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On the issue of welding longitudinal pipes with high-frequency currents

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ABSTRACT: This article presents a study of the heating process and plastic deformation during high-frequency welding of straight-seam pipes from low-carbon low-alloy steels

KEY WORDS: High frequency welding, pressure welding, draft, weld, oxide film, draft

I. INTRODUCTION

In the Republic of Uzbekistan, high-frequency welding is widely used in pipe plants in the manufacture of pipes of small diameter. Two methods of transferring energy to the welded edges are known: contact and induction. Each method has a number of features that must be considered when designing and operating welding devices.

High-frequency welding of metals is based on the use of the laws of electromagnetic induction and total current, as well as the following phenomena: surface effect, proximity effect, ring or coil effect, the influence of magnetic circuits and copper screens on the distribution of current in the conductor, changes in the properties of metals with temperature and voltage ¬nosti magnetic field, the occurrence of electromagnetic forces

II. LITERATURE SURVEY

In the induction method, a ring inductor is installed at a distance of 30-300 mm from the point of convergence of the edges, covering the tube billet. Under the action of the inductor field, a current is induced in the surface layer of the workpiece [1].

Due to the proximity effect, the largest part of the inducted current flows along the edges and closes at the point of convergence (useful current). Another part of the current closes around the perimeter inside the workpiece tube (useless current). As with the contact method of supplying current, internal and external magnetic cores are used to reduce useless current. The length of the magnetic cores with the induction method should be longer by the inductor than with the contact [2]

The energy consumption required for welding depends significantly on the distance between the inductor or contacts and the point of convergence of the edges. With increasing this distance, the heating time increases and, consequently, power loss due to heat transfer from heated edges to adjacent metal layers. This leads to a decrease in welding speed [3].

With the induction method of supplying current, the energy consumption is slightly higher than with the contact, since along with the edges the body of the tube billet under the inductor is heated. The energy utilization coefficient - the ratio of the energy spent on heating only the welded edges to the total energy absorbed by the workpiece - decreases with an increase in its diameter, since losses in the body of the workpiece increase, while the power for heating the edges remains almost constant. The advantage of the induction method is the exceptional simplicity and reliability of the inductors [4]

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Based on modern ideas about metal welding, high-frequency welding processes can be divided into three groups.
1. Pressure welding with reflow is carried out with pre-heating and local melting of the welded surfaces. The molten metal is removed from the bonding zone upon precipitation; a welded joint is formed between surfaces in the solid state. The heating rate reaches 150 • 103 ° C / s; draft - 0.15-1.5 mm; precipitation speed - 2000 mm / s.
2. Pressure welding without melting is carried out with preliminary heating of the surfaces to be welded to a temperature below the melting point of the metal being welded. The heating rate does not exceed 400 ° C / s; draft - 2.5-6.0 mm; precipitation rate - 20 mm / s.
3. Fusion welding without pressure is carried out by heating the elements to be welded before melting. The molten metal bath solidifies, forming a weld without pressure. The heating rate reaches 8000 ° C / s [5].

III. METODOLOGY

Pressure welding with reflow is most widespread in the production of welded products and semi-finished products with a continuous seam of ferrous and non-ferrous metals, including longitudinal pipes. The welded elements have the same geometric dimensions and material and are located symmetrically relative to the vertical plane (Fig. 1).

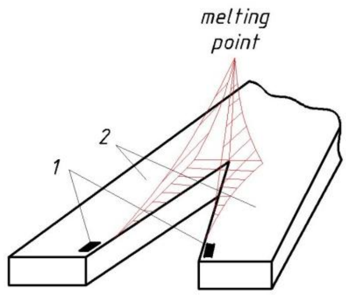

Fig. 1. Scheme of the process of high-frequency pressure welding with reflow:
1 - Place of current supply; 2 - elements to be welded

With a symmetrical supply of current to the elements to be welded, the heating is completely identical. Both elements converge at an angle α, at a certain distance from the convergence site, current is supplied to the elements using contact or induction systems, the edges are heated and melted, and sediment occurs at the convergence site.

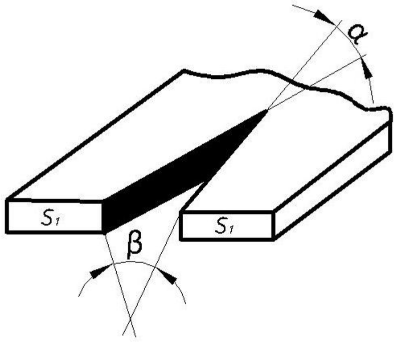

Fig. 2. Symmetric scheme of high-frequency welding of longitudinal pipes

Heating and deformation of the welded elements occur sequentially. To perform welding, physical contact between the surfaces, the creation of active centers on them, and the prevention of the possibility of destruction of the formed set points after relieving the upsetting pressure are necessary. The distance from the point of current supply to the point of convergence of the edges usually lies in the range from 25 to 300 mm. On this segment, the elements to be welded are heated to a predetermined temperature. Three heating options are possible:
1. The sections of the elements being welded to the point of convergence are heated to a temperature lower than the melting point, and due to electromagnetic phenomena, the greatest current concentration is reached at the point of convergence of the elements being welded, where they are melted. The temperature in this place can reach (1,1-, 2) melting point.

2. The sections of the elements to be welded are melted to the point of convergence. By the action of mechanical forces of an electromagnetic field, molten metal is removed from the surface of the heated elements. At a distance from the place of release of molten metal to the place of convergence of the elements, their further heating occurs, and at the place of transition from one element to another, re-fusion occurs. As in the first embodiment, the temperature at the junction can reach (1.1-1.2) the melting point.
3. The elements to be welded are heated all the way below the melting temperature, including the convergence point.
In the process under consideration, heating reduces the resistance to plastic deformation, increases the ductility of the metal and facilitates the removal of oxides from the surfaces to be welded. The resistance to plastic deformation increases with an increase in its speed at all temperatures and depends on its absolute value. Under certain conditions, this has a significant effect on draft forces.

At high gradients of the temperature field, heating is purely superficial in nature, however, it is achieved by passing current through the elements being welded. The current density is uniform over the cross section, and the heating depth is controlled by the frequency of the power supply current, the distance between the elements being welded (proximity effect) and the heating time.

A very significant role in the heating schemes under consideration is played by the removal of oxides from the surfaces to be welded that formed during the time preceding welding (during storage, transportation) and appear during heating. All metals in air are oxidized, creating thin oxide films on the surface. The film thickness depends on the oxidation time. Sometimes multilayer films are formed. In this case, a layer of oxide rich in metal appears on the surface of the metal. For example, oxidation of iron at temperatures above 600 ° C is accompanied by the formation of a three-layer oxide FeO-Fe_3O_4-Fe_2O_3. The ratio of oxides (in mass fractions) at T = 700-900 ° C is: 0.66-1.0% Fe_2O_3, 4.1-5.0% Fe_3O_4 and about 95% FeO.

Let us imagine the mechanism of destruction of oxide films under the considered heating options. In the first embodiment, when the melting occurs at the convergence of the welded elements when the temperature reaches (1.1-1.2) Tm, it is impossible to melt the oxides. The exceptions are FeO (1377 ° C) and Fe_2O_3 (1566 ° C). It can be imagined that thin films of oxides quickly heat up due to the thermal conductivity of a relatively large volume of contacted metal (starting heating). Further, the electrical resistance of the oxide films decreases rapidly and they begin to heat up by direct transmission of current. In this case, one can expect the melting of oxide films, for example, Fe_3O_4 (1597 ° C), which have a higher melting point than the base metal. Oxides having a high melting point only heat up, but do not melt. No one has been studying this phenomenon, and therefore what has been said should be regarded as a hypothesis.

In the second variant of heating, when the fusion of the elements being welded occurs to the point of convergence and the molten metal is removed from the surfaces to be welded by the mechanical forces of the electromagnetic field, the destruction of oxide films during the ejection of the metal is likely. As a result of repeated heating of the sections of the elements to be welded to the convergence site, they are again oxidized, but due to the short heating time (not more than 0.01 s), the thickness of the newly formed oxide film is small and it can be destroyed or removed together with the liquid metal in the process precipitation.

In the third variant of heating, when the surfaces being welded along the entire length, including the convergence site, are heated below Tm, obviously, oxide films cannot be destroyed. An exception may be only FeO. It follows from the foregoing that the second version of heating is the most universal, since with it, heating of the elements to be welded to the required temperature and their purification from oxides, including refractory ones, are ensured. The first heating option is advisable to use when welding low-carbon and low-alloy steels on which oxide films consist of FeO-Fe_2O_3-Fe_3O_4. The third heating option is rarely used.

Following the preparatory phase of the formation of a welded joint, heating, sedimentation and the formation of a weld occur. The total contact length of the elements to be welded, consisting of zones of upsetting, reduction (in the case of straight-seam pipe welding) and thermo mechanical hardening. It has been established that when welding straight-seam pipes from low-carbon and low-alloy steels, the total contact length is 1.5–4 times greater, the value of which varies between 1.5–2.5 mm. This zone increases with increasing thickness of the elements being welded and with an increase in the absolute value of the draft. At the most common welding speeds (0.5–2 m / s), the draft rate is in the range of

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20–2000 mm / s. To obtain a high-quality welded joint, it is necessary that all the molten metal present at the convergence site of the elements to be welded is removed during upsetting.

For a symmetric system, the sediment is determined (Fig. 3.):

$$\Delta_{draft} = (F_{in} + F_{out}) / 2s$$

where F_{in} and F_{out} are the areas of internal and external grata.

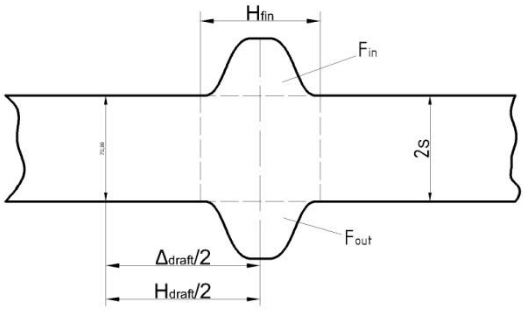

Fig. 3. Scheme for determining precipitation

The F_{in} and F_{out} values were measured during welding with current heating at a frequency of 440 kHz straight-seam pipes made of low-carbon steel st3sp with the subsequent manufacture of microsections. In fig. Figure 4 shows the dependence of the precipitation Δ_{draft} on the thickness 2s for steel strips during continuous high-frequency fusion welding.

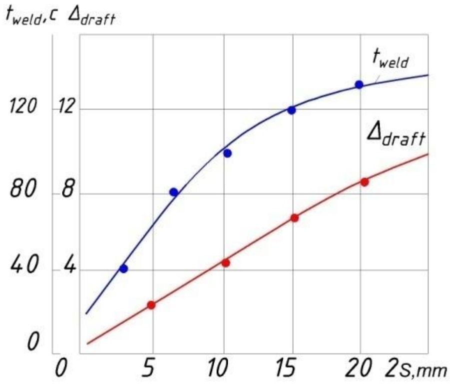

Fig. 4. Dependence of draft Δ_{draft} and welding time on the thickness of the welded strips 2s

As a result of the flow of current along the edges, their monotonous heating and melting occurs uniformly, which eliminates the formation of craters. This may be the reason for the small value of Δ_{draft}. However, in high-frequency fusion welding, uneven heating of the elements being welded due to disturbances is possible. In studies of the nature of perturbations and their influence on the temperature regime of heated elements and Δ_{draft}, it was established that perturbations are associated with instability of the energy regime of the power source, the operation of the preparation and precipitation mechanisms of the welded elements, and the quality of the workpiece.

The current distribution during the upsetting of the welded elements was studied on a model plate of non-magnetic steel with a longitudinal slit with parallel edges (α = 0). The plate thickness was 5 mm, the length of the heated edges was 80 mm. By passing a high-frequency current along the edges of the plate, a current closure is obtained in the area beyond the convergence site. This process is similar to the process of closing a welding current through a section heated above the temperature of magnetic transformations and located in the precipitation zone. Contact resistance between the edges was neglected. Such a model allows one to directly measure the magnitude of the currents closing through the plate

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body. To do this, narrow rectangular holes with a pitch of 5 mm were made in the area along which the current should close. By measuring current I sequentially in each “bridge”, a current density distribution curve is obtained along the weld (Fig. 5).

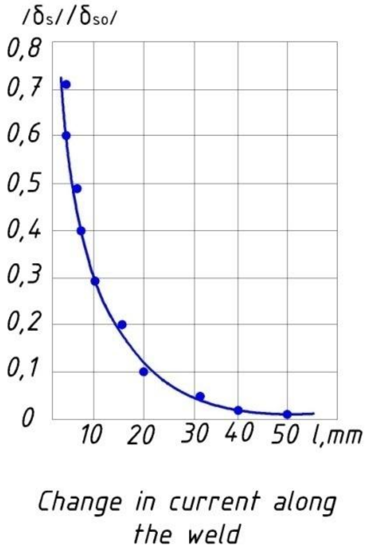

Fig. 5. Change in current along the weld.

It can be seen from the graph that in the area of the plate located between the convergence of the edges and the axis of the welding rolls, the current distribution is extremely uneven, and from 12 to 18% of the total current in the welded edges passes beyond the place of convergence. Based on the current distribution pattern, it can be argued that during high-frequency welding with reflow, the sludge occurs under current. Therefore, the conditions for the formation of a welded joint and the removal of molten metal from the weld zone are further facilitated and improved. Sediment under current favors the processes of recrystallization and the formation of common grains, which increases the ductility of the welded joint. The current during upsetting is sufficient for almost complete recrystallization of the weld zone. The place of welding is allocated only with grata. The microstructures of the weld, transition zone and base metal are identical. Standard test methods did not reveal any differences in ductility of the weld and the source metal.

IV.CONCLUSION

Research work on determining the influence of high-frequency welding mode parameters on the quality of welded joints of longitudinal welded pipes from low-carbon and low-alloy steels revealed that:
- induction high-frequency pressure welding with reflow is most widespread in the production of welded products and semi-finished products with a continuous seam of ferrous and non-ferrous metals, including straight-seam pipes;
- when welding straight-line pipes from low-carbon and low-alloy steels, the total contact length is 1.5–4 times the length of the draft, the value of which varies between 1.5–2.5 mm;
- to obtain a high-quality welded joint, it is necessary that all the molten metal present at the convergence point of the welded elements is removed during upsetting. at the most common welding speeds (0.5–2 m / s), the draft rate is in the range of 20–2000 mm / s.

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