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ИССЛЕДОВАНИЕ ОСНОВНЫХ ПАРАМЕТРОВ ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА ЭЛЕКТРОКОНТАКТНОГО ПРИВАРИВАНИЯ ПРИ ВОССТАНОВЛЕНИИ ДЕТАЛЕЙ МАШИН

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ДОСЛІДЖЕННЯ ОСНОВНИХ ПАРАМЕТРІВ ТЕХНОЛОГІЧНОГО ПРОЦЕСУ ЕЛЕКТРОКОНТАКТНОГО ПРИВАРЮВАННЯ ПРИ ВІДНОВЛЕННІ ДЕТАЛЕЙ МАШИН

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RESEARCH OF THE MAIN PARAMETERS OF THE TECHNOLOGICAL PROCESS OF ELECTRIC CONTACT WELDING AT THE RESTORATION OF MACHINE PARTS

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Приведены результаты исследования условий работы деталей машин, выявлены причины снижения их ресурса, дан анализ методов восстановления их работоспособности. Предложен технологический процесс повышения их долговечности применением более эффективного метода восстановления электроконтактным привариванием. Определены значения основных параметров предложенной технологии.

Ключевые слова: *электроконтактная приварка, технологический процесс, абразивное изнашивание, прочность сцепления, свойства покрытия.*

Приведені результати досліджень умов роботи деталей машин, виявлені причини зниження їх ресурсу, поданий аналіз методів відновлення їх працездатності. Запропонований технологічний процес підвищення їх довговічності використанням більш ефективного методу відновлення електроконтактним приварюванням. Знайдені значення основних параметрів запропонованої технології.

Ключові слова: *електроконтактне приварювання, технологічний процес, абразивне зношування, міцність зчеплення, властивості покриття.*

1. Introduction

An important task facing agricultural production is the reliable operation of machines and units.

An essential role in this is given to the development and application of advanced technological processes that allow increasing the resource and reduce their cost by 40–50 % [1].

In this regard, the issues of research on the development and implementation of electric contact welding technology in restoring parts have acquired particular urgency.

One of the methods for increasing the wear resistance of worn parts, and therefore their resource, is the electric contact welding of the metal layer (tape, wire, powder materials) [2]. Despite the fact that this technology is used, but not all of its capabilities are used today to improve the quality of the restored parts of machines.

Restoration of parts by electric contact welding can produce a surface layer superior to the corresponding properties of the new part: strength, wear resistance, corrosion resistance.

Therefore, the study of the application of technological possibilities of the electric contact welding method is actual.

2. The object of research and its technological audit

The object of research is the working organs of agricultural machines operating in an abrasive medium.

The scheme of the coating process is shown in Fig. 1.

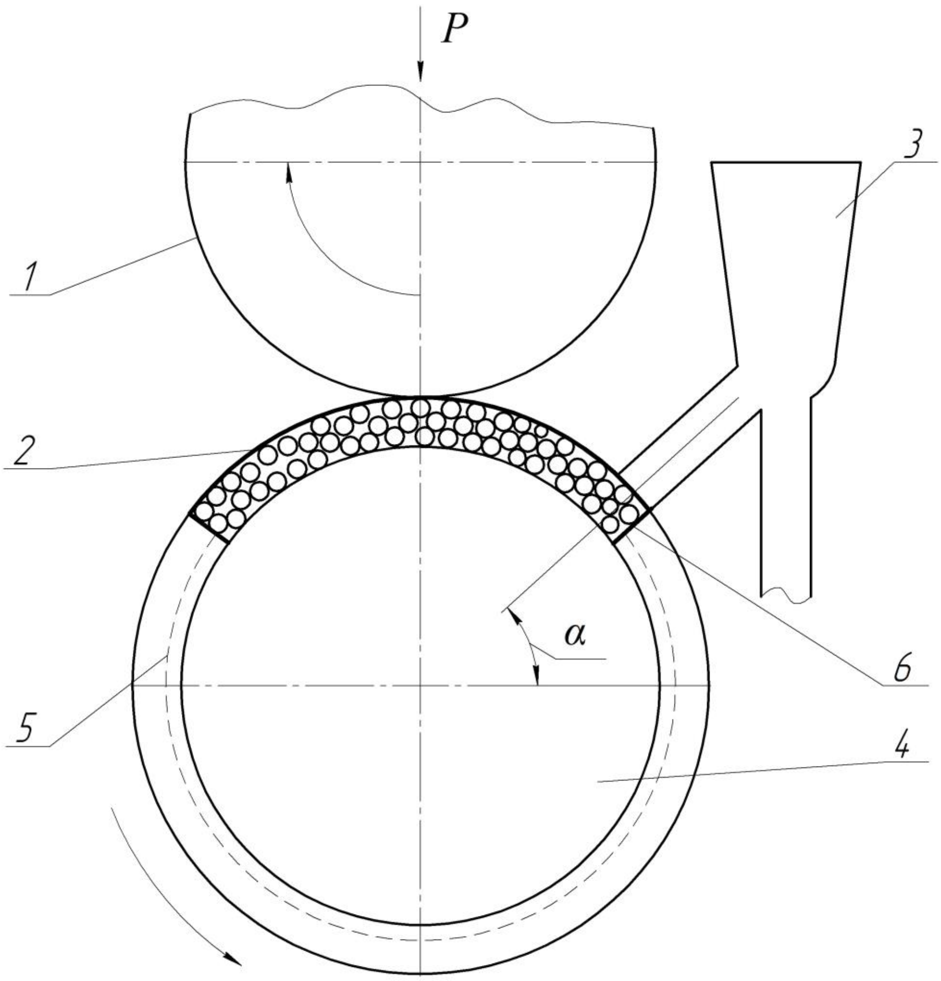

Fig. 1. Welding scheme for metal powder: 1 – roller-electrode;

2 – welded layer; 3 – bunker; 4 – part; 5 – mesh; 6 – powder

Before coating the surface of the machine part, a metal mesh is fixed. The powder is fed in front of the roller-electrode at a certain angle γ (the angle of the powder supply), which ensures the full filling of the mesh cells. When the restored part is rotated, the mesh cells transport the powder particles to the welding zone and keep them from extruding from beneath the electrodes.

In the present work, the scientific and technical issues of the creation of technological bases for restoring the details of agricultural machinery are considered, ensuring regulated reliability and saving material resources.

One of the ways to solve the national economic problem is the application of the technological process of electric contact welding of materials. Analysis of existing technological solutions aimed at strengthening the surfaces of parts, indicates the unused reserves of this process:

– use of steel tapes or steel mesh made of corrosion steels as a material to restore parts;

– wider use of metal powders as a filler material, improving the technology of their welding on worn surfaces of parts.

In addition, when restoring parts with electric contact welding, the problem of reducing the magnitude and nature of the friction can be solved, which will improve the wear resistance of the mating parts.

Optimization of ECW technological regimes will help to solve the problem of increasing labor productivity while saving raw materials and energy resources.

3. The aim and objectives of research

The aim of research is development of a technological process for the restoration of machine parts by the method of electric contact welding of materials.

To achieve this aim, it is necessary to solve the following tasks:

1. To analyze the operating conditions of these parts for the restoration of corrosion-resistant and wear-resistant materials by electric contact welding.

2. To investigate and determine the parameters of the mode of electric contact welding of wear-resistant materials, which allow to control the quality of the formed coating.

4. Research of existing solutions of the problem

One of the reasons for wearing parts of machines is friction. According to [3], there are three types of wear: mechanical, with jamming and corrosion-mechanical. For worn out parts of agricultural machines, the first type of wear is 42.8 %, the second 22.5 % and the third 35.7 %.

One of the subtypes of mechanical wear is wear with the participation of abrasive particles. Under the influence of an abrasive, various types of deformation of the surface of the material of the parts are possible: plastic and elastic deformation, the dyeing of the surface. The intensity of abrasive wear is affected by the nature of the abrasive particles, the aggressiveness of the medium, the physical and mechanical properties of the material of the parts, and other factors. Common to abrasive wear is the mechanical nature of the surface fracture, characteristic of the working organs of soil-cultivating machines.

The analysis of literature sources [4–6] demonstrates the importance of developing effective technologies for restoring the initial dimensions of the mating parts.

In the repair industry, there are some applications for surfacing and metallization methods of restoring parts [7]. It should be noted that these technological processes are characterized by considerable energy costs and have not received wide distribution in the repair industry.

The economic, resource and environmental effectiveness of methods for restoring worn parts depend on many factors, to which, first of all, the cost of materials should be attributed [8, 9].

From the standpoint of the technical rationality of recovery methods, the most preferable indicators are the normative overhaul resource, which should not be less than the resource of the new product.

An analysis of these methods of restoring worn parts shows that it is advisable to use the method of electric contact welding of materials for working organs operating in an abrasive medium.

The use of various materials in the restoration of worn surfaces of parts will improve the quality potential of this promising technological process.

Among the main ways to solve the problem, as a result of the analysis of literature data, it is possible to distinguish:

– reduction of the friction character in the construction of a friction pair and the creation of a bimetallic structure on the working surface [1–3];

– development of effective technological processes for the recovery of wear parameters of machine parts that provide high resource-saving indicators [4–6].

Creation of technological bases for the restoration of wear parts of agricultural machinery by electric contact welding of materials, ensuring optimal tribotechnical properties and increased reliability.

In particular, the paper [1] is devoted to the development of technological processes in the repair of machines and the restoration of aggregates and parts.

Some methods of strengthening parts and increasing their longevity are presented in [2, 3].

The author [4] shows the influence of the geometry of the working organs of tillage tools on the quality of soil cultivation.

In work [5] technologies of production of agricultural implements, which provide increased productivity, are given.

Issues of strengthening the structure of the metal in the process of foundry production are considered in [6].

Technological processes to improve the quality of the material during the rolling of cylindrical parts are described in [7].

The solution to the problem in [8] involves the use of electrodes with cores. It should be noted that the use of these electrodes significantly increases the cost of restored parts.

The authors [9] show the technological process of restoring bronze cylindrical parts using vibration oscillations of a working tool (punch).

The problems of restoration and strengthening of cutting elements of the working organs of tillage machines are considered in [10].

Thus, the results of the analysis allow to conclude that existing technological solutions, mainly aimed at hardening the surface, indicate that there are far unused reserves of the method of restoring machine parts by electric contact welding.

5. Methods of research

Based on the carried out analysis to improve the durability, reliability and wear resistance of machine parts, research directions have been determined. The structural scheme and sequence of the studies are shown in Fig. 2.

The samples of steel 45 and 65G were used as the base metal of the part. Steel samples were produced with a diameter of 25 mm from round bars. Welding of the coating on the samples and their machining was carried out using a specially made mandrel.

To implement the cutting of the coating, the side surfaces of the welded layer were cut to a width of 4...5 mm. Measurements were made by a sliding caliper ShTsTs-II (Ukraine) with a digital readout device with an accuracy of 0.01 mm (GOST 166-89).

To assess the mechanical properties of the base metal, the joint boundary and the welded layer, hardness and microhardness were measured on the investigated samples. The hardness was determined by the Vickers method on the TP-7-1device (Ukraine) at a load of 50 N at points uniformly in one plane perpendicular to the axis of the sample.

Microhardness was measured using PMT-3 microhardness tester (Ukraine) in accordance with GOST 9450-76. The load on the diamond pyramid during the measurement was 100 g (0.981 N).

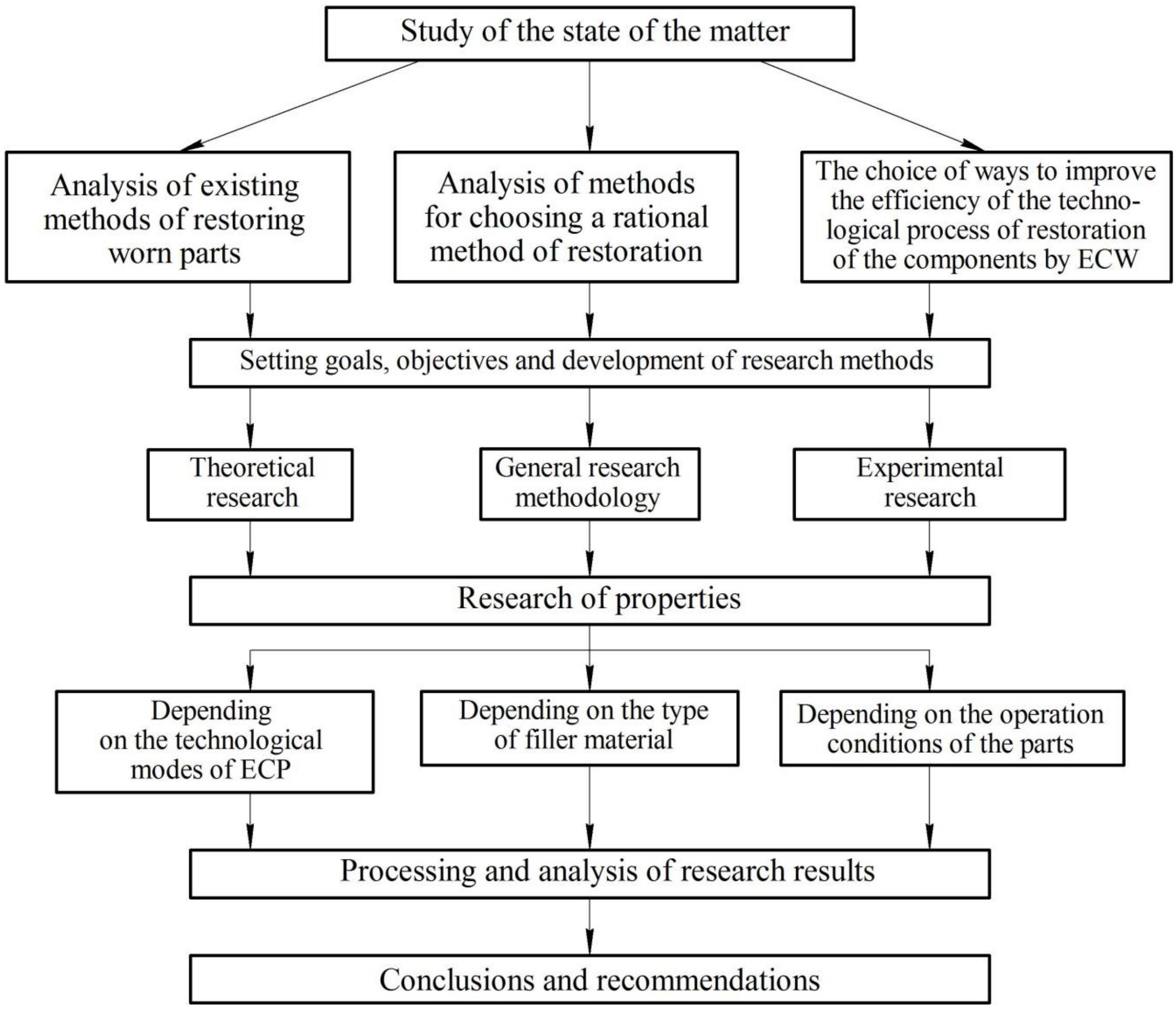

Рис. 2. Общая схема структуры исследования

The study of wear resistance was carried out in accordance with GOST 23.224-86 on a friction machine SMTs-2 (Ukraine).

The measurements were carried out with the indicator bracket SI-К (Ukraine) with a reading accuracy of 0.001 mm.

To determine the wear value of the mating surfaces, analytical scales ВЛ-200М (Ukraine) with an error of 0.0001 g was used

6. Research results

In abrasive wear, the surface of the material of the working element is destroyed as a result of the action of solid particles. Abrasive wear is the main factor limiting the resource of the working organs of tillage machines.

The performance of parts restored by electrocontact welding of a carbon steel filler tape is mainly determined by the quality of the welded tape with the surface of the restored part. With a low quality of the tape weldability with the base metal, low bond strength is observed. As a result, high hardness, strength and wear resistance of the coating can’t be realized.

It has been established that the quality of the tape adhesion to the base metal is determined by the following factors:

– value and time of the welding current passing;

– material of the part and tape;

– state of the surface of the part and tape, as well as their size.

The main of these factors are the magnitude of the current and the time it passes, which have a significant effect on the surface quality, which determines the amount of necessary allowance for subsequent machining (grinding). Table 1 shows the effect of the welding mode of a steel tape 0.5 mm thick on the size of the allowance for machining a workpiece with a diameter of 25 mm and the pressure on the rollers when processing 1.6...1.8 kN.

Table 1

The effect of welding modes on the allowance size

Welding current, A	Duration of the welding current, s	Machining allowance, mm	
		Steel grade of the tape	
		Steel 65G	Steel 45
7.0	0.9	0.18	0.20
8.0	0.9	0.30	0.32
10.0	0.9	0.32	0.34

The obtained data indicate that an increase in the current or time of its passage can lead to a loss of up to 64 % of the applied tape during machining.

From analysis of the processes occurring during friction, it follows that the wear rate of the friction surface depends on the physical and mechanical properties of materials: hardness, strength, brittleness, adhesion strength to the surface of the part.

Studies have established that for electrocontact welding to ensure the optimal quantitative composition of alloying elements in powder mixtures it is desirable to use powders of ferroalloys and alloyed steels that increase the wear resistance of the obtained coating.

The main parameters of the metal mesh, which is fixed on the surface of the workpiece, are the nominal dimension of the cell side *a* (mm) and the live section *S* (%), determined by the formula:

$$S = \frac{a^2}{(a+d)^2} \cdot 100\ \%.$$

The difference in the intensity of wear of mesh materials and powder, due to their physical and mechanical properties, creates the prerequisites for the formation of the surface relief. The resulting depressions on the working surface of the part retain the lubricant, which contributes to the increase of the wear resistance of the coating.

The use of a metal mesh in the electrocontact welding of powder materials creates theoretical prerequisites for improving the processability and operational properties of the coating. In this connection, there is a need for a theoretical justification of the technological parameters of the process.

To determine the value of the powder feeding angle γ, let's consider the scheme of forces acting on the powder particle (Fig. 3).

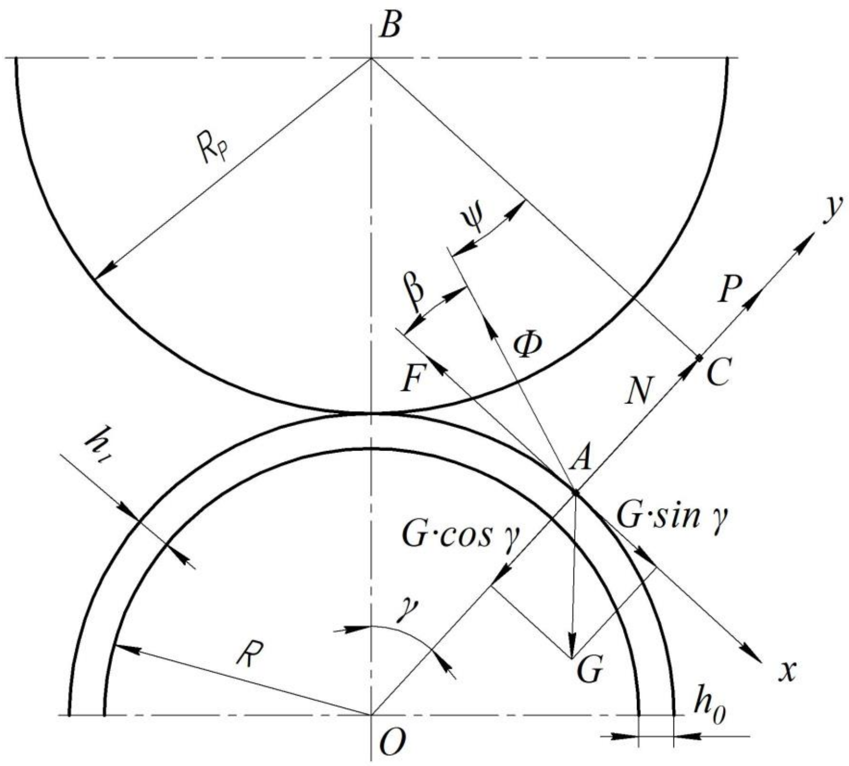

Fig. 3. Scheme of forces acting on a particle of a metal powder

The following forces act on the particle of the powder: gravity *G*, normal surface reaction *N*, frictional force *F*, centrifugal force *P* and force *Φ* due to the action of the magnetic field.

The condition for the equilibrium of these forces is the equality of the sums of their projections onto the movable axes of the coordinates *X* and *Y*, which can be written in the form of systems of equations:

$$G \cdot \sin\gamma - F - \Phi \cdot \cos\beta = 0,$$
$$N + P - G \cdot \cos\gamma + \Phi \cdot \sin\beta = 0. \quad (1)$$

Considering that:

$$P = m \cdot \omega^2 \cdot R;\ F = f \cdot N;\ G = m \cdot g,$$

obtain:

$$mg \cdot \sin\gamma - f \cdot N - \Phi \cdot \cos\beta = 0,$$
$$N + m\omega^2 R - mg \cdot \cos\gamma + \Phi \cdot \sin\beta = 0. \quad (2)$$

Taking into account the friction coefficient and friction angle φ, let's find the normal reaction N from equation (1):

$$N = \frac{mg \cdot \sin\gamma - \Phi \cdot \cos\varphi}{tg\varphi}. \tag{3}$$

Then it follows from equation (2):

$$\frac{mg \cdot \sin\gamma - \Phi \cdot \cos\varphi}{tg\varphi} + m \cdot \omega^2 R - mg \cdot \cos\gamma + \Phi \cdot \sin\beta = 0,$$
$$mg \cdot \sin\gamma - mg \cdot \cos\varphi \cdot tg\varphi + tg\varphi\left(m \cdot \omega^2 R + \Phi \cdot \sin\beta\right) - \Phi \cdot \cos\beta = 0,$$
$$mg\left(\sin\gamma \cdot \cos\varphi - \cos\gamma \cdot \sin\varphi\right) + \sin\varphi\left(m \cdot \omega^2 R + \Phi \cdot \sin\beta\right) - \Phi \cdot \cos\varphi \cdot \cos\varphi = 0.$$

So

$$\sin\left(\varphi - \gamma\right) = \frac{m \cdot \omega^2 R \cdot \sin\varphi + \Phi \cdot \sin\beta \cdot \sin\varphi - \Phi \cdot \cos\beta \cdot \cos\varphi}{mg},$$
$$\sin\left(\varphi - \gamma\right) = \frac{\omega^2 \cdot R \cdot \sin\varphi}{g} + \frac{\Phi}{mg} \cdot \left(\sin\beta \cdot \sin\varphi - \cos\beta \cdot \cos\varphi\right),$$
$$\sin\left(\varphi - \gamma\right) = \frac{\omega^2 \cdot R \cdot \sin\varphi}{g} + \frac{\Phi}{mg} \cdot \cos\left(\beta + \varphi\right).$$

From the obtained dependencies it follows:

$$\gamma = \varphi - \arcsin\left[\frac{\omega^2 \cdot R \cdot \sin\varphi}{g} - \frac{\Phi}{mg} \cdot \cos\left(\beta + \varphi\right)\right],$$
$$\gamma = \varphi + \arcsin\left[\frac{\Phi}{mg} \cdot \cos\left(\beta + \varphi\right) - \frac{\omega^2 \cdot R \cdot \sin\varphi}{g}\right].$$

Since the angular rotation speed of the part is insignificant in the case of electrocontact welding, it is possible to take:

$$\frac{\omega^2 \cdot R \cdot \sin\varphi}{g} = 0,$$

then

$$\gamma = \varphi + \arcsin\left[\frac{\Phi}{mg} \cdot \cos\left(\beta + \varphi\right)\right]. \tag{4}$$

From the scheme (Fig. 3) let's determine:

$$\sin\gamma = \frac{BC}{R+R_p-h_0+h_l},$$

so

$$BA = \frac{BC}{\cos\beta} = \frac{(R+R_p-h_0+h_l)\sin\gamma}{\cos\beta}.$$

Because $BA\cdot\sin\psi = R\cdot\sin\gamma$, so:

$$\frac{(R+R_p-h_0+h_l)\sin\gamma}{\cos\beta}\cdot\sin\psi = R\cdot\sin\gamma.$$

After conversion:

$$\beta = arctg\left[ctg\gamma - \frac{R}{(R+R_p-h_0+h_l)\sin\gamma}\right]. \quad (5)$$

Equation (5) connects the direction of the force Φ with the angle of powder supply and the geometric parameters of the technological process.

The thickness of the powder layer h_0 supplied by the rollers (Fig. 3) will be:

$$h_0 = h_m + h_{fr}, \quad (6)$$

where h_m – thickness of the metal mesh, mm;

h_{fr} – thickness of a layer of powder dragged by forces of internal friction, mm.

7. SWOT analysis of research results

Strengths. Experimental and theoretical studies of the technological process of restoring worn out parts of machines with electrocontact welding have made it possible to determine the optimal welding modes for the filler mesh to the material of the part being restored. The unequal intensity of wear of the metal mesh and the material of the part contributes to the formation on the renewable surface of the depressions that hold the lubricant, which contributes to an increase in the wear resistance of the coating.

Table 2 shows the prices of lancet cultivator paws with a capture width of 330 mm of Ukrainian and foreign manufacturers.

Table 2

The cost of lancet cultivator paws with a capture width of 330 mm of Ukrainian and foreign production

Manufacturer	Price, c. u.
«Veles Agro» (Odesa)	3.4
«Spetslesmash» (Lubny, Poltava region)	3.3
John Deer (USA)	8.6
Lemken (Germany)	9.4

The cost of one cultivator paw restored by electrocontact welding is 2.3 c. u, in 1.43...1.46 times less, the cost of new cultivator paws of Ukrainian production.

Weaknesses. It should be noted that the average installed power of electric motors (kW) in the plant for the restoration of cultivator paws is 1.43 times higher.

Opportunities. The obtained mathematical dependences of the main parameters of the technological process of electrocontact welding will be used in the continuation of the study of the problem of improving the quality of machine parts, both in production and restoration, in order to ensure their durability.

The economic effect from the introduction of the developed technology will be observed due to an increase in the wear resistance of the restored machine parts.

Threats. When implementing the developed technology for restoring worn out parts of machines in production, it will be necessary to purchase additional equipment.

8. Conclusions

1. Analysis of the operational durability of two sets (64 pieces) of lancet paws, new and restored by the method of electrocontact welding, is performed. This method provides a reduction in the wear rate of the paw blade by 1.65 times compared to the new paws.

2. Optimum modes of welding of a metal mesh on a worn out surface of a part are received: the value of a welding current 7A, duration of passage of a welding current 0.9 s. The established modes allow to receive coatings up to 1.5 mm thick and to increase the wear resistance of the restored parts by 1.45–2.1 times.

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The object of research is the process of restoring lancet cultivator paws by electrocontact welding of their working parts, the process connection with technological processing parameters and the physical and mechanical properties of their material.

One of the most problematic places in the method of electrocontact welding when restoring the working organs of tillage machines is the lack of optimal operating parameters of this technological process of strengthening the cutting elements of working organs working in the soil-aggressive environment.

Optimal parameters of electrocontact welding method of the metal mesh to the worn-out surface of the part make it possible to increase the strength of the material of the recovered parts, improve its physical and mechanical properties and increase their service life, and to reduce the magnitude and irregularity of wear.

Theoretical studies of the main parameters of the technological process are carried out using the equations of mechanics of deformed bodies with their own physical and mechanical properties.

In the course of the study, a steel mesh made of high-strength steel is used, and metal powders are used as a filler material, which strengthened the material of the component and increased its life.

Increased wear resistance of the restored parts is obtained. This is due to the fact that with this technological process, the formation of the surface relief takes place with the formation of depressions on it, which retain the lubricant, which ensures a higher coating resistance.

Due to this, it is possible to obtain a coating of parts with a thickness of up to 1.5 mm, an increase in their durability of 1.45–2.1 times and a decrease in wear intensity of 1.65 times compared to new cultivator paws.

Keywords: *electrocontact welding, technological process, abrasive wear, adhesion strength, coating properties.*