carrying out investigations of welding method with thermomechanical treatment of a weld directly during welding process is seen in the possibility of application of this technological procedure in the processes of joining the structures of thin-sheet metal and such materials for which application of conventional welding methods is impossible. The idea of metal peening in the process of its joining has been already known from the methods of forge welding, but in the variants of its application now the advantages of impact and repeated application of forging force at heating temperature of metals being joined, close to the temperature of their melting, are missed.

It is known that during impact treatment of materials the absorption of impact energy in the regions of heterogeneities of crystalline structure results in increase of level of compression stresses almost twice. The additional evolution of energy at the regions of contact of metals being joined intensifies the processes of mutual diffusion through the contact surface and accelerates the migration capability of atoms of metal in the regions of increased level of mechanical stresses [2–4].

High-speed deformation of metal is accompanied by cold working, the level of which is characterized by impact energy realized for refining the coarse polycrystalline grains of metal and forming the more homogeneous fine-crystalline structure similar to the structure of base metal [5, 6].

Thermomechanical treatment of weld metal directly in welding process is mainly used in the processes of resistance spot welding with a cycle of «peening» [7, 8]. However, the lag effect of pneumatic systems of movement of welding electrode prejudices not only the possibility of practical realization of «peening» of a weld spot, but leads to considerable and undesirable deviations of compression force in the process of a weld spot formation. It is explained by the fact that in the beginning of a heating cycle due to lag effect of a unit of electrode movement the increase of compression force is formed in the zone of a joint of parts due to sharp expansion of metal during heating, and then the electrode «hangs up» and does not manage to experience the almost sudden decrease of metal strength at the moment of its melting, thus promoting the formation of defects of welded joints and deterioration of strength characteristics of a welded joint.

To decrease the lag effect of a unit of electrode movement, the multilink system of electrode fastening

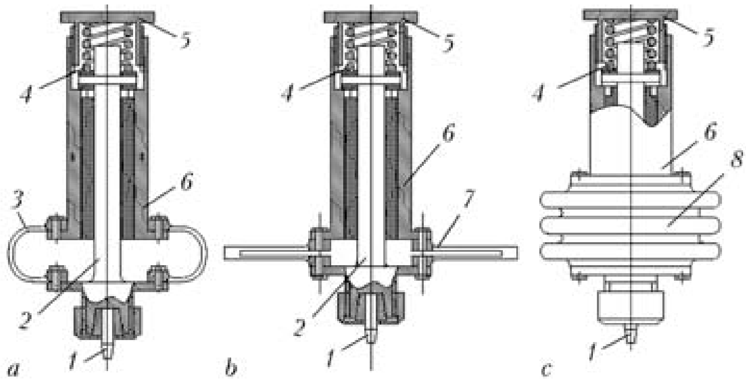

Figure 1. Diagrams of variants of lag effect of suspension of welding electrode: *a* — spring type; *b* — electrodynamic type; *c* — using electrohydraulic effect; *1* — electrode; *2* — moving part of suspension; *3*, *7* — respectively flexible and elastic current connectors; *4* — spring; *5* — controller of preliminary compression force; *6* — body of welding head; *8* — bellows

[9], for example, by arrangement of additional moving element with a lower weight at the lower end of a rod of pneumatic cylinder, which is connected with a rod by a spring-type suspension (Figure 1, *a*), or electrode unit using electrodynamic, electromagnetic forces, electrohydraulic effect and other types of energy transformation, are usually used.

In the suspension of an electrodynamic type (Figure 1, *b*) the electric current passes through two current-carrying surfaces, arranged at minimal distance perpendicularly to the axis of electrode which causes formation of electrodynamic forces in them, forming additional compression force, value and time of influence of which coincide with the shape of a welding pulse.

The considerable increase of impact pressure of compression can be achieved using electrohydraulic effect, for example, as a result of influence of high-voltage electric charge between electrodes submerged into any liquid in the bellows (Figure 1, *c*) [10].

The analysis of advantages and disadvantages of considered variants of design of electrode unit shows that system with an electrodynamic variant of applying impact compression force is more preferable as compared to the system of spring suspension of electrode, as far as the possibility of expansion of range of compression force and synchronization of compression force pulse with welding current pulse appears.

As compared to the system of electrodynamic type the electrode unit of electromagnetic system allows presetting the lag of switching on of pulse of impact influence relatively the welding current pulse, thus to carry out the thermomechanical treatment of weld metal at the preset heating temperature.

One of the advantages of electrode unit with use of electrohydraulic effect is possibility to apply higher speed of additional compression force which should be accompanied by formation of new technological effects. However at the first stage of performance of experimental technological works to confirm revealed advantages of impact thermomechanical treatment directly in the welding process of metals the scheme with electromagnetic application of impact compression force was selected allowing reduction of costs and terms of manufacturing electrode unit.

Therefore, the laboratory installation for performance of investigations of influence of thermomechanical treatment on the properties of weld was additionally equipped with the following units: welding transformer, welding head with unit of application of preliminary and impact compression force, command device and mechanism of movement of welding head (or sheets being welded) for the required distance between weld spots.

The main functions of the command device include providing the sequence of performing the following stages of realization of welding process: switching on of a preset amount of welding current periods; switching on of pulses of impact compression force after the moment of termination of heating pulses (after some time of welding current switching off); switching on of mechanism of movement of welding head or welding table with fastened parts being welded on it for a preset distance.

The design scheme of the unit of impact application of compression effort is presented in Figure 2. As is seen from the cyclogram, switching on of heating pulses of specimens being welded occurs after applying preliminary compression force P_1 to them, the value of which is controlled by variation of distance A_1 of spring compression *3*.

The influence of pulses of impact applying of compression force P_2 occurs within the preset time range t_1 after the moment of termination of heating. The number of pulses of impact application of compression force is defined by the time range t_2 preset by the command device and lag effect of moving part of the electrode unit.

The energy of pulses of impact compression is corrected by setting a gap A_2 between the edge of a solenoid core and a rod with a collet of the welding electrode fixation.

The selection of time moment t_1 is of paramount importance as far as efficiency of application of pulses of impact compression force is decreased both at its minimal value (i.e. at temperature of weld spot close

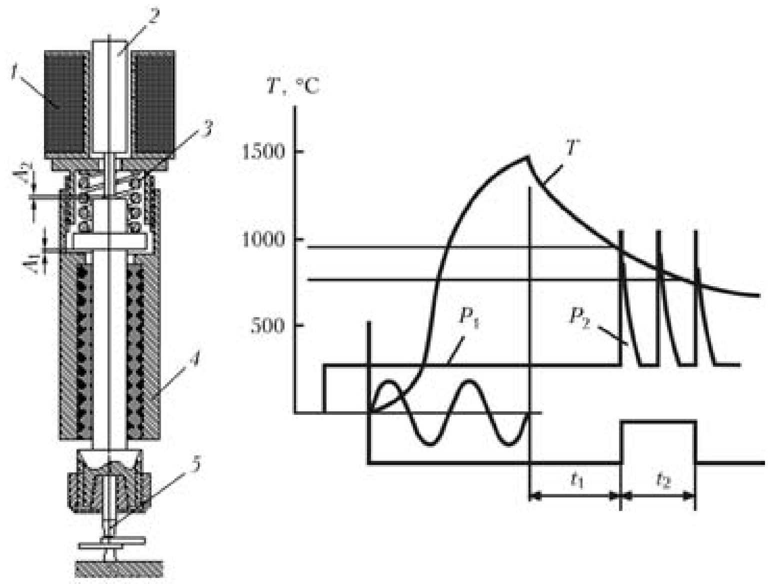

Figure 2. Schematic diagram of welding head with impact application of compression force and process cyclograms: *1*, *2* — respectively winding and core of solenoid; *3* — spring providing preliminary compression force; *4* — body; *5* — welding electrode

to the melting point of metal to be welded), as well as at its exceeding due to an abrupt increase of elastic properties of metal in the process of its cooling.

The results of carried out experiments on determination of temperature at which the application of pulses of impact compression forces leads to maximal increase of strength properties of welded joint indicate the range of 950–750 °C. However, coming from the technical difficulty of direct measurement of temperature of a weld spot metal during several fractions of a second, the indirect method of control by the time interval was used at the stage of development of this method, counted off after the moment of termination of heating, accepting the stability of parameters of heating and conditions of heat dissipation for initial conditions.

If necessary to perform seam welding of sheet materials the machine is equipped with mechanism of movement of parts being welded for the required distance between weld spots.

The obtained results of tests of welding head with electromagnetic system of application of impact compression force allow us to assume the possibility of transition from resistance spot welding to the variant of welding using indirect heating of parts being joined which represent interest from the point of view of welding of non-metallic materials. To realize the variant of indirect heating of parts being welded it is enough to complete the welding head with a plasmatron or gas-flame torch. Then the command device produces continuous succession of commands for impact treatment of a weld spot and instead of control of time range t_1 the distance between the source of indirect heating and welding head of impact thermomechanical treatment depending on the capacity of heating source and speed of movement of welding head is selected.

In this welding method the joining of sheet metal is performed in a form of succession of single weld spots with some overlapping, here each weld spot is subjected to impact effect of compression force to create mechanical compression stresses in it, sufficient for plastic deformation of weld metal.

CONCLUSIONS

1. The results of carried out tests of considered variant of welding head indicate the challenging application of electromagnetic system of impact influence of compression force in welding of steels of thickness of about 1 mm, for welding metals of larger thicknesses the transfer to the design of electrode unit using electrohydraulic effect is probably more necessary.

2. The presented design of welding head for treatment of a weld can be a base for development of new method of welding metals for which application of existing methods of joining are difficult or impossible.

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