Restoration of working bodies and parts of agricultural machinery by submerged arc welding using a modified installation using local raw materials

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Abstract. *The article studies the process of restoration of worn parts of agricultural machinery by submerged arc welding, defines similarity criteria characterizing this restoration process and revealing their physical essence. A technique has been developed and a general criteria equation has been obtained for determining and optimizing the hardness of the resulting metal coatings, which is the scientific basis for conducting targeted experiments. For surfacing of plowshares and other parts under flux, the existing standard installation was modified in order to automate the process and increase productivity, and several devices were manufactured taking into account the shape of the working elements being restored. Experimental studies were conducted as a result of which an analytical form of the criterial equation was obtained and rational modes for restoring parts during electric arc surfacing under flux were established. The composition and structure of the obtained metal coatings were studied and different compositions were proposed as new fluxes. obtained in Georgia using the remains of manganese processing in the city of Chiatura.*

KEYWORDS: *WEAR, RESTORATION, SURFACING UNDER FLUX, AGRICULTURAL MACHINERY, SIMILARITY CRITERION.*

At present, resource-saving technological processes are widely used in repair practice, allowing to restore worn-out machine parts, to increase their service life and "second life" in general. Such methods include submerged arc welding, which is used to restore large-sized parts. To study the structure and mechanical properties of metal coatings obtained by this method, we used a standard installation A 1416, which allows to restore large-sized parts with large wear. In order to expand the functionality of the installation and automate the process of restoring parts, we modified this installation by adding new DC motors and improving the power choke. The modified installation is shown below. Fig. 1. Modified installation for automatic surfacing of parts under flux It should be noted that in our experiments the surfacing process was carried out automatically, stably, and inexpensive materials obtained after processing manganese ore in the city of Chiatura were used as fluxes. The flux compositions are as follows (Table 1):

Table 1. *Flux composition.*

№	Name of sample	Silicon Si	Alumin. Al	Magn. Mg	Calc. Ca	Iron Fe	Marg. Mr	Titan. Ti	Nik. Ni	Cop. Cu	Natr. Na
1.	№ 1	23-25	12-14	0,4	10-12	8-10	0,3	2,0	------	0,002	**1-2**
2.	№ 2	20-22	12-14	1,0	12-14	10-12	0,5	2-4	------	0,002	**3-5**

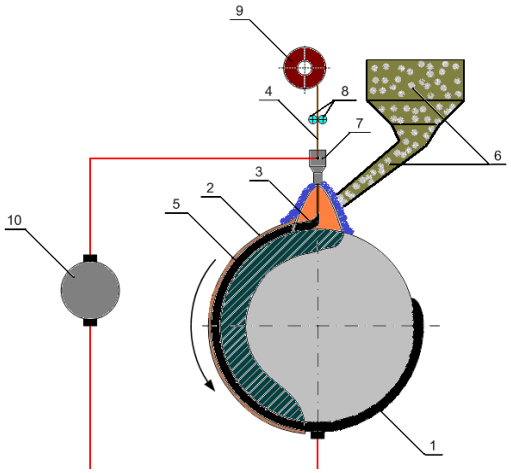
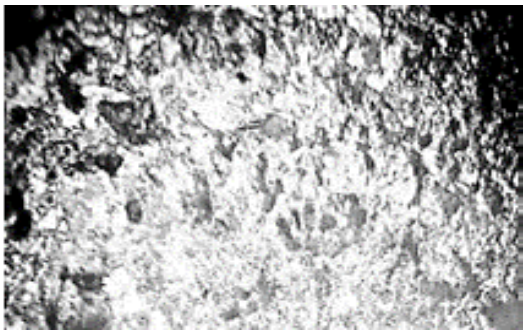


Fig.1. *Shows the operation diagram of the modified unit for automatic surfacing of parts under a flux layer [1, 2, 3].*

Fig. 1. Operation diagram of the modified unit for automatic surfacing of parts under a flux

1. Part to be surfacing. 2. Slag crust. 3. Electric arc .4. Electrode wire. 5. Deposited layer. 6. Flux feeder. 7. Nozzle. 8. Electrode wire feed mechanism. 9. Coil. 10. Current power source (Generator)

When restoring worn machine parts using this method, flux is introduced into the electric arc space, which forms a protective shell that protects the metal coating from the harmful effects of the atmosphere, and the slag crust helps to obtain a stable structure. Figure 3 shows the structures obtained by surfacing. [4, 5]



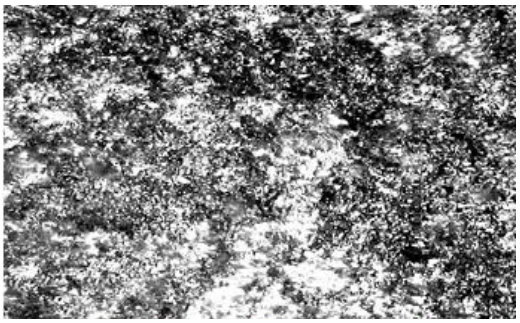


Fig. 2. *Structures of metal coatings obtained by surfacing under flux*

To restore the working parts of agricultural machines, an automatic copying device for restoring. Plowshares by surfacing under flux was designed and manufactured (Fig. 3.)

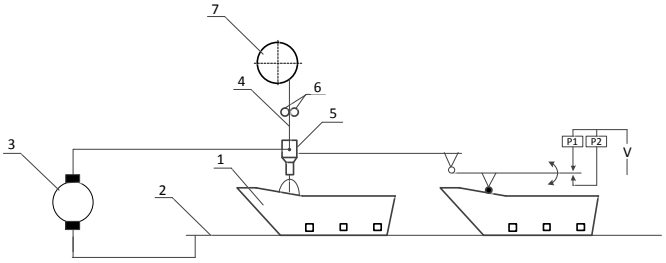


Fig. 3. *Automatic copying device for restoring plowshares by surfacing under flux 1. Plowshare. 2. Lathe-screw-cutting machine. 3. Current source (generator). 4. Electrode wire. 5. Nozzle. 6. Feed mechanism. 7. Coil.*

Then targeted scientific research was conducted to optimize the modes of the process of restoring parts by submerged arc surfacing using theories of similarity and planning of multifactorial experiments [6, 7]. In our case, the optimization parameter is the hardness of the metal coating obtained by automatic submerged arc surfacing. Based on the analysis of the conducted research and literary sources [1,5], the hardness of these coatings depends on the factors, the names and dimensions of which are presented in the table. [8, 9]. Table 2. List of factors affecting the hardness of metal coatings obtained by submerged arc surfacing.

Table 2. *List of factors affecting the hardness of metal coatings obtained by submerged arc surfacing*

№	The name of the optimization parameter and factors	Designation	The dimension in the system Si	Dimension, expressions by the symbols of quantities
1	Hardness of metal coatings	H_μ	*МПа*	$ML^{-1}T^{-2}$
2	The size of the part to be restored	L	*м*	L
3	Current intensity	$\mathcal{J}$	*A*	$\mathcal{J}$
4	Voltage	υ	*B*	$ML^2T^{-3}\mathcal{J}^{-1}$
5	Electrode feed rate	V	$м.sec^{-1}$	LT^{-1}
6	Electric resistance of an electrode	R	*Ом*	$ML\,N^{-3}\mathcal{J}^{-1}$
7	Surfacing speed	V_1	$м.sec^{-1}$	LT^{-1}
8	Electrode density	ρ	$кг.м^{-3}$	ML^{-3}
9	Density of flux	ρ_1	$кг.м^{-3}$	ML^{-3}
10	Electrode outlet	*e*	*м*	*M*
11	Consumption of flux	Q	$кг.^{-1}$	MT^{-1}

The functional relationship between the optimization parameter and the factors influencing it is as follows:

$$H_\mu = f(L, \mathcal{J}, \upsilon, V, V_1, R, \rho, \rho_1, e, Q) \dots (1)$$

The following similarity criteria were obtained [7]:

$$\pi = \frac{H_\mu L^2}{QV};\ \pi_1 = \frac{\upsilon\mathcal{J}}{QV^2};\ \pi_2 = \frac{V_1}{V};\ \pi_3 = \frac{R\mathcal{J}^2}{QV};$$

$$\pi_4 = \frac{\rho L^2 V}{Q};\ \pi_5 = \frac{e}{L};\ \pi_6 = \frac{\rho}{\rho_1}$$

The physical meaning of the obtained similarity criteria is as follows:

$\pi = \frac{H_\mu L^2}{QV}$- quality criterion – dimensionless hardness of metal coatings obtained by surfacing under flux. This is a defined criterion that must be expressed through the defining similarity criteria. It is also an optimization parameter. The rest are technological similarity criteria.

$\pi_1 = \frac{\upsilon\mathcal{J}}{QV^2}$ defining criterion that takes into account the effect of current voltage on the hardness of coatings during surfacing.

$\pi_2 = \frac{V_1}{V}$- criteria that take into account the surfacing speed.

$\pi_3 = \frac{R\mathcal{J}^2}{QV}$- criterion characterizing the effect of current resistance during surfacing.

$\pi_4 = \frac{\rho L^2 V}{Q}$ criterion that takes into account the effect of the size of the restored part.

$\pi_5 = \frac{e}{L}$ - similarity criterion, taking into account the influence of electrode extension.

$\pi_6 = \frac{\rho}{\rho_1}$- criterion, taking into account the influence of flux density on the quality of the weld. The relationship between the defining and determining criteria of similarity can be represented by the following tic:

$$\pi = \varphi(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6) \dots (2)$$

$$\frac{H_\mu L^2}{QV} = \varphi\left(\frac{\upsilon\mathcal{J}}{QV^2}, \frac{V_1}{V}, \frac{R\mathcal{J}^2}{QV}, \frac{\rho L^2 V}{Q}, \frac{e}{L}, \frac{\rho}{\rho_1}\right) \dots (3)$$

The relationship between the defining and determining criteria of similarity can be represented by the following tic:

$$\pi = \varphi(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6) \dots (4)$$

$$\frac{H_\mu L^2}{QV} = \varphi\left(\frac{\upsilon\mathcal{J}}{QV^2}, \frac{V_1}{V}, \frac{R\mathcal{J}^2}{QV}, \frac{\rho L^2 V}{Q}, \frac{e}{L}, \frac{\rho}{\rho_1}\right) \dots (5)$$

The obtained general form of the criteria equation is the scientific basis for conducting pre-planned experiments to find optimal conditions and modes for restoring parts by submerged arc welding. For convenience of experiments, the last equation can be represented as follows:

$$\frac{H_\mu L^2}{Qv} = \varphi\left(\frac{\upsilon\mathcal{J}}{QV^2}, \frac{V_1}{V}, \frac{R\mathcal{J}^2}{QV}, \frac{\rho L^2 V}{Q}, \frac{\rho V e^2}{Q}, \frac{\rho_1}{\rho}\right) \dots (6)$$

After conducting scientific experiments and mathematical processing, an analytical form of the criteria equation was obtained [1 0]:

$$\frac{H_\mu L^2}{QV} = 8{,}2 \cdot 10^{10} \left(\frac{\upsilon\mathcal{J}}{QV^2}\right)^{0{,}24} \left(\frac{V_1}{V}\right)^{-0{,}12} \left(\frac{R\mathcal{J}}{Qv}\right)^{0{,}02} \left(\frac{\rho L^2 V}{Q}\right)^{0{,}14} \left(\frac{e}{L}\right)^{0{,}3} \left(\frac{\rho}{\rho_1}\right)^{0{,}08} \dots (7)$$

Checking the adequacy of the obtained mathematical model showed that the calculation error does not exceed 4%. After analyzing the obtained equation, optimal modes for restoring plowshares by automatic submerged arc welding were established. Current J =220 A Voltage – υ=25 V Electrode extension – e=12 mm Electrode feed rate V=0.03 m/sec Surfacing speed V_1=0.001 m/sec These modes corresponded to the microhardness of metal coatings H_μ=10000 MPa.

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Conclusion:

1. A standard installation for automating the process of restoring worn machine parts by submerged arc welding has been modified.
2. Non-deficient fluxes have been obtained based on the processing of manganese ores in the city of Chiatura.
3. The structure and composition of metal coatings obtained using new fluxes have been studied.
4. An automatic copying device for restoring plowshares by submerged arc welding has been developed.
5. Characteristic similarity criteria for submerged arc welding have been derived, their physical essence has been revealed, and optimal restoration modes have been established.

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