RESISTANCE SPOT WELDING WITH SPECIAL EDGE PREPARATION*

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It is shown that beveled edge preparation of the parts to be welded ensures an inclined position of the mating planes, promoting lowering of power in spot weld formation, reduction of harmful influence of bending on the load-carrying capacity of the welded joint in resistance spot welding, and lowering of the degree of non-uniformity of shear and tear force distribution across the cast nugget section.

Keywords: *resistance spot welding, edge preparation, inclined contact plane, force distribution, fracture force*

Resistance spot welding is widely used in modern industry, especially in auto- and aircraft engineering, owing to high labor efficiency, low power consumption, absence of filler materials and shielding atmospheres, as well as good hygienic conditions of work and relatively easy robotization of the process. Peculiarity of this welding method is utilization of only overlap joints at a comparatively big width of the overlap, which makes up from 7 to 12 thicknesses of the billets to be welded [1]. Resistance spot welding is usually used for joining of parts up to 6 mm thick, and sometimes this range widens to 10 mm. Bigger thicknesses involve serious difficulties related to substantial current bridging and decreased service life of electrodes [1]. Besides, the detrimental effect of bending moment on performance of welded joints increases. This is caused by increased eccentricity of longitudinal forces applied to the parts welded. Capacity of the equipment used for resistance spot welding is also increased with increase in thicknesses of the parts welded.

Strengthening with the help of an interlayer of glue introduced in the lap area between the parts welded is used to increase performance characteristics of spot welded joints, including their static and cyclic strength [2]. However, the efficiency of this approach falls with increase in thickness of the parts welded. While at thicknesses of 0.5 + 0.5 mm the presence of a glue interlayer increases static strength 5 times, at thicknesses of 2.5 + 2.5 mm the degree of strengthening is only 70 % [2, 3]. According to the data of study [2], static strength at plate thicknesses of more than 4 mm increases so insignificantly with introduction of the glue that its utilization becomes economically inexpedient. The authors of study [2] relate this fact to low strength of the glued welded joints when they are operated under conditions of non-uniform tear, taking place due to the presence of bending moment in the overlap type joint. The authors of study [3] even consider that the riveted joints are advantageous over the welded and glued-welded ones at thicknesses of the aluminum welded parts exceeding 2 mm.

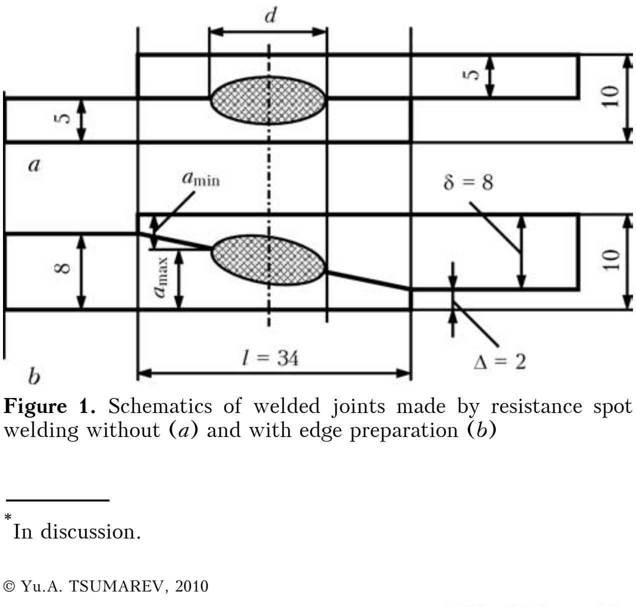

Figure 1. Schematics of welded joints made by resistance spot welding without (*a*) and with edge preparation (*b*)

It is suggested in the present study that special edge preparation in the form of bevels should be used over the entire overlap area to partially eliminate the detrimental effects related to increase in thickness of the parts welded by the resistance spot welding process. As a result, a spot joint acquires the form shown in Figure 1. Sizes of the known joint were taken from the recommendations of study [1] for the 5 + 5 mm thickness.

Geometry of the proposed joint (Figure 1, *b*) was chosen so that clearances between the electrode tips in both variants were similar, i.e. equal to 10 mm. It was assumed in this case that this choice of the geometry and sizes would allow performing resistance spot welding of the joints according to variant 1, *b* at the parameters recommended for welding of plates 5 + 5 mm thick with non-beveled weld edges.

In the proposed variant (see Figure 1, *b*), an inclined position of contact plane of the parts welded leads to violation of axial symmetry in formation of a welded joint during heating. First of all, this shows up in the fact that regions of the cast nugget adjacent to the lap ends form under the conditions of a significant difference in thicknesses of the elements being joined (minimum thickness designated in Figure 1, *b*

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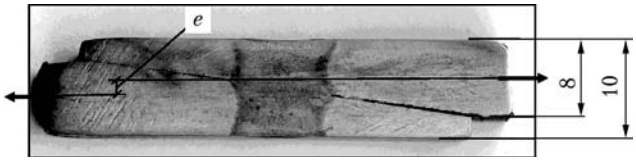

Figure 2. Macrosection (×1) of welded joint on 10kp (rimmer) steel parts with 8 + 8 mm thickness, having bevels on their mating surfaces

as a_{min} is not equal to maximum thickness a_{max}). At the same time, the central part of the cast nugget forms under the conditions characteristic of welding of parts of the same thickness. This leads to increase in the current density on a periphery of the weld spot due to spread of the current in a thicker element [1]. However, here no such phenomenon as a stronger inflow of heat to one of cooling electrodes takes place, as both electrodes are under the similar conditions. The difference in a_{min} and a_{max} thicknesses can be evaluated by using the following formulae:

$$a_{min} = \frac{\delta + \Delta}{2} - \frac{d}{2l}(\delta - \Delta), \quad (1)$$

$$a_{max} = \frac{\delta + \Delta}{2} + \frac{d}{2l}(\delta - \Delta), \quad (2)$$

where d, δ, Δ and l are the sizes of the joint shown in Figure 1, *b*.

Analysis of formulae (1) and (2) shows that $a_{max}/a_{min} = 2.5$, which is less than the three-fold value at which noticeable difficulties arise in formation of a full-valued cast nugget [1]. The experiments showed that resistance spot welding of low-carbon steel billets assembled in accordance with Figure 1, *b* involves, in fact, no difficulties related to the inclination of the contact plane. Examination of macrostructure (Figure 2) showed that the cast nugget extends along the contact plane of the billets, and the welded joint is free from any defects caused by the presence of bevels in the parts welded.

The difference between the a_{min} and a_{max} values will rise with an increase in diameter of the weld spot d or decrease in lap l. If this leads to difficulties in the process of formation of the required size and shape of the cast nugget, the electrodes with a non-round tip extended in a direction normal to size l can be recommended [4, 5]. In this case, the stress concentrator factor caused by closeness of force lines in the base metal over the spot [6] will decrease as well.

Owing to the proposed edge preparation of the parts welded, not only the clearance between the electrode tips is reduced, thus lowering the required power in welding, but also the conditions of formation of the welded joint are improved. This improvement is related to decrease in eccentricity e of the longitudinal forces applied to the parts. In a conventional variant of the welded joint, the value of eccentricity e is equal to thickness of each of the parts welded, while in the proposed variant $e = \Delta = 2$ mm. Thus, the four-fold decrease in eccentricity of the applied forces, as well as a corresponding reduction of the effect of bending strains on performance of the parts are achieved in the proposed welded joint.

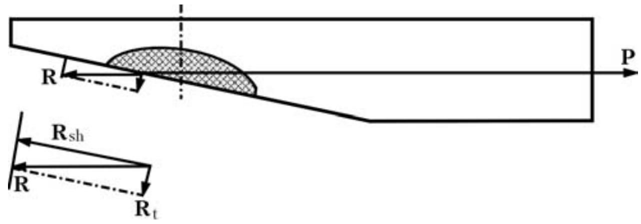

Figure 3. Schematic of equilibrium of one of the parts of the proposed welded joint

Equilibrium of one of the parts welded in the proposed welded joint is shown in Figure 3. According to the principle of rejection of bonds, instead of the rejected bond its reaction **R** is proposed, which, according to the theorem of two forces, can be reduced to a resultant. It is important that the resultant of the distributed forces making up reaction **R** is applied to a point lying on the line of action of applied force **P**. Therefore, its application point lies near to the center of gravity of weld spot section. Thus, it can be represented as a system of parallel forces distributed almost uniformly along the entire plane section of the spot.

Rejected bond reaction **R** can be expanded into constituents according to vector sum $\mathbf{R} = \mathbf{R}_{sh} + \mathbf{R}_t$, where $\mathbf{R}_{sh}$ and $\mathbf{R}_t$ are the resultants of shear and tear forces, respectively.

Vectors **R** and $\mathbf{R}_t$ were applied to one point. Hence, the degree of uniformity of distribution of the tear forces is as high as the degree of distribution of the forces making up a complete reaction.

Accordingly, the degree of uniformity of distribution for the system of parallel tear forces, forming complete reaction **R**, will also be high. Therefore, the proposed welded joint does not work under the conditions of a non-uniform tear, which deteriorate performance of the glued welds.

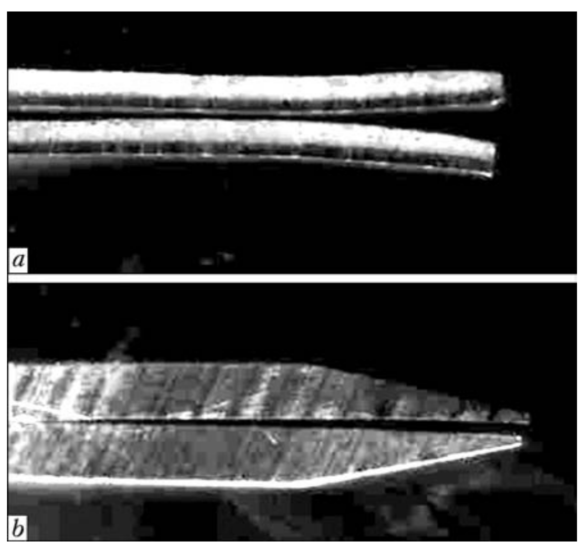

Figure 4. Appearances of specimens after mechanical tensile tests: *a* — traditional specimens; *b* — beveled specimens

In a traditional welded joint, the complete bond reaction cannot be reduced to the resultant, as any weld spot section lies aside from the line of action of the applied force. Therefore, the degree of non-uniformity of distribution of forces (including tear forces) will be much higher.

Experimental verification of the efficiency of the proposed technical solution was carried out through comparative statistical tensile tests of two batches of specimens, each batch comprising five specimens. Sizes and shapes of the specimens in both batches corresponded to the data shown in Figure 1. The first batch comprised specimens with 5 + 5 mm thickness (see Figure 1, *a*), and specimens of the second batch were beveled and had thickness of 8 + 8 mm (see Figure 1, *b*). The tests results showed that the average fracture force for specimens of the first batch was 21,950 kPa, and for specimens of the second batch it was 28,100 kPa. Therefore, strength of the second batch specimens, having the proposed edge preparation, was 28 % higher than that of the specimens made by the traditional scheme. Apparently, one of the reasons was a decreased bending effect due to eccentricity of the applied forces. Fragments of the specimen after the tests are shown in Figure 4. It can be seen from Figure 4, *a* that during testing the specimens of a conventional overlap welded joint acquired a bent shape, whereas the beveled specimens (Figure 4, *b*) remained straight.

It should be noted in conclusion that edge preparation in the form of bevels ensuring an inclined position of the mating planes reduces the equipment power consumption in formation of a weld spot, harmful influence of bending on the load-carrying capacity of the welded joint in resistance spot welding, and degree of non-uniformity of distribution of the shear and tear forces across the cast nugget section.

1. Orlov, B.D., Dmitriev, Yu.V., Chakalev, A.A. et al. (1975) *Technology and equipment for resistance welding*. Moscow: Mashinostroenie.
2. Shavyrin, V.N., Ryazantsev, V.I. (1981) *Glued-welded structures*. Moscow: Mashinostroenie.
3. Ryazantsev, V.I., Fedoseev, V.A., Abin, N.N. (1984) Technical-economical efficiency of application of welded, glued-welded and riveted joints. *Svarochn. Proizvodstvo*, **1**, 28–29.
4. Latypova, E.Yu., Tsumarev, Yu.A., Kuzmenko, I.M. et al. *Electrode for resistance spot welding*. Pat. 6379. BY. Publ. 30.09.2004.
5. Popkovsky, V.A., Latypova, E.Yu., Tsumarev, Yu.A. et al. *Electrode for resistance spot welding*. Pat. 6500. BY. Publ. 30.09.2004.
6. (1979) *Welding in machine-building*: Refer. Book. Ed. by V.A. Vinokurov. Vol. 3. Moscow: Mashinostroenie.