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On the issue of calculating the power required to heat the edges of the pipe billet to the welding temperature

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ABSTRACT: This article provides a methodology for calculating the power required for heating the edges of longitudinal seam pipes during high-frequency welding from low-carbon low-alloy steels.

KEY WORDS: High frequency current welding, thermal deformation, power,weld, oxide film

I. INTRODUCTION

In the Republic of Uzbekistan, high-frequency welding is widely used at pipe factories in the manufacture of small diameter pipes. There are two known ways of transferring energy to the welded edges: contact and induction. Each method has a number of features that must be taken into account when designing and operating welding devices.

II. LITERATURE SURVEY

With the induction method, an annular inductor is installed at a distance of 30–300 mm from the point of convergence of the edges, covering the pipe 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 induced current flows along the edges and closes at the point of their convergence (useful current). Another part of the current is closed around the perimeter inside the work piece tube (useless current). As with the contact method of supplying current, internal and external magnetic circuits are used to reduce the useless current. The length of the magnetic cores with the induction method should be longer by the length of the inductor than with the contact method [2].

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

With the induction method of supplying current, the power consumption is somewhat higher than with the contact method, since along with the edges, the body of the pipe billet is heated under the inductor. The energy utilization factor - 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 workpiece body increase, while the power for heating the edges remains practically constant. [4].

The advantage of the induction method is the exceptional simplicity and reliability of the inductors. [5].

III. METODOLOGY

When calculating the power, the following assumptions were made: 1) heat losses due to heat transfer from the surface and along the edges are very small; 2) the energy released on the side surfaces of the edges that are not subject to welding does not affect the temperature of the surface to be welded.

Despite the assumptions, this calculation is very difficult, since at the corners of the edges, even when taking into account their rounding, the surface current density is much higher than in the middle of the edges. Therefore, one cannot neglect the heat flux from the corners to the middle of the edges, although it is rather difficult to strictly take into account the influence of this flux. In view of this, the calculation of the power was carried out for two extreme cases.

1. The heat flux from the corners to the middle of the edges is very small and does not affect the temperature distribution on the surfaces to be welded. In this case, the middle part of the edges heats up to the welding temperature, and their corners overheat. The useful power is determined from the condition that the surface current density on the surfaces to be welded is constant and equal to the current density in the middle of the edges. In this case, the useful power is equal to the total power released at the edges at h / d = 0 or b / d = 0, when the heat flux is directed along the normal to the surfaces to be welded. The ratio of the total power to the useful power is denoted by kP 1 and is called the maximum power increase factor.

2. The heat flux from the corners to the middle of the edges is so great that despite the uneven distribution of the current on the surfaces to be welded, the temperature is leveled out due to thermal conductivity. In this case, all the energy released unevenly on the surfaces to be welded is useful. The ratio of the total power supplied to the edges to the power released on the surface to be welded will be called the minimum power increase factor kP 2.

Obviously, the true value of the power increase factor kP lies in the range from kP 1 to kP 2 and depends on the heating time, material properties, edge thickness, and other parameters, which are rather difficult to take into account. Therefore, this coefficient can be taken

$$k_{\text{P}} = \left(k_{\text{P1}} + k_{\text{P2}}\right)/2. \tag{1}$$

Thus, the power Pcr required for welding is found by the formula

$$P_{\text{кр}} = k_P p_0 2d\, 2l_{\text{кр}} \tag{2}$$

where p0 is the specific power determined by the method for a semi-infinite medium; lcr is the length of the edges in the heating section.

This formula, strictly speaking, is applicable if p0 does not change in the section from the contacts or inductor to the point of convergence of the edges. But in a real case, p0 is not constant in the heating section. When welding products from a non-magnetic material, it grows according to a law close to linear. When welding products from a ferromagnetic material, it grows from zero to a maximum value, then decreases in the area of loss of magnetic properties and then grows again in the area up to the point of convergence of the edges. The error in calculating Pкр, if we neglect the change in p0 in the heating section, does not exceed 10%.

Below are the formulas for calculating the power increase factors kP 1 and kP 2, obtained using the distribution of the surface current density for edges with sharp and rounded corners at different locations of the magnetic cores.

1. Edges with sharp corners and one magnetic circuit:

$$k_{P1} = \frac{2K - F\left(k,\ \tau\right) + K' - F\left(k_1 S_1\right)}{\dfrac{nt_0^2 - 1}{\left(t_0^2 - 1\right)\left(1 - k^2 t_0^2\right)} \displaystyle\int_1^{1/k} \frac{\sqrt{\left(t^2 - 1\right)\left(1 - k^2 t^2\right)}}{nt^2 - 1}\, dt}; \tag{3}$$

$$k_{P2} = \left[2K - F\left(k,\ \tau\right) + K' - F\left(k,\ S_1\right)\right] / K'. \tag{4}$$

2. Sharp edges without magnetic cores:

$$k_{P1} = \frac{K' + 2K - 2F\left(k,\ S\right)}{\left(1 + k^2\right)K' - 2E'}; \tag{5}$$

$$k_{P2} = \left[K' + 2K - 2F\left(k,\ S\right)\right] / K'. \tag{6}$$

3. Sharp edges with two magnetic circuits:

$$k_{P1} = \frac{n\left(1 - k^2\right)}{k^2\left(1 - n\right)} \frac{K' + K - F\left(k,\ v\right)}{K' - \Pi\left(n',\ k'\right)}; \tag{7}$$

$$k_{P2} = \left[K' + K - F\left(k,\ v\right)\right] / K'. \tag{8}$$

4. Edges with rounded corners without magnetic cores:

$$k_{P1} = \frac{C\sqrt{1 - k^2} + \sqrt{1 - k_1^2}}{d} \int_1^{t_1} \frac{dt}{\left(C\sqrt{1 - k^2 t^2} + \sqrt{1 - k_1^2 t^2}\right)\sqrt{t^2 - 1}}; \tag{9}$$

$$k_{P2} = \frac{\displaystyle\int_1^{t_1} \frac{dt}{\left(C\sqrt{1 - k^2 t^2} + \sqrt{1 - k_1^2 t^2}\right)\sqrt{t^2 - 1}}}{\displaystyle\int_1^{1/k_1} \frac{dt}{\left(C\sqrt{1 - k^2 t^2} + \sqrt{1 - k_1^2 t^2}\right)\sqrt{t^2 - 1}}}. \tag{10}$$

Having calculated the coefficients kP 1 and kP 2, using formulas (3) - (10), we obtain by formula (66) the values of kP for parallel edges, which are shown in Fig. 1.

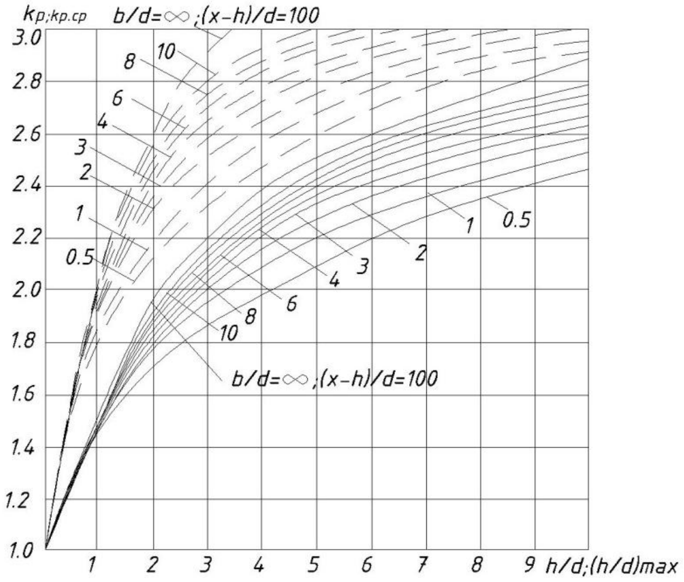

Fig.1 The values of the coefficients kP and kP av for edges with one magnetic core located in parallel (- - -) and at an angle (——)

The same figures show the values of the coefficient kP cp for edges located at an angle, which were calculated by the formula

$$k_{P\ \text{cp}} = \frac{1}{l_{\text{кр}}} \sum_{m=1}^{m=n} k_{Pm} \Delta l_m \tag{11}$$

where kPm is the coefficient for section m.

As can be seen from Fig. 1, the power required to heat the edges to the welding temperature depends significantly on the gap between the edges, and therefore on the angle of convergence of the edges.

For example, at b / d = ∞, a halving of the relative clearance (h / d) max allows the power to be reduced by about 25%. With a minimum angle between the edges, the power can be further reduced if magnetic cores are placed inside and outside the pipe billet, the effectiveness of which increases with a decrease in the gap between the magnetic cores and the edges. With very small gaps between the edges near their point of convergence, the influence of the magnetic cores is insignificant, and therefore they should not be placed in this zone.
The kP 1, kP 2, kP and kP av values calculated for edges with rounded corners are slightly less than the values obtained for r = 0. However, the difference is small and should be taken into account when calculating kP 1, kP 2 and kP for h / d ⩾ 2.5 and when calculating kP cf for h / d ⩾ 2.5.

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:

- at a minimum angle between the edges, the power can be reduced if magnetic cores are placed inside and outside the pipe billet, the effectiveness of which increases with a decrease in the gap between the magnetic cores and the edges;
- with very small gaps between the edges near their place of convergence, the influence of magnetic circuits is insignificant, and therefore they should not be placed in this zone.

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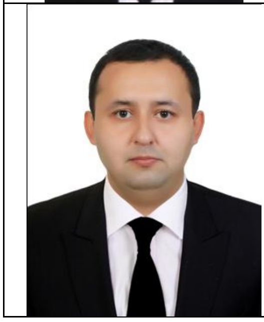	**Xudoyorov Sardor Sadullayevich**, Doctor of Philosophy in Technical science, Associate professor was born Mart 7, 1989 year in Tashkent city, Republic of Uzbekistan. Has more than 30 published scientific works in the form of articles, journals, theses and tutorials. Currently works at the department of “Technological machines and equipment” in Tashkent State Technical University.