TECHNOLOGY OF PROJECTION WELDING OF PARTS OF LARGE THICKNESSES WITH T-SHAPED JOINTS

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T-shaped joint projection welding of large-cross section low-carbon steels was studied. It is shown that the programmable change of compression force at the stage of melting and solidification of welded joint metal allows increasing heat input into welding zone, avoiding defects occurrence in joint formation and obtaining higher mechanical characteristics of welded joint. It was established that control of compression force yields the greatest effect in welding large cross-section products, when welding machines do not have required power factor for welding under rigid conditions.

Keywords: *projection welding, low-carbon steels, T-shaped joint, large sections, cast nugget*

The progress of modern machine building depends on implementation of resource-saving technological processes increasing labor efficiency and quality of products. The resistance projection welding process meets these requirements. However, nowadays the influence of technological parameters of welding conditions on the formation of welded joints of large area has not been yet studied sufficiently. The purpose of this work is to study influence of changes of welding force on heating in the contact zone, sizes of cast nugget and strength of T-shaped welded joint of section area of 1200 mm^2. The welded assembly of low-carbon steel represents a threaded nut of rectangular section of 26 × 47 mm and 28 mm height, welded-on to the plate of 20 mm thickness, and is a ledge of a frog.

In projection welding of T-joints in a form of rods, bolts, threaded nuts, welded-on to the plate, the cycle pattern with constant clamping force is mainly applied. It is predetermined by a small area of a welded joint and design of welding equipment, which does not provide the necessary quick response of a power drive of the welding machine.

To prevent crystallization cracks and pores in resistance spot welding and, as a result, to increase mechanical properties of welded joints, the recommendations exist on using forging force, however as for projection welding with T-joints, the rationality of its use has not been studied sufficiently. In practice the value of constant welding force is selected experimentally coming from the need to prevent initial and final splashes of molten metal at preset value of welding current. The required sizes of a cast nugget are provided by adjustment of welding current and time of welding. However, under the conditions of T-shaped joint projection welding of a rod with a plate, the formation of a joint is occurred under the conditions of solid-liquid state of metal in contact and significant plastic deformation, which restricts the influence of time of welding on heat input into the metal of a joint being formed. The basic factor influencing the formation of welded joint is temperature of plastic deformation front depending on density of current and welding pressure.

The threaded nut has a non-axial symmetric shape, which requires applying several projections to obtain the fusion zone over all the welding area with formation of a cast nugget. It provides stirring of metal of the surfaces being joined even at the presence of scale, rust and other contaminations, and guarantees obtaining high strength properties.

The variant with two deformable cones and limiting rim was designed, which maintains molten metal from splashes and during deformation it forms area of plastic deformation around the cast nugget. In the course of experiments it was established that optimal variant is the cone with the apex angle of 160°. Such projection provides the most quality welding without preliminary and final splashes, prevents deformation around the perimeter of the threaded nut and high mechanical properties of welded joints. The shape of projection allows performing welding even along the layer of a rust and scale without significant decrease of mechanical properties of metal and provides stable quality of welded joint.

Let us study the influence of cycle pattern of welding force on heating in the contact zone, sizes of cast nugget and strength of T-shaped welded joint. Figure 1 shows cycle pattern of

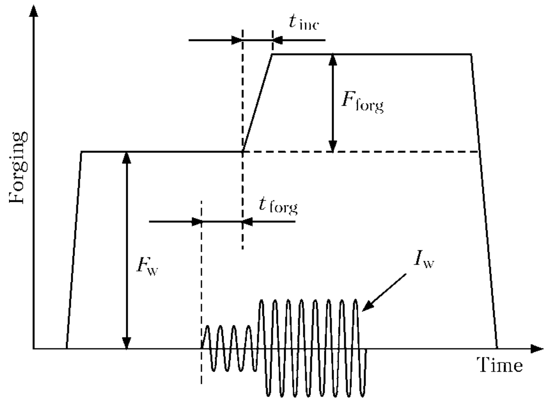

Figure 1. Cycle pattern of welding with forging force (see designations in the text)

welding with application of forging force. Welding force F_w, forging force F_{forg} and time of forging switch-on t_{forg} were the main parameters.

As is known the heat evolution in the contact is proportional to electric resistance of a contact and related to compression force in welding. This relation is non-linear and depends on temperature of a contact. In this connection, the comparative change of dynamic electric resistance of a contact at constant welding force and with applying of forging force was carried out. The dynamic resistance of a contact can be calculated knowing the drop of voltage, current during welding and resistance of welding circuit at open electrodes.

Figure 2 shows changes of contact resistance at optimal conditions with constant F_w = 3200 kN and conditions, at which the initial F_w = = 2000 kN and F_{forg} = 4000 kN. The welding current amounted to 34.5 kA, time of welding was 100 periods (2 s). The higher electric resistance in the zone of welding was obviously due to the higher temperature of deforming metal of projection and the whole zone of welded joint.

The measurement of temperature fields depending on F_w and F_{forg} is presented in Figure 3. The thermal effect and higher temperature of welding zone at the stage of formation of fusion zone at cycle patterns with increase of pressure per welding cycle are obvious. The record of temperature fields showed that temperature in near-contact zone in the spot of cut-in of thermocouple at the moment of formation of fusion zone increased by 140 °C, which proves the increase in thermal efficiency coefficient of the process.

The decrease of welding pressure F_w down to 1500 kN results both in more intensive heating, as well as in initial splashes of metal.

The optimal is the condition when F_w = = 2000 kN and increase of forging pressure during period of welding up to 4000 kN (Figure 4), current of 34.2 kA, time of welding of 120 mains

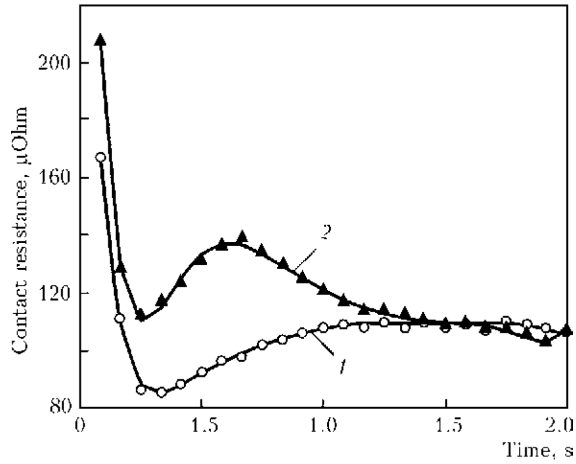

Figure 2. Change of contact resistance during welding: *1*, *2* — constant and increasing force, respectively

periods (modulation of increase of welding current from zero to nominal amounted to 10 mains periods).

The diameter of fusion zone and penetration depth amounted to 25 and 5 mm relatively, which is 12 and 25 % higher than in welding at a constant compression.

The experiments were also conducted under relatively mild and rigid conditions as to preset one providing the quality joint formation. Mild conditions have lower current and longer welding time, characterized by the more intensive heat removal into metal of a part and electrodes. Rigid conditions have higher current and shorter time

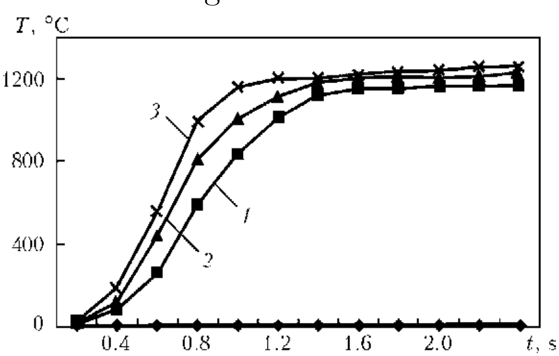

Figure 3. Heating of welding zone under different conditions of applying welding pressure: *1* — F_w = 3200 kN; *2*, *3* — F_{forg} = 4000 kN (*2* — F_w = 2000; *3* — 1500 kN)

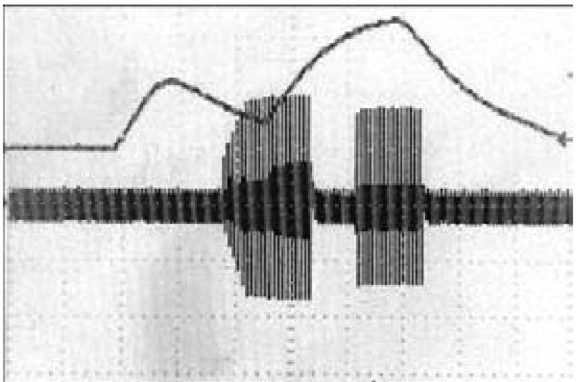

Figure 4. Oscillogram with increasing compression force

Figure 5. Macrosection (×4) of joint at increasing welding force

of welding, at rigid conditions such defects as initial and final splashes are possible. Three series of experiments, each consisted of three trials, were conducted. The results of mechanical shear P_{sh} and rupture P_r tests were carried out (Table).

Figure 5 represents macrosection of welded joint obtained with increasing welding force. The width of fusion zone is 25 mm, penetration depth is 7 mm, width of zone of thickening band (zone of solid-phase welding) is 2.5 mm.

In the zone of plastic deformation close to nugget zone the amount of bainite is larger, which allows supposing that metal of this zone was heated up to higher temperatures. In this zone of specimen the partial fusion of grains is observed, which evidences about deformation in a solid-liquid state.

The central zone has no clear features of cast dendrite structure, intercrystalline liquation and shrinkage defects. It evidences that formation of welded joints in T-shaped projection welding always occurs with plastic deformation of contact zone.

The metallographic analysis of zone of welded joint shows that in the specimen with changeable cycle pattern of pressure the metal of plastic deformation zone was heated up to higher temperature as a result of larger heat evolution and higher temperature of deformation front due to increase of welding force proportionally to increase of area of deformation zone.

Projection welding under mild (Nos. 1–3), optimal (Nos. 4–6) and rigid (Nos. 7–9) conditions

Condition No.	$U_{o.-c}$, V	I_w, kA	t_w, s	P_{sh}, kN	P_r, kN
1	8.5	30.5	2.7	28700	23100
2	8.5	30.5	2.7	29000	23900
3	8.5	30.5	2.7	27900	23300
4	9	34.2	2.4	31700	25500
5	9	34.2	2.4	32400	26100
6	9	34.2	2.4	31300	25200
7	9.5	37.1	2	29100	23900
8	9.5	37.1	2	29400	23000
9	9.5	37.1	2	29800	23500

CONCLUSION

The projection welding of low-carbon steels of large sections with T-shaped joints was studied. It was shown that programming change of welding force at the stages of fusion and crystallization of metal of welded joint allows increasing heat input into welding zone, avoiding defects in formation and obtaining higher mechanical characteristics of welded joint.

The control of compression force gives the maximum effect in welding of products of large section, when welding machines do not have necessary reserve for welding under rigid conditions.

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