first of all, by the volume density of the thermal power. The latter, in turn, is determined by the dynamic pressure of the flow of the working fluid, as well as, in certain limits, by the polarity of the electrodes. In this connection, it is possible to easily control the quality of the heat sources on the electrodes, and consequently the quality of the erosion process, performing processing irrespective of the current in a wide range of modes, beginning from rough sized melting and to prevailing thin dimensional evaporation.

The physical process of electric erosion during dimensional processing by electric arc is characterized by a continuous supply of energy to the treatment zone, continuous burning of the arc and the continuous existence of heat sources at the electrodes. So the thermal effect of the discharge on the electrodes is continuous and the process of erosion is continuously proceeding.

Described according to the existing ideas in the field of the physics of thermal processes, some qualitative characteristics of heat sources on electrodes under conditions of dimensional processing by an electric arc and their correspondence to experimental data for electrodes from iron and steels.

electric arc, anode, cathode, arc column, source of heat, working fluid, current density

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Improved quality control of welded joints

In this work, the magnetic field was reconfigured to control the suture. A computational model with a layout scheme for the horizontal and vertical magnetic fields of the seam bead with reference to the Cartesian coordinate system is proposed. The magnetic charges for a given welding roller are calculated. The topography of the defect field on the surface of the butt weld has been estimated. The results of the calculation of the tangential component of the field of convexity of the weld are obtained when the object is magnetized at an angle to the surface by the primary. The results of theoretical and experimental studies have shown high consistency, it is established that when the object is magnetized simultaneously perpendicular and parallel to its surface, the tangential component of the field The convexity of the seam is skew-symmetric, reminiscent of a sinusoid. The change in the convexity parameters of the weld does not change the field in the plane of its symmetry.

control, quality, object, welding compound, roller, topography, field, reliability, joint welding joint, defect, surface, magnet, Cartesian coordinate system

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Повышение контроля качества сварных соединений

В работе проведено перестроение магнитного поля для контроля сварочного шва. Предложена расчетная модель со схемой расположения горизонтального и вертикального магнитных полей валика шва с привязкой к декартовой системе координат. Произведен расчет магнитных зарядов для заданного сварочного валика. Оценена топография поля дефекта на поверхности стыкового сварного шва Получены результаты расчета тангенциальной составляющей поля выпуклости шва при намагничивании объекта под углом к поверхности первичным Результаты теоретических и экспериментальных исследований показали высокую согласованность, установлено, что когда объект намагничен одновременно перпендикулярно и параллельно его поверхности, тангенциальная составляющая поля выпуклости шва является кососимметричной, напоминающей синусоиду. Изменение параметров выпуклости шва не приводит к изменению поля в плоскости его симметрии.

контроль, качество, объект, сварочное соединение, валик, топография, поле, надежность, стыковой сварочный шов, дефект, поверхность, магнит, декартова система координат

Statement of the problems. Welding works occupy a significant share in the production of machine building and construction. An important factor in increasing the service life of welded joints is improving the control of welded joints. To increase the reliability of the magnetographic inspection of butt welded joints, it is necessary to rebuild from the fields due to the presence of the convexity of the welded seam.

Analysis of recent researches and publishing. The results of theoretical and experimental studies of magnetostatic fields on the surface of the convexity of the seam during magnetization by a field directed parallel to the surface of the controlled article are given in [1-3]. To extend the capabilities of the magnetographic method of control allows the use of a permanent small-sized magnet in the form of a parallelepiped, which is moved directly above the controlled surface on which the magnetic tape is laid, and a face with one pole facing it, to magnetize instead of an electromagnet [4]. In this case, the primary field $\overline{H_0}$ in the control zone becomes inhomogeneous and contains both normal and tangential components. An investigation of the magnetostatic field of the convexity of the welded joint was carried out in [5] for the case when the primary field is directed normally to the surface of the article.

The main material. The task of this work was to study the topography of the magnetostatic field caused by a defect-free welded roller on the surface of a welded joint under the action of a normal Nox and the tangential Ho of the components of the primary field.

Let's assume that the welded seam is made on the surface of a ferromagnetic plate made of low-carbon steel, which makes it possible to neglect the influence of chemical and structural inhomogeneities on the magnetic properties of the weld and the weld zone. Let the height of the seam bead c, width b (Fig, 1). The external field is directed at an angle to the surface of the plate. The position of the Cartesian coordinate system is shown in Fig. 1. In this case, the Z axis is directed along the longitudinal axis of the seam.

Since the value of the normal component Hoy of the primary field under the magnet pole can be regarded as a first approximation in the constant

Dividing the reinforcement height of the seam by planes parallel to XZ into $(c/c_1)\cdot n$ equal parts, where c_1 = 1 mm, we use for analysis the approximation of the surface of reinforcement of the seam by the broken surface ABCDE [1] (Fig. 1). When a perpendicular plate is magnetized by an external field on its surface ($|x| > b/2$) and on all planes of a broken surface parallel to XZ, negative bound "magnetic charges" with density $\sigma_1 = k\cdot H_{oy} = \sigma\cdot\sin\beta$. Since the value of the normal component H_{oy} of the primary field under the magnet pole can be regarded as a constant in the first approximation, then the value of σ1 can be assumed unchanged on all horizontal areas. On all vertical faces of the broken surface parallel to YZ, positive "charges" arise with a surface density $\sigma_{2k} = k \bullet H_{oxk} = \sigma \cos\beta$, the value of which depends on the distance b_k from the Y axis to the k-th pad, since the value of the tangentia component of the primary field H_{ox} varies linearly with respect to the width of the pole and is zero for x = 0.

The calculation procedure is similar to [1, 5].

The tangential H_x and normal H_y components of the field strength at an arbitrary point are determined by summing, respectively, H_{xi} and H_{yi} of the field components from the action of the "magnetic charges" of each of the sections of the computational model [1, 5]. The components of the field strength, due to the charge density σ_1 on the horizontal sections of the plate at $-\infty \le x_1 \le -b/2$ and $b/2 \le x_1 \le \infty$, are defined as

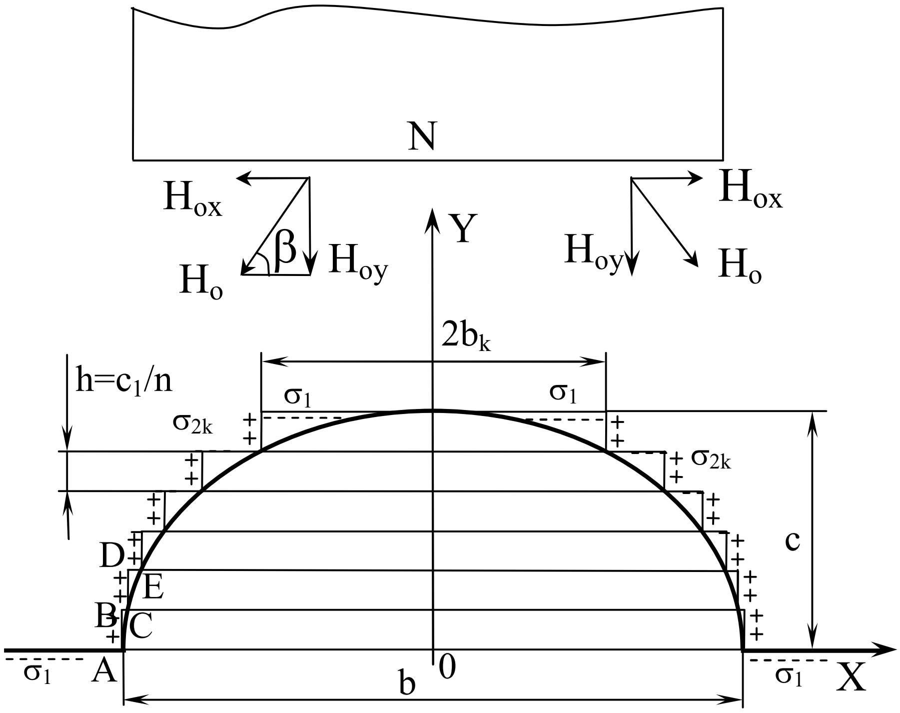

Figure 1 – Calculation model

$$dH_{x1} = -2\sigma_1 \frac{x - x_1}{(x - x_1)^2 + y^2} dx_1 ; \tag{1}$$

$$dH_{y1} = -2\sigma_1 \frac{y}{(x - x_1)^2 + y^2} dx_1 . \tag{2}$$

From the charged element dx_{2k} k- th horizontal platform for $-b_k \le x_{2k} \le -b_{k+1}$ и $b_{k+1} \le x_{2k} \le b_k$

$$dH_{x2k} = -2\sigma_1 \frac{x - x_{2k}}{(x - x_{2k})^2 + (y - y_k)^2} dx_{2k} ; \tag{3}$$

$$dH_{y2k} = -2\sigma_1 \frac{y - y_k}{(x - x_{2k})^2 + (y - y_k)^2} dx_{2k} . \tag{4}$$

From the charged element $d\eta$ k- th vertical platform left for $-b/2 \le x_{2k} \le 0$

$$dH^{лев}_{x3k} = 2\sigma_{2k} \frac{x + b_k}{(x + b_k)^2 + (y - y_k + \eta)^2} d\eta ; \tag{5}$$

$$dH^{лев}_{y3k} = 2\sigma_{2k} \frac{y - y_k + \eta}{(x + b_k)^2 + (y - y_k + \eta)^2} d\eta . \tag{6}$$

From the charged element $d\eta$ k- th vertical platform on right for $0 \le x_{2k} \le b/2$

$$dH^{пр}_{x3k} = 2\sigma_{2k} \frac{x - b_k}{(x - b_k)^2 + (y - y_k + \eta)^2} d\eta ; \tag{7}$$

$$dH^{пр}_{y3k} = 2\sigma_{2k} \frac{y - y_k + \eta}{(x - b_k)^2 + (y - y_k + \eta)^2} d\eta , \tag{8}$$

where

$y_k = k\dfrac{c_1}{n}$, at $|x| < b/2$; $y_k = -k\dfrac{c_1}{n}$, at $|x| \geq b/2$.

After integration of expressions (1) - (4) with respect to *x* in the indicated limits, and expressions (5) - (8) with respect to η in the range from 0 to h and their summation, we obtain:

$$H_{x\subset\supset} = \sigma_1\left\{\ln\frac{(x+b/2)^2+y^2}{(x-b/2)^2+y^2} + \sum_{k=1}^{k=c\cdot\frac{n}{c_1}} \ln\frac{\left[(x+b_{k+1})^2+(y-y_k)^2\right]\cdot\left[(x-b_k)^2+(y-y_k)^2\right]}{\left[(x+b_k)^2+(y-y_k)^2\right]\cdot\left[(x-b_{k+1})^2+(y-y_k)^2\right]}\right\} +$$

$$+2\sum_{k=1}^{k=c\cdot\frac{n}{c_1}} \sigma_{2k}[\mathrm{arctg}\frac{\frac{c_1}{n}(x+b_k)}{(x+b_k)^2+(y-y_k)(y-y_k+\frac{c_1}{n})} + \mathrm{arcrc}\frac{\frac{c_1}{n}(x-b_k)}{(x-b_k)^2+(y-y_k)(y-y_k+\frac{c_1}{n})}]; \quad (9)$$

$$H_{y\subset\supset} = \sigma_1\left\{\mathrm{arctg}\frac{b\cdot y}{y^2+x^2-b^2/4} + 2\sum_{k=1}^{k=c\cdot\frac{n}{c_1}}[\mathrm{arctg}\frac{(b_{k+1}-b_k)(y-y_k)}{(y-y_k)^2+(x+b_{k+1})(x+b_k)} + \mathrm{arctg}\frac{(b_{k+1}-b_k)(y-y_k)}{(y-y_k)^2+(x-b_{k+1})(x-b_k)}]\right\} +$$

$$+\sum_{k=1}^{k=c\cdot\frac{n}{c_1}}\sigma_{2k}\ln\frac{\left[(x+b_k)^2+(y-y_k+\frac{c_1}{n})^2\right]\cdot\left[(x-b_k)^2+(y-y_k+\frac{c_1}{n})^2\right]}{\left[(x+b_k)^2+(y-y_k)^2\right]\cdot\left[(x-b_k)^2+(y-y_k)^2\right]}. \quad (10)$$

If the weld surface in the plane, normal longitudinal axis of the weld, is approximated by a parabola, then b_k and b_{k+1} are determined according to [1] as

$$b_k = x\big|_{y=y_k} = \frac{b}{2}\sqrt{1-k\frac{c_1}{c\cdot n}} \quad (11)$$

and correspondingly

$$b_{k+1} = x\big|_{y=y_{k+1}} = \frac{b}{2}\sqrt{1-(k+1)\frac{c_1}{c\cdot n}}\,. \quad (12)$$

The dependences (9) and (10) make it possible to determine the tangential $H_{x\subset\supset}$ and the normal $H_{y\subset\supset}$ components of the magnetic field strength outside the seam, since in this case the axes τ and n coincide with X and Y. On the surface of the welded joint (|x| <b/2), the axis τ is tangential to the convexity of the seam [1, 5] and forms the angle α (x) with the X axis. In this case, the tangential and normal components of the joint convexity field on the joint surface are determined from the expressions:

$$H_{\tau\subset\supset} = H_{x\subset\supset}\cos\alpha(x) - H_{y\subset\supset}\sin\alpha(x); \quad (13)$$

$$H_{n\subset\supset} = H_{x\subset\supset}\sin\alpha(x) - H_{y\subset\supset}\cos\alpha(x). \quad (14)$$

The results of calculating the tangential component of the field of convexity of the seam when the object is magnetized at an angle to the surface by the primary field are shown in Fig. 2.

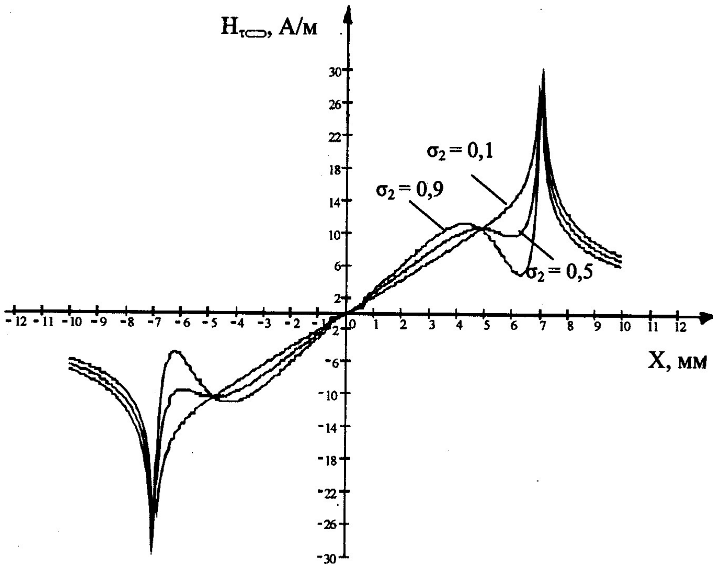

Figure 2 - Dependence of the tangential component on the surface of the welded joint on the magnetization conditions b = 14 mm, c = 2 mm, σ_1 = 1.5 A / m, σ_2 = 0.1; 0.5; 0.9 A / m

To assess the analytical dependencies obtained, experimental studies of the topography of the tangential component of the magnetic field strength on the surface of the welded surface of the weld have been carried out, since it is this field component that is recorded on the magnetic tape. To create a magnetizing field directed at an angle to the surface of the test sample, a permanent magnet was used. The sample was made in the form of a steel plate with a welded bead on its surface. To measure the magnetic field strength, a millislotometer ION-3 was used. The results of the measurements are shown in Fig. 3.

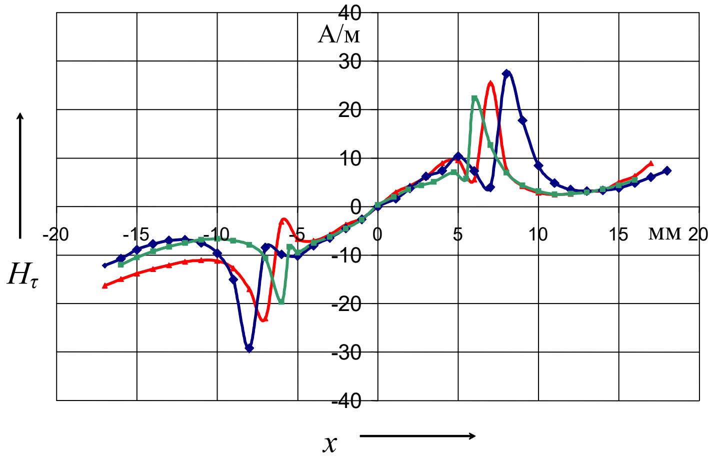

Figure 3 – Experimental topography of the tangential component of the field of convexity of the seam, caused by the normal and tangential components of the external magnetic field: 1) b = 11 mm; c = 1.5 mm; 2) b = 12.5 mm; c = 1.7 mm; 3) b = 14 mm; c = 3 mm

Conclusion. Thus, based on the results of calculation and experiment, it is established that when the object is magnetized simultaneously perpendicularly and parallel to its surface, the tangential component of the field of convexity of the seam is skew-symmetric, resembling a sinusoid. The change in the parameters of the convexity of the seam does not lead to a change in the field in the plane of its symmetry. An increase in the horizontal component of the primary field, which is equivalent to an increase in σ_2, leads to an increase in the modulus of tension $H_{\tau\subset\supset}$ in the middle part of the seam (but not in the plane of symmetry) and to a decrease in the approach to the edges of the seam.

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Підвищення контролю якості зварних з'єднань

Для достовірності та підвищення якості магнітографічного контролю проведено дослідження магнітного поля зварювальних швів на поверхні опуклості шва. Метою даної роботи є аналіз існуючих методів магнітного контролю зварних швів і підвищення якості контролю зварних з'єднань шляхом формування магнітостатіческого поля в зоні зварного з'єднання при намагнічуванні полем, спрямованим паралельно і перпендикулярно поверхні контрольованого вироби.

Для підвищення надійності магнітографіческіе контролю стикових зварних з'єднань, необхідно перебудувати магнітні поля через наявність опуклості зварного шва. Запропоновано розрахункову модель зі схемою розташування горизонтального і вертикального магнітних полів валика шва з прив'язкою до декартовій системі координат. Зроблено розрахунок магнітних зарядів для заданого зварювального валика. Оцінена топографія поля дефекту на поверхні стикового зварного шва. Отримано результати розрахунку тангенціальної складової поля опуклості шва при намагнічуванні об'єкта під кутом до поверхні первинним полем. **Для оцінки отриманих аналітичних залежностей були проведені експериментальні дослідження топографії тангенціальної складової напруженості магнітного поля на поверхні опуклості зварного шва. Для вимірювання напруженості магнітного поля використовували сучасне обладнання.** Результати теоретичних і експериментальних досліджень показали високу узгодженість.

Виходячи з результатів розрахунку і експерименту, встановлено, що коли об'єкт намагнічений одночасно перпендикулярно і паралельно його поверхні, тангенціальна складова поля опуклості шва є кососімметрічной, що нагадує синусоїду. Зміна параметрів опуклості шва не призводить до зміни поля в площині його симетрії.

контроль, якість, об'єкт, зварювальне з'еднання, валик, топографія, поле, надійність, стиковий зварювальний шов, дефект, поверхня, магніт, декартова система координат

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