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On the issue of calculating the parameters of the edges during high-frequency welding of a pipe billet from a ferromagnetic material

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ABSTRACT: This article provides a method for calculating the edges to be welded during high-frequency welding of pipes from low-carbon low-alloy steels.

KEY WORDS: High frequency current welding, thermal deformation, ferromagnetic material,weld

I. INTRODUCTION

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 shields on the current distribution in a conductor, changes in the properties of metals with changes in temperature and voltage ¬the magnetic field, the occurrence of electromagnetic forces

II. LITERATURE SURVEY

The law of electromagnetic induction manifests itself in the fact that if the magnetic flux Φ passing through a surface bounded by a certain contour changes in time, an emf is induced (induced) in this contour, the instantaneous value of which e is determined by the formula

$$e = \oint E_{инд} dl = -d\Phi / dt \qquad (1)$$

where Eind is the vector of the electric field strength (induced); dl is a vector equal to the length of the contour section dl and directed tangentially to the contour in the direction of the bypass; dΦ - change in the magnetic flux through the surface bounded by the contour during the time dt [1].
Direction e. etc. with. is determined by the rule of the right-hand screw, while if the screw is tightened so that its tip moves in the direction of the magnetic forces with increasing flux, then the positive direction for the induced emf. coincides with the direction of rotation of the head of this screw. In fact, the induced emf at this moment has a negative direction, therefore, a minus sign is put in formula (1) [2].

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The surface effect is manifested in the uneven distribution of alternating current over the cross section of the conductor. The highest current density is observed at the outer surface of the conductor. With increasing distance from the outer surface, the current density gradually decreases. The higher the frequency, the faster the current density decreases. At a very high frequency, the current flows only through the thin surface layer of the conductor. The surface effect significantly increases the resistance of the conductors, which greatly complicates the transmission of alternating current. However, the surface effect makes it possible to concentrate the release of energy in the surface layers of the heated product, which is important when carrying out the processes of hardening, high-frequency welding, etc. [3]

The proximity effect is manifested when an alternating current flows in the conductor system. Moreover, each of them is located not only in its own alternating magnetic field, but also in the field of other conductors. The effect of proximity is manifested the stronger, the smaller the distance between the conductors and the higher the frequency of the current. With induction heating, the currents in the inductor and the heated part are almost exactly in antiphase. Therefore, using the proximity effect, it is possible by selecting the appropriate shape of the inductor to concentrate the current on the parts of the product that need to be heated [4].

The effect of magnetic circuits on the current distribution in a conductor is that if a conductor through which a high-frequency current is passed is surrounded on three sides by a ferromagnetic material having a high electrical resistivity (ferrite or stratified iron), then the current distribution in the conductor will change dramatically ... It can be assumed with sufficient accuracy for practice that almost all the current will be pulled to the open edge [5].

III. METODOLOGY

When welding pipes, the material of the surfaces to be welded by the end of heating loses its magnetic properties to a depth of up to (2 ÷ 3) Δ in the middle of the edges and up to (3 ÷ 5) Δ at the corners. Approximately 80–85% of the length of the edges in the heating section has the surfaces to be welded, heated to the temperature of loss of magnetic properties to a depth equal to or greater than Δ. Therefore, the real edges can be reduced to the one shown in Fig. 1 system.

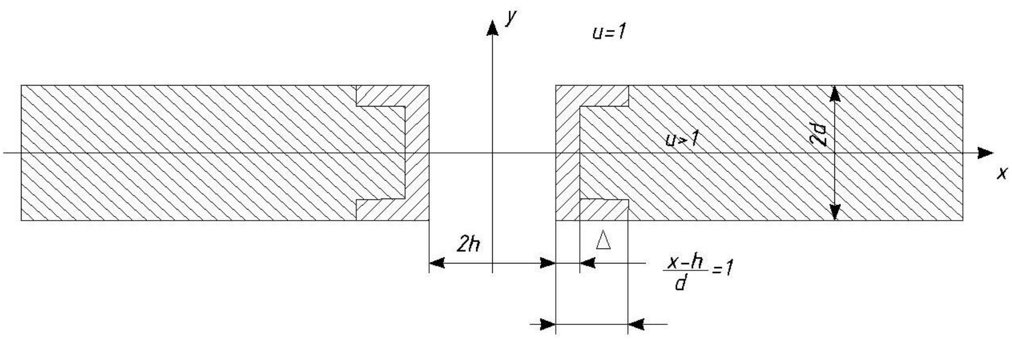

Fig. 1. The flat system to which the
weldable edges made of ferromagnetic material

Measurements have shown that the distribution of the surface current density on models made of ferromagnetic material, in which
the surfaces to be welded to a depth of (1 ÷ 2) Δ are non-magnetic, the same as on models made of non-magnetic material (maximum discrepancy 12%).

Consequently, with the same distribution of the surface current density on the non-magnetic and ferromagnetic edges, the useful power is approximately the same. The total power on the ferromagnetic edges is somewhat higher, since on the lateral surfaces the magnetic permeability $\mu > 1$ and the specific power is higher than at $\mu = 1$.

The power required for welding and the resistance of ferromagnetic edges increase in comparison with the power and resistance of non-magnetic edges in proportion to the coefficient

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$$k_\mu = \frac{\int\limits_{S_2} |\delta_S|^2 |dz| + 0,55 \int\limits_{S_3} \sqrt{\mu_e} |\delta_S|^2 |dz|}{\int\limits_S |\delta_S|^2 |dz|}, \qquad (2)$$

where S2, and S3 are the contours of integration in the sections with μe = 1 and μe> 1 (μe is the relative magnetic permeability on the surface of the edges.

Using formula (2), the values of kμ for parallel edges were calculated, from which the average coefficients kμ cf for edges located at an angle were then obtained. The values of these coefficients for edges with different arrangement of magnetic circuits are shown in Fig. 2, from which it can be seen that kμ av depends on the welding current and the gaps between the edges, as well as the gaps between the magnetic cores and the edges..

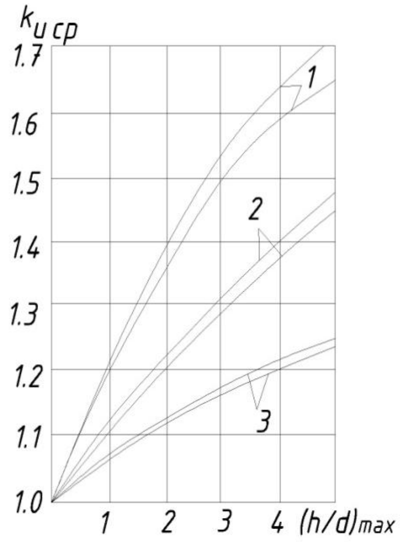

Fig. 2. Values of the coefficients kμ cp for ferromagnetic
edges located at an angle with and one magnetic core (b / d = 10 - solid lines, b / d = 6 - dashed lines);
1 – $I_{кр}$ / 2d = 15·10^4 А/м; 2 – $I_{кр}$ / 2d = 45·10^4 А/м; 3 – $I_{кр}$ / 2d = 90·10^4 А/м

The coupled contour method can be used to calculate the parameters of an inductor used to weld pipes made of ferromagnetic material without using magnetic cores. The system under study (inductor - pipe billet) is divided into elements isolated from one another. The cross-section of the conductors of each element is taken so small that the current density within the cross-section can be considered constant. Breaking the outer and inner surfaces of the pipe billet into elements, we obtain two circuits I and II (Fig. 3) with elementary currents: one is formed by currents flowing along the outer Inap and inner Iin surfaces of the pipe, and the second is formed by the current flowing along the inner surface of the pipe Iin , and the current passing along the welded edges Icr. In this case, the real spreading of the current over the surfaces of the pipe billet is replaced by the idealized one. The inductor also breaks down into elements.

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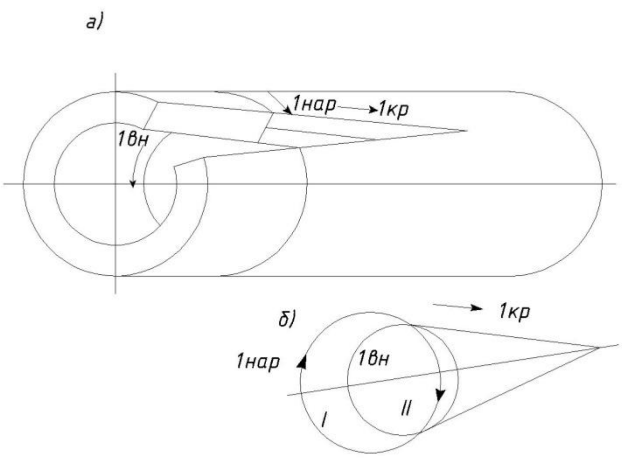

Fig. 3. Idealized surface spreading pattern
pipe billet and an element consisting of contours
current with inductive current supply

The solution of the system of equations for the contours of the pipe billet and the inductor makes it possible to obtain the distribution of the current density and specific power on the surfaces of the pipe billet and the inductor; equivalent active, inductive and impedance of the inductor and the welding power required to heat the edges to the welding temperature; choose the optimal dimensions of the inductor and its location.

IV.CONCLUSION

Research work on determining the influence of thermal deformation parameters during high-frequency welding on the quality of welded joints of longitudinal welded pipes of low-carbon and low alloy steels revealed that:

- with the same distribution of the surface current density on the non-magnetic and ferromagnetic edges, the useful power is approximately the same;
- the power required for welding and the active resistance of edges made of ferromagnetic material are increased compared to the power and active resistance of edges made of non-magnetic material.

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