INFLUENCE OF WELD METAL IMPACT TREATMENT ON WELDED JOINT STRENGTH

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The paper gives the results of experiments on qualitative assessment of the influence of thermomechanical treatment on the strength of spot welded joint. Rationality of shock application of the compressive force at the temperature close to the recrystallisation point of the metal being welded is shown.

Keywords: *resistance spot welding, welded joint, thermomechanical treatment, shock application of compressive force, crystalline structure refinement, mechanical strength*

As is known, the most widely accepted cause for lowering of welded joint strength is development of tensile stresses in the weld zone, caused by metal shrinkage during cooling.

The level of residual mechanical stresses is lowered using thermal, thermomechanical [1,2] and shock-mechanical kinds of weld zone treatment, which is conducted after completion of welding operation. For instance, performance of strengthening by the method of high-frequency mechanical peening [3, 4], hammer peening [5] or shot blasting [6] allows several times increase of cyclic fatigue life of the welded structure due to redistribution of residual mechanical stresses in the weld zone. The above strengthening methods are characterized by multiple shock application of the compressive force, which is performed at the speed of about a hundred meters per second.

«Peening» term characterizes a process of welding at a much lower speed of compressive force application (not more than a dozen meters per second) and one-time action, which is due to the inertia of the pneumatic drive assembly of electrode displacement both at the stage of welding, and peening.

This led to the need to reject the term «peening» from resistance welding area and use a term from a related area of engineering, namely «impact treatment of metal» [3–6], which characterizes high-speed and multiple treatment of metal directly during the welding process at the stage of spot weld cooling.

The disadvantages of welded joint heat treatment include the need for either long-term (for several hours) heating by a certain cycle of the entire welded product in furnaces, or not less long-time local heating of the weld zone.

In some cases, however, it turned out to be possible to replace the expensive and power-consuming heat treatment of the entire product by additional surface melting of welds by arc heating in argon. This technology was developed at PWI. Results of the conducted studies showed that argon-arc surface melting of welds allows recovering the weld metal impact toughness, improving the welded joint fatigue limit, which, as was explained by the author of [7], is related to structural changes in the weld metal.

Lowering of the level of residual tensile stresses in welded joints can be achieved also through application of special filler materials, characterized by low temperature of interphase transfer in the weld metal [8].

Compressive stresses in welded joints form directly during the welding process, for instance, at spot resistance welding with a peening cycle envisaging the impact of an additional and higher force of metal compression at the stage of cooling of the formed spot weld. This treatment variant was accepted in welding metals prone to cracking and porosity formation, in order to lower residual stresses and improve the fatigue strength of welded joints [9, 10]. This treatment variant, however, is characterized by a low level of compressive stresses induced in the spot weld metal, because of the low speed of peening force application and inertia of the compressive mechanism; moreover, it excludes the possibility of variation of the moment of peening pulse application relative to the temperature of spot weld metal heating.

Shock-mechanical kinds of welded joint treatment include peening with a pneumatic vibration tool, shot blasting and ultrasonic peening. Technical literature gives information about improvement of cyclic fatigue life of welded joints by several times after performance of the operation of metal peening with a pneumatic hammer or its shot blasting. Ultrasonic treatment also allows an improvement of mechanical strength, for instance, in treatment of welded joints of 20KhGSA steel and some aluminium alloys [11, 12].

In view of the technological disadvantages inherent to the above treatment techniques, high-frequency mechanical peening became widely accepted now. Conducted studies [3, 4] showed that application of this kind of treatment, even without metal preheating, allows achieving a more favourable redistribution of residual stresses in the metal surface layers and forming a sufficiently high level of compressive stresses, in particular in the base-to-weld metal transition zone.

Proceeding from the above said, it may be anticipated that the joint action of heat treatment and mechanical peening can turn out to be an effective means of improvement of both the mechanical strength, and

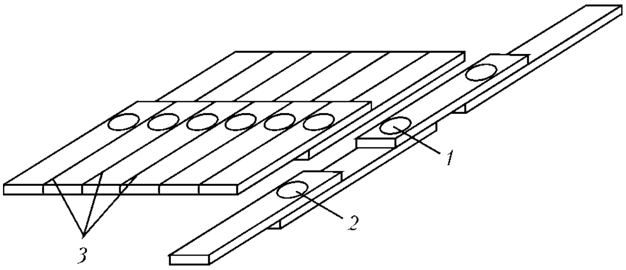

Figure 1. Schematic of sample preparation to rupture testing: *1*, *2* — spot welds with peening and without it, respectively; *3* — cut lines

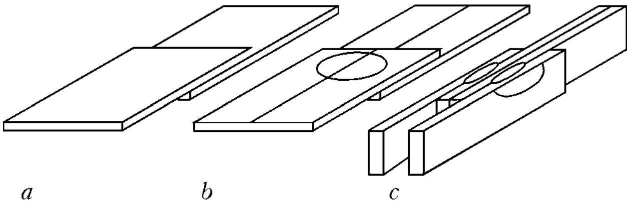

Figure 2. Schematic of welded sample preparation to microsection cutting out: *a* — before welding; *b* — after welding with the line of the cut along the spot weld; *c* — for microsection preparation

endurance limit of welded joints. Action of impact treatment at increased temperature certainly should increase the depth of the surface layer of metal where plastic deformation takes place, and, therefore, also the dimensions of the zone of residual (post-weld) mechanical stress.

This gives rise to the following questions, requiring experimental verification of the possibility of improvement of welded joint mechanical strength, namely determination of the optimum temperature range, in which the shock impact of the compressive force is favourable, optimum ratio of thermal and mechanical impact energy, and optimum speed of compressive force application.

Solution of these problems is of theoretical and practical interest not only for improvement of the methods of welding metals and joining new structural materials, but also during performance of repair-maintenance operations on welded structures. It is also necessary to assess the effectiveness of application of different kinds of heating, namely electric contact, arc, flame heating, for this purpose.

This work is an attempt at a qualitative evaluation of the attractiveness of impact treatment of weld metal in resistance welding of sheet steel.

In order to perform technological verification of the anticipated positive effect of shock application of the compressive force on mechanical strength due to refinement of the spot weld metal crystalline structure we have performed investigations by the following procedure. St3 steel plates of 100 × 30 × 1 mm size were used as the samples. Selection of St3 steel 1 mm thick was supported by the generally accepted current practice of application (for the sake of lowering product cost at the expense of reducing item service life from dozens of years to dozens of months) of low-alloyed sheet steel with unspecified content of impurities for mass-produced items (for instance, automotive products, electrical equipment, household appliances).

The laboratory resistance spot welding machine used for this experiment included the module for adjustment of the number of welding current pulses (from 1 to 8 half-periods) and module of setting the moment of sending the voltage pulse to the solenoid of the assembly of shock application of the compressive force, adjusted in the range from 1 up to 12 half-periods.

After mechanical and chemical cleaning to remove contamination, samples were resistance welded in two modes: with the use of the device to provide the shock application of the compressive force and without thermomechanical treatment. To perform comparative evaluation of the strength of welded joints made in the above modes, the welded plates were cut into 5 mm wide strips, which were joined in pairs to each other by resistance spot welding, as shown in Figure 1.

Thus, during rupture testing the rupture load was simultaneously applied to three spot welds made with one power source mode, but differing by the impact or absence of shock application of compressive force at the temperature close to metal recystallization point.

To assess the effect of peening on welded joint strength, instead of measuring the breaking force it turned out to be sufficient to record the fracture of one of the spot welds, having minimum strength, i.e. the weakest link in joints of four strips welded in three points.

Such a preparation of welded joint samples allowed elimination of a number of negative factors, namely possible influence of fluctuations of initial metal properties on its strength; differences in the thickness and composition of oxide films on the surfaces being joined; random deviations of welding mode and tem-

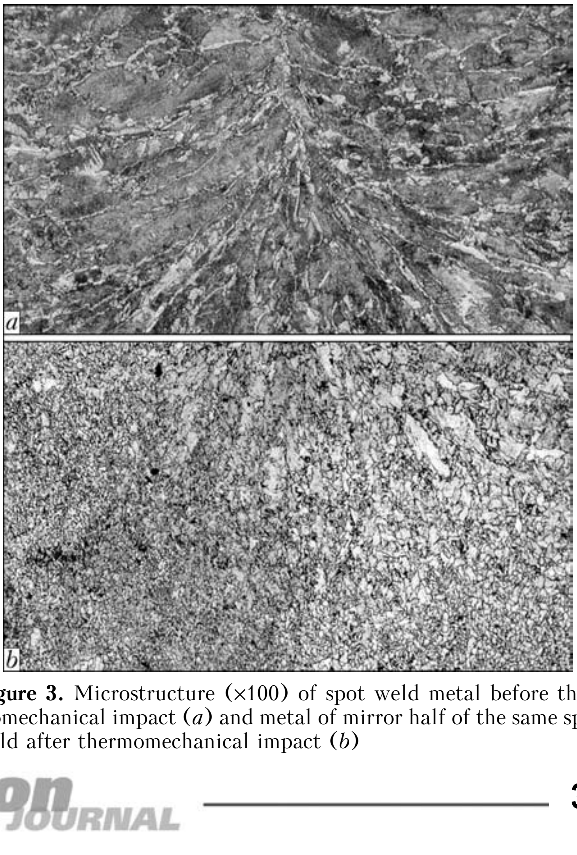

Figure 3. Microstructure (×100) of spot weld metal before thermomechanical impact (*a*) and metal of mirror half of the same spot weld after thermomechanical impact (*b*)

perature, at which the shock application of the compressive force is applied.

The proposed comparative assessment of welded joint strength can be regarded as a procedure of qualitative evaluation of the effectiveness of the impact of the modes heating and subsequent thermomechanical action. Despite a limited scope of information on joint strength, obtained with application of the proposed testing procedure, it has the advantage of the possibility of evaluation of the results for a specific technological sample in minimum time, which is particularly valuable during adjustment operations.

Results of the conducted rupture testing of samples showed that more than 97 % of welded joints fail through the spot welds, not treated by shock application of the compressive force.

In order to asses the influence of shock peening on the change of spot weld metal structure, samples were made by spot welding (Figure 2, *a*), which were cut along the strips and through the spot weld (Figure 2, *b*). One of the spot weld halves was reheated to the temperature of (600 + 50) °C (near the steel recrystallization point) and shock compressive force was applied starting from the moment of the thermocouple recording the specified temperature. Then the two halves of the spot weld were joined to produce a macrosection as shown in Figure 2, *c*.

As the time of cooling of spot weld metal in the selected samples is equal to about 0.5 s, the spot weld can be subjected to one or several dozens of shocks even at pulse repetition rate of 50 Hz.

As is seen from Figure 3, the microstructures of mirror halves of one spot weld differ significantly both by the crystallite size, and homogeneity of metal structure near the spot weld. Microstructures of peened joints show a significant refinement of the largest crystallites, which grew out of the spot weld central zone.

In addition, the spot weld metal shows a lowering of the content of foreign particulates and porosity, i.e. the difference between the structure of metal of the spot weld, HAZ and base metal becomes smaller.

Thus, the conducted technological studies of the influence of shock thermomechanical treatment performed directly during welding, showed the possibility of an essential improvement of welded joint mechanical strength.

Proceeding from the existing interrelation between the parameters of the metal crystalline lattice and its operating properties, it can be anticipated that impact treatment of the weld at the temperature close to recrystallization point will allow improvement of welded joint fatigue limit.

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