BRAZE-WELDING WITH WELD METAL PEENING DURING ITS SOLIDIFICATION

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Advantages of the process of braze-welding of zinc-plated steel, including impact peening of metal in the joint zone at metal cooling stage, are considered in comparison with the widely accepted process of brazing by copper-based filler metals with arc heating.

Keywords: *resistance spot welding, braze-welding, peening, explosion compression mechanism, joint strength*

At present the process of brazing by Cu-based filler metals with arc heating became widely accepted for joining sheet Zn-plated steel. Selection of this variant of the joint is due, unfortunately, not to the desire to achieve a high quality of the joint, but to a possibility of improvement of process efficiency using currently available equipment for automatic or semi-automatic arc welding in the atmosphere of active shielding gases [1].

Main difficulties in welding Zn-plated steel are caused by that zinc starts evaporating much earlier than base metal melting temperature. Because of appearance of zinc vapours over the weld pool, electric arc loses its stability that promotes appearance of weld porosity, undercuts and other defects.

In this connection, in arc welding of Zn-plated steel the mode of heating with lower heat input is used, and Cu-based alloys, for instance of CuSn6P, CuSi3, CuSi2Mn, CuSi3 composition, are applied as filler wire [1, 2].

As in case of application of the above filler materials it is possible to avoid base metal melting, joints of this kind can be included into the category of brazed joints, even though in this process the fluxes, which are compulsory for conducting the process of brazing in an uncontrolled atmosphere, are not used. Here, the arc is a heat source, comparable in its intensity with the heat evolved, for instance, at flame heating.

Unfortunately shielding gasses (argon, helium) used in arc welding do not provide the necessary degree of wetting and spreading of Cu-based filler metal over Zn-plated steel surface. This circumstance leads to appearance of undercuts in the joint zone, and promotes initiation of microcracks lowering the joint strength at its operation under the conditions of cyclic load application.

In view of such shortcomings of the process of brazing Zn-plated steel with arc heating, the question of selection of an optimum variant comes up, which would provide not only high efficiency of the technological process, but also high quality of the joint.

One of the promising variants of producing joints of coated metals is braze-welding, which is a unique method to produce joints of similar- and dissimilar metallic and nonmetallic materials. A significant difference of braze-welding from other joining methods is preliminary addition of low-melting (compared to materials being joined) interlayer between the materials being joined or its formation during heating. In the case of joining Zn-plated steel, such an interlayer is the zinc coating which melts at the temperature much lower than that of steel melting.

In addition, braze-welding process is characterized by application of single or multiple compression force (peening), required for removal of the greater part of low-melting interlayer from the joint zone, that greatly increases joint strength.

Attempts to apply metal peening at the final stage of the welding process to improve welded joint strength were realized, for instance, in the units for resistance spot welding of metal [3, 4].

This variant became applied in welding of metals prone to formation of cracks, looseness and pores, in order to improve the fatigue strength of welded joints. However, in practice this kind of «peening» did not lead to any noticeable increase of joint strength, because of the low speed of compression force application, caused by the use of a pneumatic drive of displacement of mobile welding electrode and inertia of its suspension assembly. As a result, instead of high-speed peening the weld spot metal was exposed to static compression force.

Delaying of the moment of peening force impact on the weld spot metal at temperature below the points of structural transformations of treated metal crystalline lattice, for instance, point A_{c1}, did not lead to any significant deformation of weld spot metal or development of mechanical compressive stresses in the near-weld zone. In addition, application of peening force to solidified metal did not promote removal of the greater part of low-melting interlayer from the joint zone, particularly, in braze-welding processes that might have essentially improved the joint strength.

Improvement of the effectiveness of peening of welded or brazed joint metal turned out to be possible due to an abrupt increase of the speed of compressive force application. Results of the conducted comparative studies of the produced joint strength show the obvious advantages of impact application of the compressive force, compared to the strength of joints, produced at application of static compressive force [5].

Impact peening of metal in the joint zone, conducted at its solidification stage, leads to development of several technologically important phenomena, promoting an improvement of welded joint strength.

The features of this variant of thermomechanical treatment of metal in braze-welding or welding processes include development of mechanical compressive stresses, both in the connecting weld metal, and in the HAZ, which are preserved in the process of further cooling of the metals being joined. In addition to that, improvement of welded joint strength is further promoted by the processes of refinement of metal crystalline structure in the joint zone caused by high-speed deformation at higher temperature.

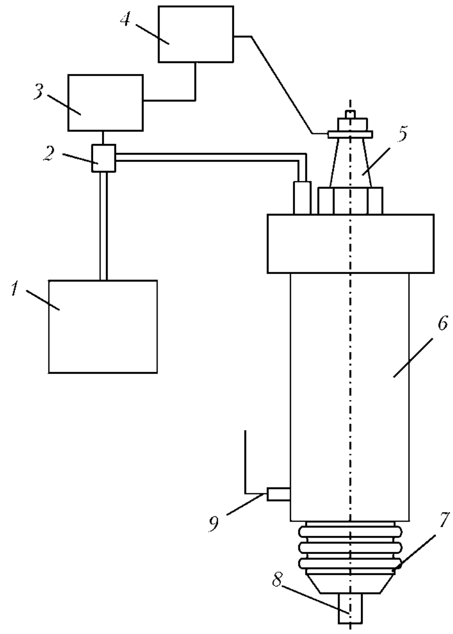

Figure 1. Schematic of the drive of electrode assembly for spot braze-welding (for *1*–*9* see the text)

Results of technological studies described in [5] were obtained at application of an electromagnetic drive of the system of compressive force impact. However, inertia of the mobile part (suspension) of welding electrode limited the speed of compressive force application on the level of 300 m/s [6].

The assumption of a good potential for increasing the upsetting speed in the processes of resistance spot welding or braze-welding is based mainly on the experience of forge welding with indirect heating of the metals being joined. Moreover, an abrupt increase of the compressive force speed, in all probability, should inevitably be accompanied by appearance of new technological effects.

Speed of compressive force application can be increased by using an explosion of hydrogen-oxygen mixtures, in which the velocity of propagation of the shock wave front reaches 3000 m/s [7]. Even higher speeds (up to 6000 m/s) can be achieved at application of the electrohydraulic effect [8].

This work presents a variant of the process of resistance spot braze-welding with application of a compressive force on weld metal, which is created as a result of an explosion of hydrogen-oxygen mixtures of a stoichiometric composition, produced by electrolysis of water in portable gas generators. For instance, a generator of P-105 type which was developed by PWI for flame brazing and welding of small-sized products provides the efficiency of hydrogen-oxygen mixture of up to 350 l/h at up to 0.07 MPa excess pressure.

Schematic of explosive drive of displacement of electrode assembly of the unit for spot braze-welding, which does not differ so much from the known schematics of the units using peening, is given in Figure 1. As shown in the Figure, the hydrogen-oxygen mixture is generated in electrolyzer *1* and comes to the electrode assembly through electropneumatic valve *2*, which is switched on by controller *3*. The latter ensures switching on the heating current, regulation of the number of alternating current pulses, time of delay of electropneumatic valve switching on after completion of a series of current pulses for heating the samples being joined, switching on generator *4* of high-voltage pulses applied to the device for firing the combustible mixture *5*. Electrode component is made in the form of cylinder *6*, the lower part of which accommodates bellows *7* with the assembly for fastening replaceable welding electrode *8* and drainage hole for discharging the combustion products *9*.

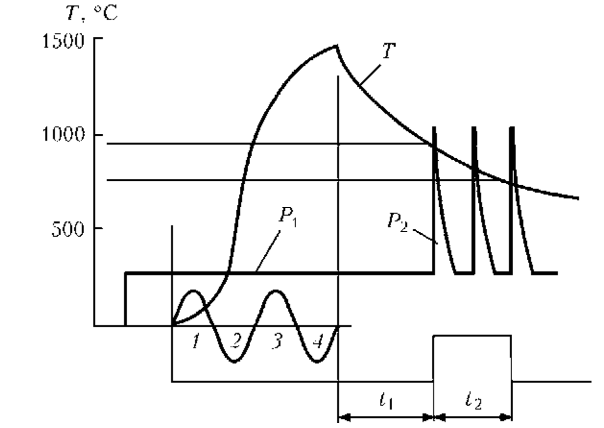

Figure 2. Cyclogram of the process of braze-welding with impact application of the peening force

Figure 3. Welding head with explosion type mechanism of impact treatment of the weld

The assembly of fastening the welding electrode is made on the basis of bellows, the corrugations of which close completely at the initial moment to ensure the preliminary compressive force, but allow additional displacement of welding electrode in the vertical direction under the impact of pressure pulse formed in the explosion chamber at firing of the combustible mixture.

Process cyclogram (Figure 2) shows the sequence of impact of the following technological parameters: application of compressive force (preliminary P_1 and impact action P_2); curve of temperature rise in the joint zone when going through four half-cycles (*1*–*4*) of heating current; time interval of delay of the impact of compressive force t_1 and moment of application of high voltage to the firing device of the system of electrode suspension with an explosion drive of electrode assembly of the unit for spot braze-welding (in this case a unit pulse of peening force application is implemented) or with an electromagnetic drive, providing the impact of several pulses of the peening force.

As is seen from the cyclogram, after creating a preliminary compressive force in the joint zone, the electropneumatic valve connecting the gas volume of electrolyzer with the explosion chamber operates at switching on the heating current. Blowing of explosion chamber volume through the drainage hole is performed, with its subsequent filling with the combustible mixture. After disconnection of explosion chamber volume from the electrolyzer volume the controller ensures connection of electric circuit of power source of combustible mixture firing system. Drainage hole remains open after blowing of explosion chamber volume, as it was experimentally established that the small diameter of this hole (about 1 mm), high velocity of explosion wave propagation and short time interval between the moment of completion of explosion chamber filling and moment of application of the high-voltage pulse of mixture firing almost do not lower the effectiveness of the explosion wave.

Welding head with the mechanism of impact treatment of the weld of explosion type is shown in Figure 3.

Figure 4 gives a typical oscillogram of arrangement of welding current pulses (four half-cycles in this case) and pulses of current, ensuring firing of the combustible mixture.

Signal for firing the combustible mixture comes from the controller of welding circuit power unit after counting the time of delaying the time interval from the moment of completion of welding current pulse, set by the operator. This completes the cycle of welding an individual spot and it is repeated many times in this sequence at process realization, similar to the process of resistance seam brazing.

Technological studies of the process of braze-welding with explosive application of unsetting force were performed using samples of Zn-coated St3 steel 0.3 mm thick. Process of braze-welding was conducted in a laboratory unit for resistance

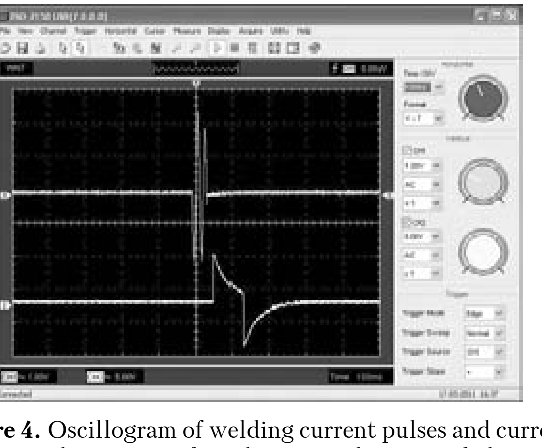

Figure 4. Oscillogram of welding current pulses and current pulses in the circuit of explosive application of the compressive force

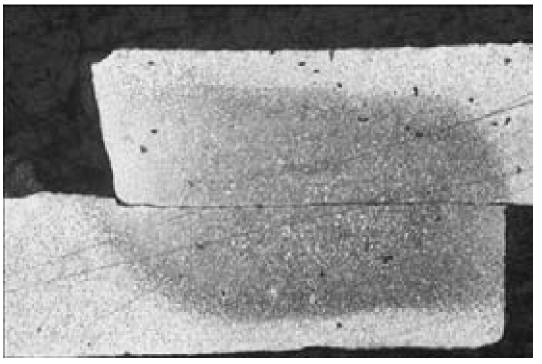

Figure 5. Typical macrosection (×50) of brazed joint with impact peening of the joint zone

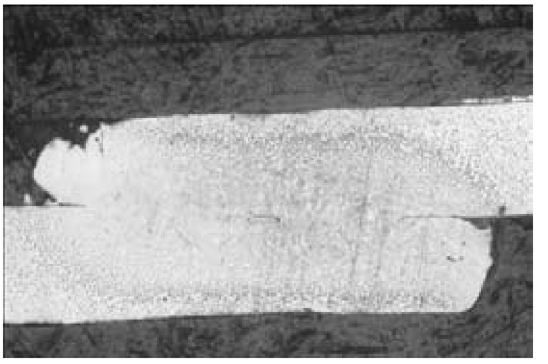

Figure 6. Macrosection (×50) of braze-welded joint across the section near the joint center

spot welding, in which the upper electrode holder supported the electrode assembly with an explosion upset drive.

Results of technological experiments show the ability to preserve the continuity of zinc coating in the zone of contact of the sheets being joined with welding electrodes due to lowering of the level of heat evolution on transient resistances and intensive heat removal from this zone into forcibly cooled electrodes, ensuring the compressive force in braze-welding zone.

Impact action of pressure at the stage of metal solidification in the joint zone promotes an abrupt increase of heat removal from the surface layers of the metals being joined, which were subjected to peening, thus leading to narrowing of the HAZ.

As is seen from the photograph of macrosection of brazed joint with zinc coating (Figure 5), dimensions of HAZ can be essentially reduced even at joining sheets of greater thickness (0.4 mm).

One of the features of braze-welding process with impact upsetting in some cases is an almost complete ousting of the low-temperature interlayer at minimum thinning of the joined sheets in the zone of Zn-plated sheet joint (Figures 5 and 6).

As shown by experimental results, the effectiveness of impact application of upsetting force can be realized not only at heating by electric current, but also for other variants of joint zone heating, for instance, flame, microplasma and arc. Advantages of flame heating (hydrogen-oxygen mixtures) include high accuracy of the parameters, purity of gas mixture, and possibility of fine adjustment of the required thermal energy, applied to the joint zone (in the pulsed heating mode).

Possibility of application of indirect heating is the only technological variant allowing welding of nonmetallic materials to be performed.

In order to realize the variant of indirect heating of the parts being welded it is sufficient to fit the welding head with a plasmatron or flame torch. In this case the controller should ensure a continuous sequence of commands for feeding a thermal energy pulse of specified value to the heating zone and impact treatment of the joint zone. In the future transition from pulsed heating to continuous heating is possible, which can be controlled by selection of heating source power, speed of welding head displacement, and distance between indirect heating source and joint zone.

CONCLUSIONS

1. Impact peening of metal during spot braze-welding of Zn-coated sheet steel is not only the most acceptable, but also the only, in our opinion, variant of producing the joints, the good prospects of which are proved by the possibility of preservation of the initial coating layer after heating of the sheets being joined above zinc melting point and improvement of corrosion resistance of the joints in service due to elimination of copper and its alloys from the joint zone.

2. Impact application of the compressive force during welding at the stage of metal cooling in the joint zone promotes an increase of braze-welded joint strength due to refinement of metal structure, and lowering of the probability of defect development in the joint zone, particularly, pores, cracks, and gas inclusions.

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