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CHOICE OF THE ECONOMICAL METHOD OF WELDING AT MAKING OF STEEL CONSTRUCTIONS

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Summary. In the given article the method of decision of expense of electric energy for various types of welding, comparative analysis of efficiency of different ways of welding, is resulted. Tabl. 3, fig. 5, source 25.

Key words: welding, economy, economy of electric energy.

INTRODUCTION

In different industries of industry will remain basic materials on the nearest decades to steel and alloys on the basis of iron, and leading technological process of receipt of permanent connections – welding.

In the conditions of market competition at making of the welded constructions it is necessary to develop technologies which allow to provide the best quality and the least cost of good.

THE ANALYSIS OF PUBLICATIONS, MATERIALS, METHODS

Basic directions of economy in welding production are following [Gedrovich A.I., Druz O.N., 2002, Gedrovich A.I., Druz O.N., 2003, Gedrovich A.I., Gidkov A.B., 2003, Gitlevich A.D., 1985, Gracheva K.A., 1984, Shebeko L.P., Gitlevich A.D., 1986]: transition to sheet metal ware (use of metal-roll of small thicknesses, to 10 mm); reduction of prices of process of welding (power reduction) and welding materials.

On today the methods of fuse welding are most developed, that is related to simplicity of their realization. An anchorwomen the role belongs to the arc welding which will in the near future remain the basic type of fuse welding here. Such position of the arc welding is explained by high concentration of thermal energy, universality of process, by possibility of welding under various conditions and spatial positions, simplicity, by reliability and is relative by the low cost of equipment, stability of strength characteristics descriptions of the welded connections, comparative simplicity of mechanization of process of welding.

THE PURPOSE AND STATEMENT OF PROBLEM OF RESEARCHES

Working up of method of estimation and choice of the most economy method of welding with minimum consumption of electric energy at making of steel constructions from thin metal-roll is the target of the given article.

Most perspective path of development of welding technologies of – economy resources material and power at welding. Here, foremost, it is necessary to mechanize and automatize (robotize) the process of receipt of the welded connection and aspire to the burst performance, with the improvement of terms of labour of welder. However sharp transition to total automation of process of welding is related to the enough large capital investments, therefore it is not needed to renounce the semi-automatic methods of welding. Expediently to modify and combine existent technologies of welding. From the existent methods of fuse welding it is necessary to choose economical and with the least consumption of electric energy.

THE BASIC SECTION WITH RESULTS AND THEIR ANALYSIS

For the decision of method of fuse welding with minimum consumption of electric energy their comparison was conducted. In technical literature estimated dependences on the decision of power consumptions (electricity charges) on 1 kg of weld metal and on 1 m of the welded stitch [Gitlevich A.D., 1985, Gracheva K.A., 1984, Shebeko L.P., Gitlevich A.D., 1986, Karnauh A.K., Mazur A.A., Panashenko N.I., 1995, Mazur A.A., Karnauh A.K., Panashenko N.I., 1996, Panashenko N.I., 1996, Panashenko N.I., Gavva V.M., Karnauh A.K., 1996, Panashenko N.I., Karnauh A.K., 1995, Panashenko N.I., Mazur A.A., Karnauh A.K., Beynish A.M., 1995] are brought over, basic design formulas (1 – 5) are resulted in the table 1.

In our opinion the analysis of consumption of electric energy must be conducted on 1 m of welding stitch, as not in all methods of welding a adding electrode metal is used.

For the calculation of consumptions on electric energy the dependence (5) from table is most preferable. 1, as it takes into account the losses at idling of arc welding source. The sentinel expense of electric energy at idling can makes 15...27 % sentinel expense during burning of welding arc at the use of transformers of direct current, 2,5...12,5 % – at rectifiers and 3,5...6,5 % – at transformers. Along with it the recommended dependences (tabl. 1) for the calculation of consumption on electric energy do not take into account its expense to work of electric motors of mechanisms of serve of electrode wire, works and adjusting moving of welding vehicle or welded product. They do not take into account also the losses of electric energy in a network.

Table 1. **Formulas for the decision of power consumptions at welding**

Design formula	Table of symbols
$C_e = qQ_w P_e$, (1)	C_e – consumptions on electric energy per 1 m of stitch, q – expense of electric energy per 1 kg of weld metal (kW·h/kg), P_e – price 1 kW·h electric energy (monetary items), U – tension on a welding arc, (V), η – output-input ratio of arc welding source, W_i – power of idling of arc welding source, (kW), a_m – coefficient of basic time, equal to attitude of basic time toward piece calculation time of welding, Q_w – mass of the weld metal per 1 m of welding stitch, (kg), S – speed of welding deposition or welding, (kg/h), I – welding current, (A), α_d – coefficient of welding deposition, (g/A·h), t_0 – basic time of welding per 1 m of stitch, (h/m).
$C_e = \frac{t_0 IUP_e}{\eta 1000}$, (2)	
$C_e = \frac{Q_w IUP_e}{S\eta 1000}$, (3)	
$C_e = \frac{Q_w UP_e}{\eta \alpha_d}$, (4)	
$C_e = t_0 \left(\frac{IU}{\eta 1000} + W_i \frac{1 - a_m}{a_m} \right) P_e$. (5)	

For setting of norms of consumptions of electric energy per 1 m of stitch at all arc methods of welding it is recommended to use the following dependence:

$$N_{em} = E_{bm} + E_{im} + E_{em}, \qquad (1)$$

where: E_{bm} – expense of electric energy for basic time of welding;
E_{im} – specific losses of electric energy in the alternated mode of operations of welding source in the period of idling;
E_{em} – electric energy consumption by an engine.

The E_{bm} value is determined on the following formula:

$$E_{bm} = \frac{IUT_{bm} \cdot 10^{-3}}{\eta}, \qquad (2)$$

where: I – strength of welding current (A);
U – tension on a welding arc (V);
T_{bm} – basic time of welding 1 m of stitch or fuse welding 1 kg of metal (period of burning of arc) (h/m); $T_{bm} = 1/v_w$, for the automatic welding and $T_{bm} = M / I\alpha_d$, for the manual arc welding and semi-automatic welding
M – mass of added metal on 1 m of stitch (g);
η – output-input ratio of arc welding source.

The E_{im} value is determined on the following formula:

$$E_{im} = P_w \cdot T_{bm} \cdot K_i, \qquad (3)$$

where: P_w – power of arc welding source on idling (kW);
K_i – coefficient taking into account the period of idling of welding source in relation to basic time of welding.

The mean values P_w for a single-operator transformer make 1,2...1,6 kW, for a semiconductor rectifier – 0,2...0,3 kW, for a transformer – 0,35...0,4 kW.

The mean values K_i for the terms large-scale production and mass production make 0,4...0,6, and for individual production and small-scale production – 0,7...0,8.

Or $K_i = (1 - K_0)/K_0$, K_0 – coefficient of time of burning of arc in common time on welding.

The E_{em} value is found on the following formula:

$$E_{em} = \sum_{i=1}^{n} P_i \cdot K_{pi} \cdot T_{pi} \qquad (4)$$

where: P_i – the installed power for one electric motor (kW);
K_{pi} – activity factor for one electric motor on power;
T_{pi} – duration of work one electric motor (h/m).

It Is Recommended η_i to accept equal: 0,75…0,94 for welding solvent sealing; 0,54...0,94 for the manual arc welding by the covered electrodes; 0,7...0,85 for welding in inert gases; 0,7...0,94 for welding in active gases and mixtures of gases; 0,66…0,86 for welding of flux-cored welding and superficially activated.

Graphic presentation of distributing of middle output-input ratio of welding processes is represented on the fig. 1.

We will define the consumptions of electric energy on the butt-seam single-pass arc welding in the air quality of protective gases of two leaves from construction steel plate (type of the connection C4) thickness 4 mm (GOST 8713-79). We will adopt length of stitch of equal 1 m, individual production, for all methods of arc welding as a welding source the semiconductor rectifier of the type VDU-1001 is used. We adopt the modes of welding from reference data [Kitaev A.M., Kitaev Ya.A., 1985, Lihachev V.L., 2004, Nikiforov N.I., 1999, Asnis A.E., 1980, Malishev B.D., 1989, Chernishov G.G., Mordinskiy V.B., 2004]. The technological modes and output computation are taken in table 2 and represented on the fig. 2. The middle consumptions of electric energy per 1 m of the welded stitch of the connection C4 for different ways of welding are represented on the fig. 3.

However, In spite of such distributing of consumption of energy on the methods of welding, cost 1 m of stitch to it short of, that is related to the additional consumption on the receipt of the welded connection (cleaning of the welded edges, assembling for welding, pay-envelope of welders and auxiliary personnel, consumption for repair and production service, welding materials and etc) [Gitlevich A.D., 1985, Gracheva K.A., 1984, Shebeko L.P., Gitlevich A.D., 1986, Mazur A.A., Karnauh A.K., Panashenko N.I., 1996, Panashenko N.I., 1996, Panashenko N.I., Gavva V.M., Karnauh A.K., 1996, Panashenko N.I., Karnauh A.K., 1995, Panashenko N.I., Mazur A.A., Karnauh A.K., Beynish A.M., 1995]. Average cost 1 m of the end joint stitch C4 at the thickness of sheet 4 mm of got different ways of the arc welding is represented on the fig. 4.

From tabl. 2 and the fig. 2 is visible, that minimum consumption of electric energy, other things being equal, the methods of welding are had in protective gases (their mixtures) with activators. Welding under water and welding in the environment of aquatic steam can be de bene esse considered welding in an active gas environment, consisting of products of decomposition of water (pair) and gases selected at dissociation of stock of powder-like wares [Asnis A.E., 1980, Gusachenko A.I., Kononenko V.Ya., 1989, Zorbidi V.N., 1989, Kononenko V.Ya., Ribchenkov A.G., 1994, Pohodnya I.K., Gorpenyuk V.N., Kononenko V.Ya., Ponomarev V.E., Maksimov S.Yu., 1990, Smiyan O.D., Kononenko V.Ya., 1987].

Table 2. **Welding conditions of automatic methods butt-welded joint C4 and power imputs per 1 m of stitch on a design formula (6)**

Welding conditions					Power imputs per 1 m of stitch, (κW·h/m)	Method of welding
I, (A)	U, (B)	V_w, (m/h)	D_{ei}, (mm)	Performance index		
1	2	3	4	5	6	7
250	26	24	2	0,75	0,4094	Automatic welding in the protective environment CO_2
350	30	40	2	0,75	0,3790	Automatic welding in the mixture $70\%CO_2+30\%O_2$
370	30	40	2	0,75	0,3990	Automatic welding in a mixture a $85\%CO_2+15\%O_2$ wire with additions Ce and La
540	26	50	4	0,75	0,3976	Automatic solvent sealing on melt backing
480	30	49	4	0,75	0,4155	Automatic solvent sealing on copper-melt backing
280	28	25	2	0,75	0,4645	Automatic welding in inert gases (Ar)
280	28	30	2	0,75	0,3871	Automatic welding in the mixture $85\%Ar_2+15\%CO_2$
170	28	25	2	0,75	0,3003	Automatic welding in the protective environment Ar on the layer of activator (welding compound)
180	28	25	2	0,75	0,3152	Automatic welding in a mixture $85\%Ar+15\%CO_2$ on the layer of activator (welding compound)
280	40	45	2	0,75	0,3576	Automatic welding in the protective environment CO_2 on the layer of activator (welding compound)
200	28	20	2	0,75	0,4313	Automatic welding under water by a bare wire without additional defense
250	23	30	2	0,75	0,2942	Automatic welding under water by a bare wire with the additional defense CO_2
200	28	20	1,6	0,75	0,4313	Automatic welding under water by the powder-like wire PPC-5AN
180	30	20	1,6	0,75	0,4180	Automatic welding under water by the powder-like wire PPC-AN1
160	30	20	2	0,75	0,3780	Automatic welding in the environment of aquatic steam

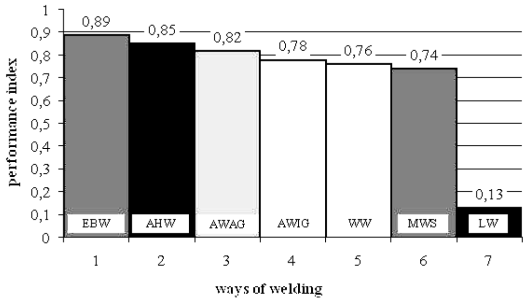

Fig. 1. Distributing of middle output-input ratio (performance index) of various ways of welding: EBW – electron-beam welding; AHW – automatic hidden arc welding; AWAG – automatic arc welding in active gases (CO_2); AWIG – automatic arc welding in inert gases (Ar); WW – welding by a powder-like wire; MWS – manual arc welding by a stick electrode; LW – laser welding

For the input analysis energies use comparative descriptions of heat source (thermal energy), for example, rate of energy input welded elements, which is determined on a formula [Kuzminov S.A., 1974]:

$$q_n = \frac{\eta_r Q}{V_w} = 0{,}24 \frac{I_w U_d}{V_w} \eta_r \,, \tag{5}$$

where: q_n – rate of energy input of the welded elements (cal/sm);
v_w – middle speed of welding (sm/s);
η_r – effective output-input ratio of process of heating by an arc.

Table 3. **Descriptions of thermal current of welding arcs**

Description of welding arc	Maximal specific thermal thread, (cal/ (sm^2·c))	Coefficient of concentration K, (1/sm^2)
Arc of unfluxible carbon electrode	1000—2000	1—1,5
Arc of unfluxible electrode (tungsten) in the Ar stream	500—600	6—14,0
Arc opened of fluxible electrode (iron)	1000—2000	1—1,5
Arc submerged arc of fluxible electrode (iron)	6000	6—10,0

The indexes of efficiency of welding sources of heat (arcs) are: degree of localization of input of heat in product, maximal power of welding source, maximal effective input in the center of spot of heating, output-input ratio of the use of power. In the table 3 comparative descriptions of sources of heat are resulted.

The concentrated of heating of article within the limits of spot of heating at the use of various sources of heat is represented on the fig. 5. Approximately distributing of thermal thread on the surface of spot of heating is determined to the curve of Gauss:

$$q_2(r) = q_{2m} \cdot e^{-Kr^2} \tag{6}$$

where: $q_2(r)$ – intensity of specific thermal thread in any place of spot (W/sm^2);

q_{2m} – the most specific thermal thread (W/sm^2);
r – radial distance from the axis of symmetry of source to the examined point (sm);
K – coefficient of concentration, characterizing the geometrical form of curve, 1/sm^2 (coefficient K is determined by an experimental path and relied on the type of thermal energy source and its thermal power);
e – foundation of natural logarithm.

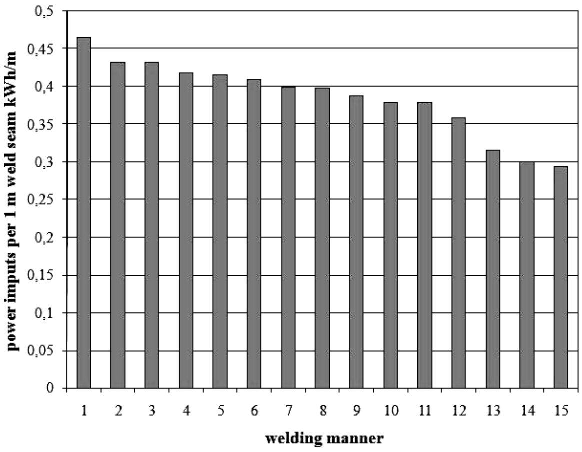

Fig. 2. Cost sharing of electrical energy per 1 m of stitch of the connection C4 for various ways of the arc welding in protective gases: 1 – automatic welding in the environment of inert gases (Ar); 2 – automatic welding under water by a bare wire without additional defense; 3 – automatic welding under water by the powder-like wire PPC-AN5; 4 – automatic welding under water by the powder-like wire PPC-AN1; 5 – automatic solvent sealing on copper-melt backing; 6 – automatic welding in the protective environment CO_2; 7 – automatic welding in a mixture by a 85%CO_2+15%O_2 electrode wire with additions Ce and La; 8 – Automatic solvent sealing on melt backing; 9 – automatic welding in the mixture 85%Ar_2+15%CO_2; 10 – automatic welding in the mixture 70%CO_2+30%O_2; 11 – welding in the environment of aquatic steam; 12 – automatic welding in SO_2 on the layer of activator (melt);13 – automatic welding in a mixture 85%Ar+15%CO_2 on the layer of activator (melt);14 – automatic welding in the protective environment Ar on the layer of activator (melt);15 – automatic welding under water by a bare wire with the additional defense CO_2

Most maximal power is practically attained at the slag welding – 250 kW and arc welding – 100kW. By the range of powers to 50 kW electron-beam welding set are characterized. Maximal power 30 kW is achieved in setting for welding by a laser. Maximal power of the practically applied gas welding flame is limited 10 kW.

On the useful use of power of energy (on the effective input of heat in the welded article) source by the most high value of output-input ratio an cathode ray and welding arc are characterized. The use of power of laser and gas welding flame is less effective considerably.

It ensues from the above-mentioned data, that on the given stage of development of welding technologies it is necessary to work at development, first of all, arc welding in the environment of protective gases and their mixtures, as one of the most alternative technology and technology of permanent connection simple in realization (automations).

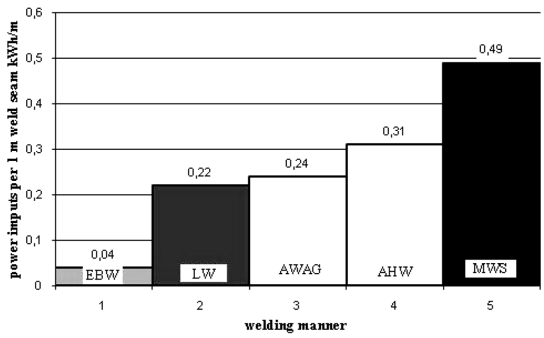

Fig. 3. Cost sharing of electrical energy per 1 m of stitch of the connection C4 for various ways of the welding: EBW – electron-beam welding, LW – laser welding, AWAG – automatic arc welding in active gases, AHW – automatic hidden arc welding, MWS – manual arc welding

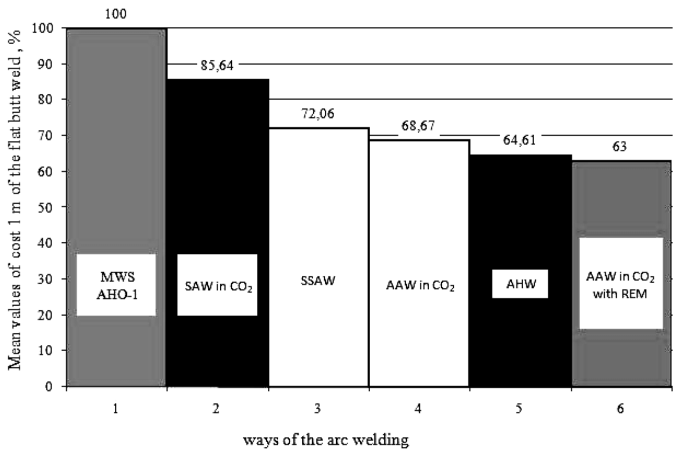

Fig. 4. Mean values of cost 1 m of the flat butt weld C4 at the thickness of sheet 4 mm in relative units (the hang-the-expense approach method of welding is accepted after 100%) on various ways of the arc welding: MWS AHO-1 – manual arc welding by the custom-made electrode of the AHO-1 brand, SAW in CO_2 – semi-automatic arc welding in the protective environment CO_2, SSAW – semi-automatic submerged arc welding, AAW in CO_2 – automatic arc welding in the protective environment CO_2, AHW – automatic submerged arc welding, AAW in CO_2 with REM – automatic arc welding in the protective environment CO_2 with additions of rare-earth metals to the electrode

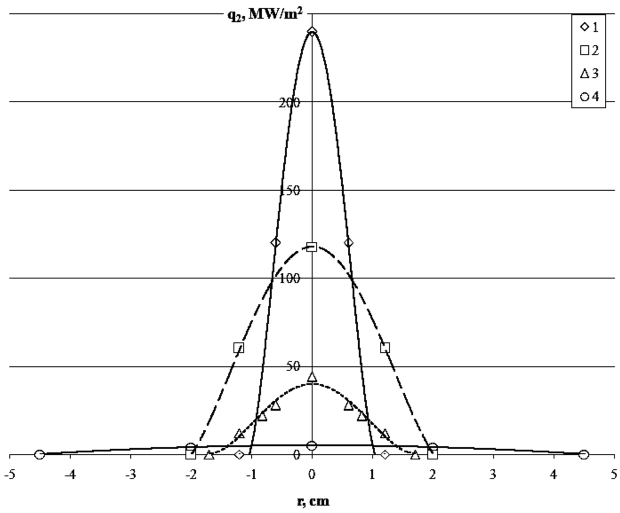

Fig. 5. Graph of efficiency of thermal action of various sources of heat: *1* – metallic submerged arc (q=27,5 kW); *2* – metallic arc opened (q=29,1 kW); *3* – metallic arc opened (q=9,9 kW); *4* – gas flame (q=9,4 kW; head № 7)

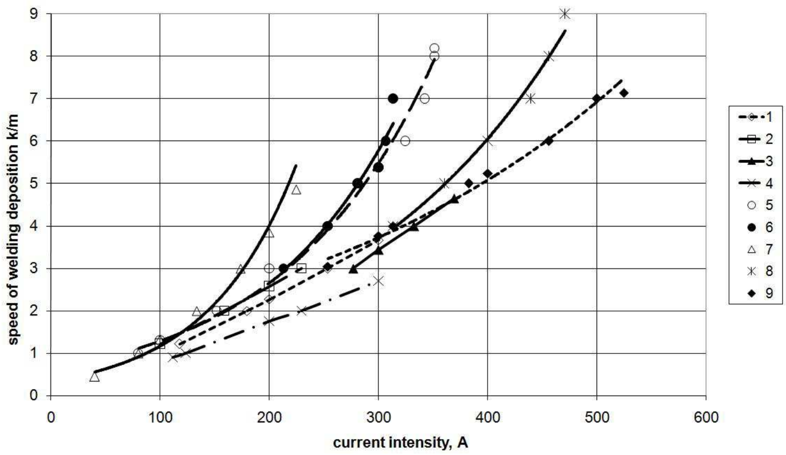

Fig. 6. Dependence of productivity welding deposition of arc methods of welding on strength of current: 1 – manual arc welding, electrode with basic coverage; 2 – manual arc welding, electrode with cellulose coverage; 3 – manual arc welding, electrode with retile coverage and ferrous powder; 4 – manual arc welding, electrode with retile coverage; 5 – welding in a protective environment the CO_2 wire the diameter 1,2 mm; 6 – powder-like wire the diameter 1,6 mm (brands – FCW AWS E6XT5); 7 – welding in a protective environment the CO_2 wire the diameter 0,8 mm; 8 – powder-like wire the diameter 1,6 mm (brands – FCW AWS E6XT1); 9 – powder-like wire the diameter 2,4 mm (brands – FCW AWS E6XT1)

In practice often the economic factors of arc welding are determined by productivity of welding deposition. Dependence of speed of welding deposition on welding current strength represented on the fig. 6.

CONCLUSIONS

1. Perspective for application, development, improvement and modification there is the method of the arc welding in the environment of protective gases and their mixtures with additions of activators, steel with thickness to 10 mm.

2. Application of plasma, electron-beam and laser methods of welding are expedient only in case of impossibility of the use of other methods of welding.

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ВЫБОР ЭКОНОМИЧНОГО СПОСОБА СВАРКИ ПРИ ИЗГОТОВЛЕНИИ СТАЛЬНЫХ КОНСТРУКЦИЙ

Олег Друзь, Светлана Житная

Аннотация В данной статье приведена методика определения расхода электрической энергии для различных видов сварки, сравнительный анализ эффективности различных способов сварки. Табл. 3, рис. 5, ист. 25.

Ключевые слова: сварка, экономия, сбережение электрической энергии.

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