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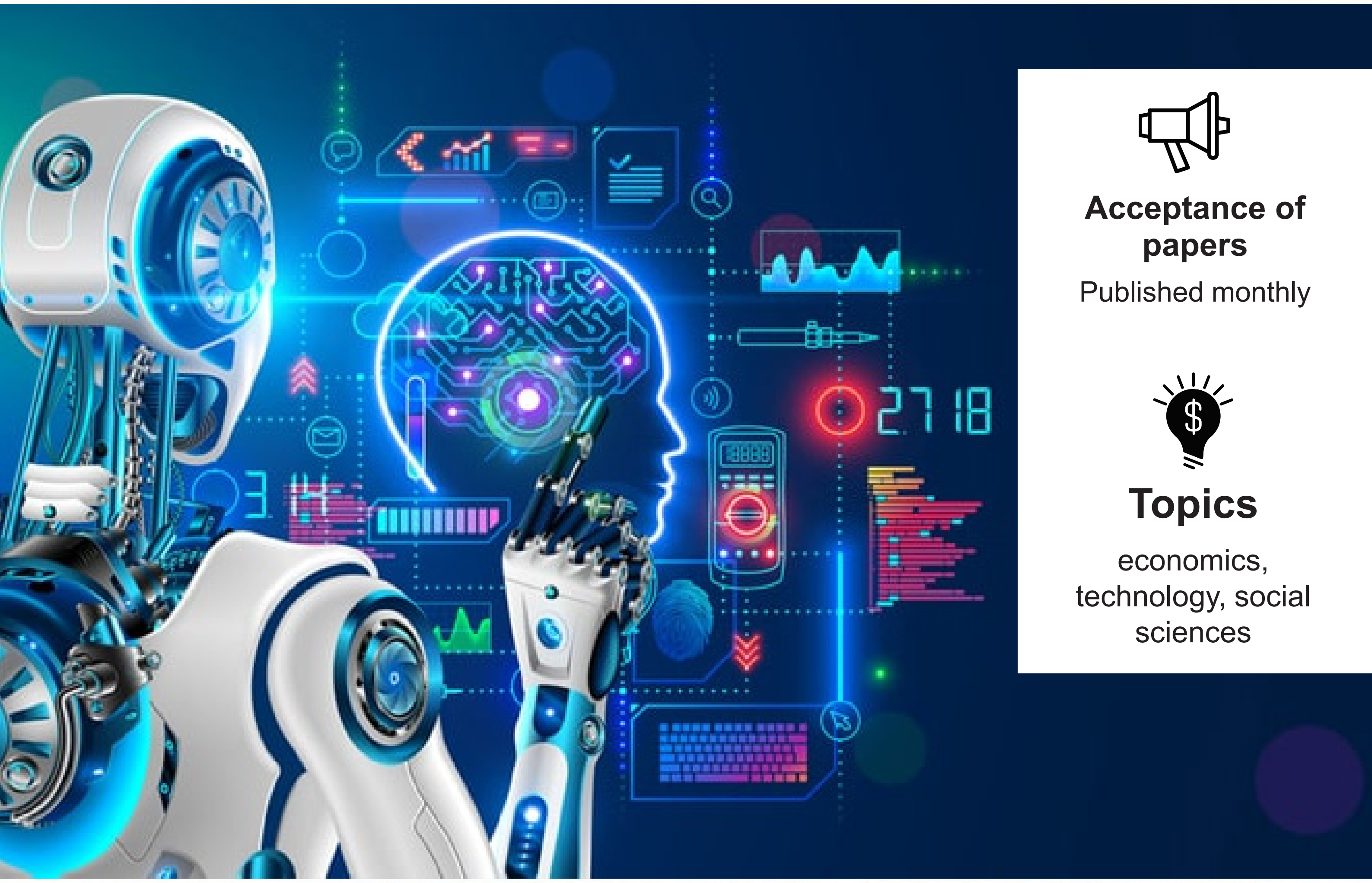

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CONTENTS

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: The article proposes a methodology for calculating the power required to heat the edges of a pipe billet to the welding temperature during high-frequency welding of longitudinally welded pipes made from low-carbon and low-alloy steels. The contact and induction methods of energy supply are considered, and the influence of the distance from the inductor (or contacts) to the edge convergence point, as well as the configuration of magnetic cores, on energy consumption and welding speed is analyzed.

The authors introduce power increase factors k_P1 (maximum) and k_P2 (minimum), which account for the uneven distribution of surface current density along the edges, including cases of sharp and rounded edges, and the presence of one or two magnetic cores. A formula is proposed for determining the average factor k_P as the half-sum of the extreme values, as well as for calculating the required power P_кр, taking into account the variation of specific power along the heating zone.

It has been established that the gap between the edges (and, accordingly, the angle of their convergence) significantly affects the consumed power. It is shown that placing internal and external magnetic cores allows reducing the power at minimal convergence angles of the edges; however, their effectiveness decreases in the zone of very small gaps.

The results of the work can be used in the design and optimization of equipment for high-frequency welding of pipes at pipe mills.

Key words: roll calibration, continuous pipe welding mills, high-frequency welding, pipe blank forming, single-radius calibration, double-radius calibration, oval calibration, edge pre-forming, corrugation, welded seam, electric-welded pipes.

Annotatsiya: Maqolada past uglerodli va past legirli po‘latlardan yasalgan uzunchoq tikuvli quvurlarni yuqori chastotali payvandlashda quvur tayyorlovchisining qirralarini payvandlash haroratigacha isitish uchun zarur bo‘lgan quvvatni hisoblash metodikasi taklif etilgan. Energiyani uzatishning kontakt va induksion usullari ko‘rib chiqilgan, induktor (yoki kontaktlar)dan qirralar yig‘ilish nuqtasigacha bo‘lgan masofa, shuningdek magnit o‘tkazgichlar konfiguratsiyasining energiya sarfi va payvandlash tezligiga ta’siri tahlil qilingan.

Mualliflar tomonidan qirralarda yuzaki tok zichligining notekis taqsimlanishini hisobga olgan holda quvvat oshish koeffitsientlari k_P1 (maksimal) va k_P2 (minimal) kiritilgan, jumladan o‘tkir va yumaloq qirralar, bitta yoki ikkita magnit o‘tkazgich mavjud bo‘lgan holatlar uchun. O‘rtacha k_P koeffitsientini ikki chekka qiymatning yig‘indisining yarmiga teng deb hisoblash formulasi, shuningdek isitish zonasi bo‘ylab o‘zgaruvchan maxsus quvvatni hisobga olgan holda zarur quvvat P_кр ni aniqlash taklif etilgan.

Qirralar orasidagi bo‘shliq (va shunga mos ravishda ularning yig‘ilish burchagi) sarflanadigan quvvatga sezilarli ta’sir ko‘rsatishi aniqlangan. Quvur tayyorlovchisi ichida va tashqarisida magnit o‘tkazgichlarni joylashtirish qirralar yig‘ilishining minimal burchaklarida quvvatni kamaytirish imkonini berishi ko‘rsatilgan, biroq ularning samaradorligi juda kichik bo‘shliqlar zonasida pasayadi.

Kalit so‘zlar: valklarni kalibrlash, uzluksiz quvur payvandlash agregatlari, yuqori chastotali payvandlash, quvur tayyorlovini shakllantirish, bir radiusli kalibrlash, ikki radiusli kalibrlash, oval kalibrlash, chekka qismlarni shakllantirish, gofrirovka hosil bo‘lishi, payvand chok, elektropayvandlangan quvurlar.

Аннотация: В статье предложена методика расчёта мощности, необходимой для нагрева кромок трубной заготовки до температуры сварки при высокочастотной сварке труб с продольным швом из низкоуглеродистых и низколегированных сталей. Рассмотрены контактный и индукционный способы подвода энергии, проанализировано влияние расстояния от индуктора (или контактов) до точки схождения кромок, а также конфигурации магнитопроводов на энергозатраты и скорость сварки.

Авторами введены коэффициенты увеличения мощности k_P1 (максимальный) и k_P2 (минимальный), учитывающие неравномерность распределения плотности поверхностного тока по кромкам, включая случаи острых и скруглённых кромок, наличия одного или двух магнитопроводов. Предложена формула для определения среднего коэффициента k_P как полусуммы крайних значений, а также расчёт требуемой мощности P_кр с учётом изменения удельной мощности вдоль зоны нагрева.

Установлено значительное влияние зазора между кромками (и, соответственно, угла их схождения) на потребляемую мощность. Показано, что применение внутренних и внешних магнитопроводов позволяет снизить мощность при минимальных углах схождения кромок, однако их эффективность падает в зоне очень малых зазоров.

Ключевые слова: калибровка валков, непрерывные трубосварочные агрегаты, высокочастотная сварка, формовка трубной заготовки, однорадиусная калибровка, двухрадиусная калибровка, овальная калибровка, профформовка кромок, гофрообразование, сварной шов, электросварные трубы.

INTRODUCTION

In the Republic of Uzbekistan, the production of small-diameter steel pipes occupies a significant place within the metallurgical and machine-building sectors. One of the most efficient and widely implemented technologies in this field is high-frequency welding, which enables continuous, high-speed pipe formation while ensuring acceptable mechanical strength and geometric accuracy of the welded joint. The reliability and quality of the welded seam largely depend on the thermal regime established in the welding zone, particularly on the accurate determination of the power required to heat the edges of the pipe billet to the welding temperature.

In high-frequency pipe welding, energy is supplied to the edges being joined through electromagnetic processes that cause localized heating due to induced currents and resistive losses. At present, two principal methods of energy transfer to the welded edges are employed in industrial practice: contact welding and induction welding. Each of these methods is characterized by distinct physical mechanisms of heat generation, current distribution, and energy concentration, which directly affect heating efficiency, power consumption, and the stability of the welding process.

Contact welding provides direct current transfer through sliding contacts, offering relatively simple design solutions but introducing issues related to contact wear, surface contamination, and process instability at high production speeds. Induction welding, on the other hand, ensures non-contact energy transfer and higher operational reliability, though it requires more complex electromagnetic systems and precise control of process parameters. These differences necessitate a rigorous analytical approach to calculating the required heating power, taking into account material properties, billet geometry, welding speed, frequency of the current, and heat losses.

Therefore, the problem of accurately calculating the power required to heat the edges of a pipe billet to the welding temperature remains a key engineering and scientific task. Its solution is essential for optimizing welding equipment design, reducing energy consumption, improving seam quality, and enhancing the overall efficiency of pipe manufacturing processes under modern industrial conditions.

REVIEW OF LITERATURE ON THE SUBJECT

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 workpiece 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].

RESEARCH METHODOLOGY

The study is based on analytical and computational methods. Initial data were obtained from theoretical models of high-frequency heating, material properties of steel pipe billets, and technological parameters of the welding process. The analysis was carried out by comparing calculated power values with thermal balance conditions and evaluating the influence of key parameters on heating efficiency.

ANALYSIS AND RESULTS

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

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

(1)

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

$$P_{\hat{e}\eth} = k_P p_0 2d2l_{\hat{e}\eth}$$

(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:

$$k_{P1}=\frac{\partial K-F\left(k,\quad\right)+K'-F\left(k_1S_1\right)}{\dfrac{nt_0^2-1}{\left(t_0^2-1\right)\left(1-k^2t_0^2\right)}\displaystyle\int_1^{1/k}\frac{\sqrt{\left(t^2-1\right)\left(1-k^2t^2\right)}}{nt^2-1}dt};$$

(3)

$$k_{P2}=\left[\partial K-F\left(k,\quad\right),+K'-/F\left(k\quad S_1\right)\right]\quad K'$$

(4)

2. Sharp edges without magnetic cores:

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

(5)

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

(6)

3. Sharp edges with two magnetic circuits:

$$k_{P1}=\frac{n\left(1-k^2\right)}{k^2\left(\ddot{\mathbf{\imath}}-n\right)}\frac{K'+K-F\left(k,\ v\right)}{K'-\quad\left(n'\quad k'\right)};$$

(7)

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

(8)

4. Edges with rounded corners without magnetic cores:

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

(9)

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

(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.

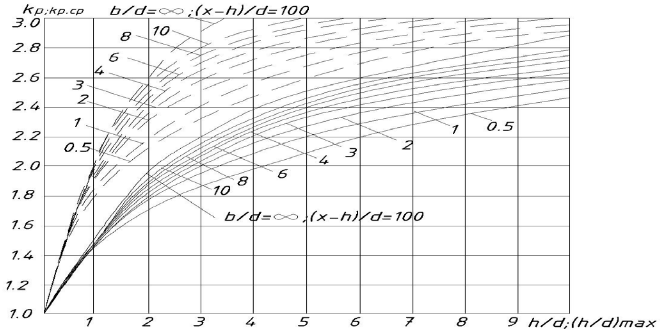

Figure 1. The values of the coefficients kP and kP av for edges with one magnetic core located in parallel (- - -) and at an angle (–––)

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

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

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.

CONCLUSIONS AND SUGGESTIONS

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.

List of used literature:

1. Zairkulov E.E., Dunyashin N.S. To the question of studying the influence of high-frequency welding mode parameters on the quality of welded joints // Materials of the Republican Scientific and Technical Conference “Resource- and Energy-Saving, Environmentally Friendly” - T.: SUE “Fan VA Tarrakiyot”, 2019 - P. 162-164

2. Zairkulov E.E., Dunyashin N.S. To the question of determining the power absorbed by a conductive medium during high-frequency welding of longitudinal pipes // Actual issues in the field of technical and socio-economic sciences. Republican interuniversity collection. - Tashkent: TCTI, 2019 - S.255-257
3. Alzhanov MK, Tursynbekova A. U. Issues of improving the design of pipe welding equipment based on ferrite heaters // Young scientist. - 2016. - No. 2. - S. 117-121.
4. Danchenko V.N., Kolikov A.P., Romantsev B.A., Samusev S.V. - Technology of pipe production: Textbook for universities /.- M.: Intermet Engineering, 2002
5. Osadchy V.Ya., Vavilin A.S. - Technology and equipment for pipe production. Intermet Engineering, 2001

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