selecting the necessary gap between the blades of the screw working body for intensifying the process of mixing materials of different fractions, for which Ukrainian patents were obtained, as well as mixer conveyors with a rotating casing without forced rotation of the casing with the possibility of braking and with forced rotation of the casing with the possibility of changing the length of the mixing track and moving materials, for which applications for obtaining patents of Ukraine have been submitted. The developed structures can provide significantly higher productivity and efficiency of the technological process of mixing with screw conveyors-mixers, as well as have extended functional characteristics. A dependency was also developed, according to which the final selection of synthesized constructive solutions of GKZOK is carried out by maximizing the expected positive result, which takes into account the weight of such factors as the total cost, productivity, efficiency of the technological process of mixing and the number of functional characteristics.
structural-schematic synthesis, screw conveyor-mixer, rotary casing, mixing, morphological analysis, screw working body

Одержано (Received) 12.10.2023 *Прорецензовано (Reviewed) 24.10.2023*
Прийнято до друку (Approved) 30.10.2023

УДК 640.412 UDC 669.1:537.5 DOI: https://doi.org/10.32515/2664-262X.2023.8(39).1.95-104

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Increasing the wear resistance of the working bodies of soil processing machines by nitridation in the ignition discharge

The article considers the problem of increasing the wear resistance of the cutting elements of the working bodies of tillage machines by nitriding in a glow discharge.

Solving the problem of increasing the wear resistance of the cutting elements of the working bodies of soil tillage machines reduces the resistance to cutting when tilling the soil, which helps to reduce the traction force of the unit and, in the final version, save fuel.

Nitriding of the studied samples was carried out on the UATR-1 installation, designed for surface modification of parts, tools and equipment by the BATR method or similar diffusion vacuum processes.

It was established that the following main mutually competing processes occur during anhydrous nitriding in a glow discharge: formation of nitrides, diffusional saturation of the surface with nitrogen, and sputtering of the surface layer. The formation of nitrides occurs at low values of the specific energy flow, the surface sputtering process is activated at high voltage values, and the current density is responsible for nitrogen diffusion into the depth of the metal.

The structure and phase composition of nitrided layers is determined by a combination of regime and energy parameters. The ability to control the energy parameters of the armored personnel carrier allows you to significantly expand the area of obtaining nitrided layers with predetermined operational characteristics of parts of machines and equipment while simultaneously reducing the energy consumption of the nitriding process.

The research results showed that the amount of wear of a nitrided tool, compared to a non-nitrided one, decreased by 25-40%.
anhydrous nitriding in glow discharge (ANGD), cutting bodies of soil tillage machines (CBTM), operational and energy parameters of ANGD

Status of the issue and statement of the problem. The weak point of soil tillage machines is the wear resistance of the cutting elements of the working bodies, which has a decisive influence on the quality and efficiency of the technological processes of soil treatment, in the final version on the productivity of the process of growing products of the agro-industrial complex.

The reason for the loss of efficiency of the working bodies of tillage machines is the blunting (change of geometrical parameters) of the cutting elements.

The blunting of the cutting elements of the working bodies of soil tillage machines (ANGD) leads to an increase in fuel consumption due to an increase in the traction force of the unit and a deterioration in the quality of the execution of technological operations: a decrease in the depth of cultivation; reduction in the percentage of weed cutting; deterioration of the grinding of plant remains, etc. [1].

Therefore, special requirements are imposed on ANGD (ploughshares, cultivator paws, harrow discs) from the point of view of the brand of manufacturing material, heat treatment modes, method of surface strengthening, etc. The ANGD material should be wear-resistant, corrosion-resistant, strong and have high impact toughness, because the parts work in a corrosive-abrasive environment and are subjected to significant dynamic loads. Thus, when the plow body hits obstacles in the soil in the form of stones, soil compactions, the load on the plowshare increases by 10 or more times compared to its average value during normal plowing [2].

According to the data of many years of research and analysis of the results of operational tests of various types of ANGD, only in the first year of operation due to deformation with subsequent breakage, about 40% of plowshares, 15% of shelves, 20% of cultivator paws, and 30% of various types of disk cutters fail [2] . Some researchers hypothesize that the main reason for numerous failures is the low fatigue life of the materials from which ANGD parts are made [3]/

In work [3], a method of strengthening cultivator paws with metal-ceramic coatings of discrete-variable composition was developed. The operational tests of such paws have established that the durability of the paws strengthened by the developed technology is 1.45 times higher than that of serial ones, and it is guaranteed to work up to 32 hectares of soil.

To ensure the self-organization of the shape of the cutting elements during operation, the technology of strengthening the working organs with concentrated flows of laser radiation energy is proposed. It is shown that when applying the proposed technology, there is a reduction in manufacturing operations and an increase in the wear resistance and durability of parts, as well as the realization of the effect of self-sharpening of cutting elements of ANGD [4].

Today, to strengthen the wings of the cultivators' paws, the technology of hardening with high-frequency current (microwave) or deposition of powder, metal-ceramic coatings is used.

In agricultural engineering, 90% of all strengthening work is induction surfacing. The main disadvantage of this method is the high cost of surfacing alloys [5].

There are also known works on strengthening ANGD by anhydrous nitriding in a glow discharge (CBTM) [6, 7] and applying composite electrolytic coatings (CEC) [8], which made it possible to increase their wear resistance by 30-40%. At the same time, for most regions of Ukraine, one set of parts of working bodies of tillage machines is not enough for the current annual cycle (spring + autumn).

The purpose of the work is to study the influence of the CBTM on the wear resistance of structural steels for the manufacture of ANGD in the interaction of regime (temperature, composition of the saturation medium, pressure of the medium in the gas discharge chamber and saturation time) and energy (current density and voltage at the electrodes of the gas discharge chamber) parameters.

Research methodology. Nitriding of the studied samples was carried out on the UATR-1 installation, designed for surface modification of parts, tools and equipment by the CBTM method or similar diffusion vacuum processes.

A feature of this installation is the use of anhydrous gas mixtures (a mixture of nitrogen and argon) as a saturating medium in the process of nitriding, which excludes hydrogen embrittlement of the metal surface. The absence of hydrogen in the saturating medium, which is a good metal reducer and neutralizes oxygen, requires the use of particularly pure saturating gases (99.99%) and high tightness of the gas supply system and vacuum chamber.

A power supply unit from an independent source, as well as a switching and control unit for a cyclically switched discharge, have been added to the scheme. In addition, the installation is additionally equipped with heating elements placed in the gas discharge chamber, which made it possible to arbitrarily change the energy parameters - the voltage U and the value of the current density j (the ratio of the current to the total area of the cage and suspension) [9].

Experimental studies of samples for wear resistance were carried out on a universal machine for testing materials for friction, model 2168UMT. The friction scheme is "disc-finger"; contact type – plane-on-plane sliding (the end of the cylindrical sample slides on a flat metal disc; the material of the counterbody is steel SHX15 with a base hardness of HRC61; pressure in the contact zone p = 16 MPa; sliding speed v = 0.1 m/s [9].

The controlled parameter is linear wear h, which was determined as a change in the linear size of the sample, measured normal to the friction surface, as a result of passing a section of length l.

Research was conducted in two stages. At the first stage, they were performed on samples in order to optimize nitriding parameters to achieve optimal wear resistance characteristics of the modified surface layer. At the second stage, research was carried out on full-scale samples in field conditions.

For the study of the influence of CBTM, structural steels of the following brands were selected: 45-carbon high-quality, 40Cr, 9CrC, 9Cr18 - chrome and 38CrMUA - high-quality chrome-aluminum with molybdenum, as the most often used for nitriding in the glow discharge.

Based on the experience of experimental and production practice, the following parameters of the CBTM were adopted to optimize the number of experiments: temperature T=833K, nitriding time - 4 h, composition of the gas mixture 75% N2 + 25% Ar. An arbitrary voltage value was chosen, and the current density (j=I/S, where I is the current strength, A; S is the surface area of the cathode, which is equal to the sum of the areas of the suspension and the samples, m2) was determined by a combination of an arbitrarily set voltage and gas mixture pressure. We also found the specific power of the electric discharge in the gas discharge chamber W=UI/S, kW/m2. The values of the CBTM parameters are given in Table 1.

Metallographic studies of nitrided samples were performed after etching in a 3% alcoholic solution of nitric acid. The thickness of the nitride zone was measured on an RX50M microscope. Microhardness was determined on a DuraScan-20 microhardness tester under a load of 1.0 N, with fixation of microhardness values both on the surface and at a distance from it of 0; 25; 50; 100; 200; 300; 500 microns.

The thickness of the nitride zone was measured using a MIM-10 microscope, which allows quantitative analysis of the phase and structural composition of nitrided surfaces.

Table 1 – Battle Royale Modes with independent parameters

Regime	1*	2	3	4*	5	6	7*	8	9
Pressure *p*, *Pa*	53,2			106,4			159,6		
High-voltage*U*, *V*	1100	820	515	840	515	300	700	515	300
Current density *j*, *A/m²*	11,0	7,2	3,2	13,2	7,2	2,8	15,8	12,8	7,2
Specific power *W*, *kW /m²*	12,2	5,9	1,65	11,1	3,71	0,84	11,1	6,59	2,2

* Modes are performed with dependent nitriding parameters (without additional heating of samples)
Source: developed by the authors

X-ray phase analysis of nitrided samples was performed on a DRON-3 diffractometer in filtered radiation of an iron anode in the range of q angles from 20° to 100° with a scan step of 0.1° and an exposure time of 10 s. X-ray imaging was carried out from the surface to the depth of the nitrided layer.

Research results. The presented work is a continuation of the cycle of works in which the mechanisms of the processes of formation of nitrided surface layers of metals are considered in the interaction of mode (temperature, composition of the saturation medium, pressure of the medium in the gas discharge chamber and saturation time) and energy (current density, voltage and power at the electrodes of the gas discharge chamber) saturation parameters. Based on the obtained experimental data, it is planned to formulate provisions for the practical use of a fundamentally new technological process with optimization of the combination of its mode and autonomous saturation parameters. At the same time, the authors of the work rely on the developed fundamentally new energy model of the nitriding process in the glow discharge, the main feature of which is the provision of prioritizing those sub-processes in strengthening the surface layers of metals that are most appropriate in the specific conditions of operation of the parts [10].

For greater clarity, the set of technological processes carried out (Table 1) is represented by a diagram (Fig.1), where the numbers near the points correspond to the number of the corresponding mode, and the lines connecting them correspond to the same pressures of the gas mixture: p1=53.2 Pa , p2=106.4 Pa and p3=159.6 Pa. Points 1, 4, 7 correspond to modes conducted without an additional heating source, that is, with interdependent parameters of the CBTM (each pressure of the gas mixture corresponds to a certain combination of voltage and current at the electrodes of the gas discharge chamber).

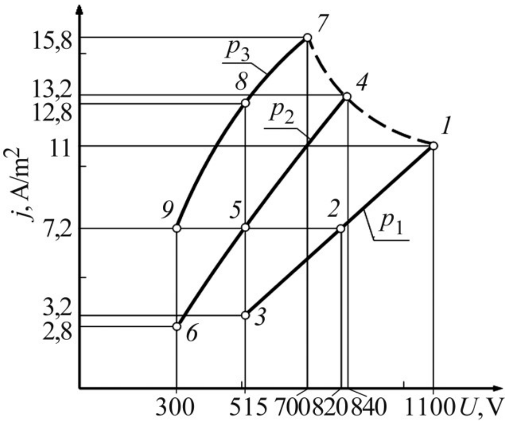


Figure 1 –The nature of changes in energy parameters U and j
Source: developed by the authors

The analysis of the obtained dependence shows (Fig.1) that with the increase in the pressure of the gas mixture p3 > p2 > p1 for the CBTM without additional heating, the current increases with a decrease in the voltage in the gas discharge chamber, and the specific power W is approximately the same 11.1...12.1 kW/ m2 and 9.3...10.4 kW/m^2 when changing the shape of the suspension (cathode surface area). The latter is achieved both by automatically changing the current density j and the voltage U (points 1*, 4*, 7* in Fig. 2).

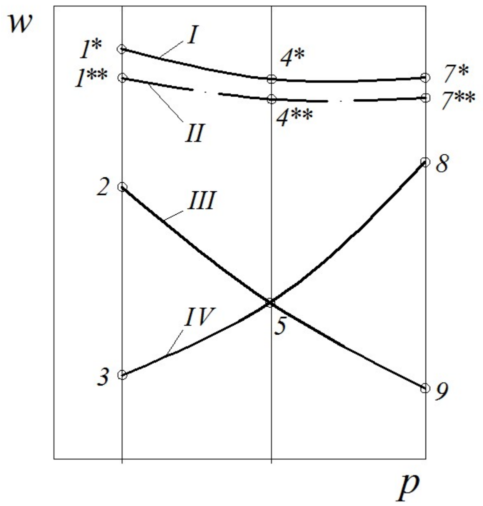


Figure 2 –Dependence of the specific power of the discharge W of the gas mixture impression: I, II – without additional heating; III, IV - with autonomous modes (with additional heating of the camera)
Source: developed by the authors

In the case of an armored personnel carrier with autonomous energy modes, significantly smaller values of j and U are required to maintain a glow discharge in the chamber, for example, points 9 and 7 at pressure p3 and points 6 and 4 and 3 and 1 at pressures p2 and p1, respectively. At the same time, at U=const (points 3, 5, 8), an increase in j is necessary to maintain the glow discharge, and at j=const (points 9, 5, 2), U increases. It should also be noted that at U=const, an increase in pressure leads to to an increase in j (points 3, 5, 8), and when j=const, on the contrary, an increase in pressure (points 2, 5, 9) leads to a decrease in U. It follows that the energy parameters are closely related to the pressure of the gas mixture. Therefore, in fig. 2 presents the dependence of the change in the specific power of the glow discharge W on the pressure of the gas mixture p. Curves I, II in Fig. 3 refer to the armored personnel carrier without chamber heating, but with two different suspensions, which indicates the importance of optimizing the suspension design (in option II - an additional series of experiments, energy losses are lower). We have completely different dependencies in the case of an armored personnel carrier with autonomous energy parameters (Fig. 2, curves III, IV). At the same time, when U=const with increasing pressure (points 3, 5, 8 in Fig. 2), W increases, and when j=const (points 2, 5 and 9 in Fig. 2), on the contrary, W decreases. Fig. 2 also shows that taking into account the energy parameters of the armored personnel carrier makes it possible to significantly reduce the energy consumption of the nitriding process.

The authors of the work [11] note that the pressure of the gas medium, which corresponds to the maximum specific power of the discharge, ensures obtaining the nitrided layer of the greatest thickness. In our experiments conducted on cylindrical samples, completely different results were obtained (Fig. 7, curves I and II). By the way, similar results were obtained in [12] on ellipsoidal samples, which ensured the absence of field concentrators. In any case, the question of the influence of the energy characteristics of the glow discharge on the physicochemical characteristics of the nitrided layer remains unresolved and requires further research.

The data presented in [12] indicate that with a decrease in the specific power of the electric discharge in the gas discharge chamber, the thickness of the h and hN layers also decreases. It is known [10] that the following main processes take place during CBTM: formation of nitrides, diffusional saturation of the surface layer with nitrogen, and sputtering of the surface. The energy levels of the main subprocesses differ significantly. Thus, the formation of nitrides occurs at low energies (modes 3, 6, and 9), and surface sputtering is activated at high voltage values. Thus, the structure and phase composition of nitrided layers is determined by a combination of technological and energetic processes of formation of the nitrided layer. For example, when the power of the energy flow is increased, the previously formed layer of nitrides is sprayed and the process of nitrogen diffusion into the depth of the surface is stimulated. In the case when the flow energy is insufficient to disperse the formed nitride layer hN, it acts as a barrier that prevents the process of diffusion into the inner layers of the metal (mode 9) or gives low indicators of the characteristics of the nitrided layers (modes 3 and 6).

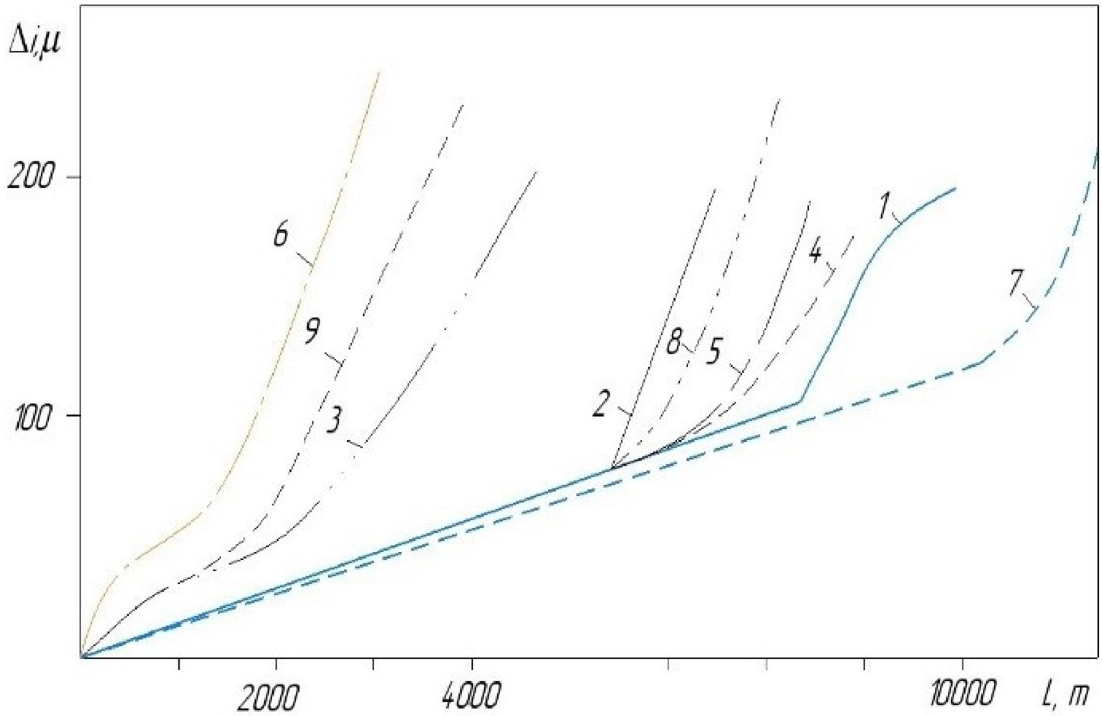


Figure 3 –Wear curves of steel 45 of reinforced armored personnel carriers
(the numbers on the curves correspond to the nitriding regimes in Table 1)

Source: developed by the authors

As a result of the experiments, it was found that under conditions of dry friction for surfaces modified with higher energy indicators, the intensity of wear (Fig. 3) decreases, and the time to the onset of catastrophic wear increases significantly. At the same time, with an increase in the content of alloying elements in steel, this pattern becomes more pronounced.

Analogous wear resistance curves were obtained for 40Cr and 38Cr2MUA steels.

The given data make it possible to draw a quite obvious conclusion that the influence of voltage and current density on the characteristics of the modified layer is not only significant, but decisive. Moreover, in the field of energy parameters of the regime, there is a certain limit below which carrying out the CBTM process loses its meaning in general, as it leads to unacceptable results, and this is despite the fact that the values of the regime characteristics remain constant. This means that traditionally fixed regime parameters (temperature, pressure, gas mixture composition and process duration) do not provide an unambiguous description of the CBTM process, and therefore cannot be the basis for predicting its results.

In the case of BATP, a nitride layer is formed on the metal surface, which is the ε-phase (Me2-3N) or -phase (Me4N) and a diffusion zone (zone of internal nitriding – nitrogenous α-solid solution (α+Me[N]) [12] . The nitride zone containing only the -phase is characterized by high plasticity, and the zone containing the ε-phase has significantly less plasticity, but higher corrosion resistance. The single-phase nitride zone increases the physical and mechanical properties of the nitrided surface in contrast to (ε+), which has increased fragility compared to the single-phase zone. However, in case of cavitation, erosion or at a high friction speed (VT=16 m/s), the two-phase zone (ε+) increases the stability characteristics of hardened steel surfaces in corrosive-active environments both due to increasing the corrosion resistance of the surface, as well as due to less adhesion of the friction surfaces.In general, the thinner the nitride zone, the more ductile the nitrided layer [13], but the lower the resistance to abrasive wear, especially in dry friction conditions.

Thus, according to [14], for parts operated in corrosive environments and for wear at negligible contact voltages, CBTM should be carried out at the maximum possible values of voltage and current density, which contributes to the formation of the ε-phase and, accordingly, we have high corrosion resistance, and also good running-in of friction surfaces. At the same time, in order to avoid the transition of the glowing discharge into an electric spark, the condition W<Wkr should be observed, i.e. The specific power of the glow discharge should not exceed the critical specific power of the electric arc discharge. A decrease in voltage and current density leads to an increase in the fraction of the -phase, which contributes to an increase in the strength of parts operating under conditions of corrosive-mechanical wear (CMR) in corrosive-active environments [9, 12].

Based on the analysis of previously conducted studies (Table 1 and Fig. 3), the CBTM was carried out according to the regime: the composition of the gas medium is 75% N2 + 25% Ar, the nitriding temperature is 833 K, the pressure in the discharge chamber is 159.6 Pa, the duration of the process saturation - 6 hours, voltage - 700 V, current density - 15.8 A/m2, specific power - 11.1 kW/m2. The hardness and surface microhardness of ANGD are shown in Table 2.

Table 2 –Hardness and microhardness of ANGD before and after hardening

№	Working body	Material	Hardness HRC/HV0,1	
			unmodified	modified
1	Disc harrow ("Chamomile" type)	9X18	50/450	40/800
2	Ploughshare	9XC	50/360	42/650
3	Chisel	9XC	50/440	38/650

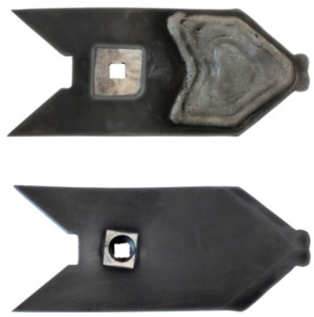
*Numerator before and denominator after CBTM

Source: developed by the authors

Based on the results of hardness measurements on the HRC scale and microhardness HV0.1, it can be concluded that the initial hardness (after quenching) decreased, and the surface hardness (after nitriding) increased. A decrease in total hardness will not have a significant effect on wear resistance, and an increase in surface microhardness will contribute to an increase in wear resistance.

Modification of the tillage tool involves certain stages, which are presented in the table. 3. Together with the modification tool, samples made from the materials of the corresponding tillage tools were subjected to modification.

Table 3– Stages of soil tillage tool modification

Output option	Prepared for modification	The instrument is modified
		
		
		

Source: developed by the authors

The wear resistance of the modified samples, in comparison with the unmodified ones, increased by an average of 1.5 times.

The wear resistance of real nitrogenized samples (the Chamomile-type harrow, ploughshare, and chisel) installed on work units together with non-nitrogenized ones was controlled by taking measurements of the dimensions of the elements in characteristic cross-sections during their wear according to the standard procedure. The research results showed that the amount of wear of a nitrided tool, compared to a non-nitrided one, decreased by 25–40%.

It is obvious that further research should take into account not only the materials of ANGD, but also the conditions of their operation.

Conclusions. 1.The following main mutually competing processes take place during CBTM: formation of nitrides, diffuse saturation of the surface with nitrogen and sputtering of the surface layer.

2. The formation of nitrides occurs at low values of the specific energy flow, the surface sputtering process is activated at high voltage values, and the current density is responsible for the diffusion of nitrogen into the depth of the metal.

3. The structure and phase composition of nitrided layers is determined by a combination of regime and energy parameters. The ability to control the energy parameters of the armored personnel carrier allows to significantly expand the area of obtaining nitrided layers with predetermined operational characteristics of machine and equipment parts while simultaneously reducing the energy consumption of the nitriding process.

4. Research results showed that the amount of wear of a nitrided tool, compared to a non-nitrided one, decreased by 25-40%.

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Підвищення зносостійкості робочих органів ґрунтообробних машин шляхом азотування в тліючому розряді

У статті розглядається проблема підвищення зносостійкості різальних елементів робочих органів ґрунтообробних машин азотуванням в тліючому розряді.

Вирішення проблеми підвищення зносостійкості різальних елементів робочих органів ґрунтообробних машин зменшує опір різанню при обробці ґрунту, що сприяє зменшенню тягового зусилля агрегату і в кінцевому варіанті економії пального.

Азотування досліджуваних зразків проводились на установці УАТР-1, призначеній для поверхневої модифікації деталей, інструменту та оснащення методом БАТР або аналогічних дифузійних вакуумних процесів.

Встановлено, що при безводневому азотуванні в тліючому розряді (БАТР) відбуваються такі основні взаємоконкуруючі процеси: утворення нітридів, дифузійне насичення поверхні азотом і розпорошення поверхневого шару. Утворення нітридів відбувається при низьких значеннях питомого енергетичного потоку, процес розпорошення поверхні активізується при високих значеннях напруги, а за дифузію азоту в глибину металу відповідає густина струму.

Структура і фазовий склад азотованих шарів визначається комбінацією режимних і енергетичних параметрів. Можливість керування енергетичними параметрами БАТР дозволяє значно розширити область отримання азотованих шарів із наперед заданими експлуатаційними характеристиками деталей машин і обладнання при одночасному зниженні енергоємності процесу азотування.

Результати досліджень показали що величина зношування азотованого інструменту, в порівнянні з не азотованим зменшилась на 25 – 40 %.

безводне азотування в тліючому розряді (БАТР), ріжучі органи ґрунтообробних машин (РГМ), робочі та енергетичні параметри БАТР

Одержано (Received) 02.10.2023 *Прорецензовано (Reviewed) 14.10.2023*
Прийнято до друку (Approved) 30.10.2023

УДК 631.356.22 DOI: https://doi.org/10.32515/2664-262X.2023.8(39).1.104-116

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Математична модель переміщення зрізаної гички коренеплодів цикорію в направляючому каналі

На основі аналізу технологічного процесу зрізування гички коренеплодів Г-подібними ножами роторного гичкоріза розроблено математичну модель, яка функціонально описує переміщення зрізаної гички в направляючому каналі гичкозрізувальної машини залежно від конструктивно-кінематичних параметрів робочих органів різального апарату.

На основі рішення математичної моделі отримано рівняння профілю поверхні кожуха направляючого каналу з умов рівних післяударних швидкостей і рівних швидкостей руху зрізаної гички.

Встановлено, що найбільш прийнятним є профіль, у якого кут зіткнення, або кута між напрямком вектора доударної швидкості та дотичною до профілю направляючого каналу в точці удару дорівнює 25 град., при цьому висота профілю направляючого каналу становить 1,2 м. За значення кута між напрямком вектора доударної швидкості та дотичною до профілю направляючого каналу в точці удару 30…35 град. початкова швидкість руху зрізаної частинки гички знаходиться у діапазоні 9,5…10,5 м/с, а на виході з вихідної горловини – 2,5…3,5 м/с, при цьому час переміщення гички по направляючому каналу становить 0,15…0,2 с.

коренеплоди цикорію, процес, зрізана гичка, модель, профіль, параметри