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THE RELEVANCE OF DEVELOPING A METHODOLOGY OF ASSESSMENT OF THE QUALITY INDICATORS OF WORKING PARTS OF TILLAGE MACHINES

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An analysis of the current state of use of tillage machinery working parts reveals that a wide variety of factors influence the wear process of the working part. Abrasive wear alters the cutting-edge parameters and geometry of the working parts, which is the primary cause of non-compliance with agricultural requirements, as well as significant energy costs and, consequently, economic losses. Furthermore, a plowshare has a limited lifespan, and while a wide variety of hardening and restoration technologies currently exist, a simple and reliable method for assessing the quality of plowshares, whether new or hardened or reconditioned, is lacking. This is the main factor hindering the development of methods for hardening and restoring soil-cutting parts. This study substantiates the need for an objective and simple method for assessing the quality of tillage machinery working parts based on an analysis of wear factors, regulatory requirements, and expert assessments. A set of indicators and criteria is proposed that allows for a quantitative assessment of plowshare quality and an accurate comparison of various hardening and restoration technologies. The methodology was

validated using comparative tests of plasma-hardened ploughshares. The results confirm the feasibility of the proposed approach for improving the operational reliability of tillage machines and enhancing the efficiency of agricultural machinery.

Key words: *methods of wear assessment, abrasive wear, wear resistance, strengthening, plasma hardening, ploughshare.*

ТОПЫРАҚ ӨНДЕУ МАШИНАЛАРЫНЫҢ ЖҰМЫС ОРГАНДАРЫ САПАСЫНЫҢ КӨРСЕТКІШТЕРІН БАҒАЛАУ ӘДІСТЕМЕСІН ӨЗІРЛЕУДІҢ ӨЗЕКТІЛІГІ

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Топырақ өңдеу машиналарының жұмыс бөлшектерін пайдаланудың қазіргі жағдайын талдау жұмыс бөлігінің тозу процесіне әртүрлі факторлар әсер ететінін көрсетеді. Абразивті тозу жұмыс бөліктерінің кесу жиектерінің параметрлері мен геометриясын өзгертеді, бұл ауылшаруашылық талаптарына сәйкес келмеудің, сондай-ақ айтарлықтай энергия шығындарының және соның салдарынан экономикалық шығындардың негізгі себебі болып табылады. Сонымен қатар, үлестің қызмет ету мерзімі шектеулі, және қазіргі уақытта үлесті қатайту және қалпына келтіру технологияларының кең ауқымы болғанымен, жаңа немесе қатайтылған немесе қалпына келтірілген үлестердің сапасын бағалаудың қарапайым және сенімді әдісі жетіспейді. Бұл топырақ кесетін бөлшектерді қатайту және қалпына келтіру әдістерін өзірлеуге кедергі келтіретін негізгі фактор. Бұл зерттеу тозу факторларын талдау, нормативтік талаптар және сараптамалық бағалау негізінде топырақ өңдеу машиналарының жұмыс бөлшектерінің сапасын бағалаудың объективті және қарапайым әдісінің қажеттілігін негіздейді. Бөлшек сапасын сандық бағалауға және әртүрлі қатайту және қалпына келтіру технологияларын дәл салыстыруға мүмкіндік беретін бірқатар көрсеткіштер мен критерийлер ұсынылады. Әдістеме плазмамен қатайтылған соқалардың салыстырмалы сынақтарын қолдану арқылы тексерілді. Нәтижелер топырақ өңдейтін машиналардың жұмыс сенімділігін арттыру және ауылшаруашылық техникасының тиімділігін арттыру үшін ұсынылған тәсілдің орындылығын растайды.

Түйінді сөздер: *тозуды бағалау әдістемесі, абразивті тозу, тозуға төзімділік, нығайтылған, плазмалық сәндіру, лемех соқасы.*

АКТУАЛЬНОСТЬ РАЗРАБОТКИ МЕТОДИКИ ОЦЕНКИ ПОКАЗАТЕЛЕЙ КАЧЕСТВА РАБОЧИХ ОРГАНОВ ПОЧВООБРАБАТЫВАЮЩИХ МАШИН

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Анализ современного состояния вопроса использования рабочих органов почвообрабатывающих машин показывает, что на процесс износа рабочего органа влияет большое многообразие факторов. В результате абразивного изнашивания меняются параметры режущей кромки и геометрия рабочих органов, это является основной причиной нарушения агротехнических требований, а также значительных энергетических затрат и в результате – экономических потерь. Вместе с тем лемех имеет лимитированный ресурс и сегодня существует большое разнообразие технологий упрочнения и восстановления лемехов, однако отсутствует простая и достоверная методика оценки показателей качества лемехов, как новых, так и упрочненных или восстановленных. Это является главным фактором, сдерживающим развитие методов упрочнения и восстановления почворежущих деталей. В исследовании обоснована актуальность разработки объективной и простой методики оценки качества рабочих органов почвообрабатывающих машин на основе анализа факторов износа, требований нормативной документации и результатов экспертных оценок. Предложен комплекс показателей и критериев, позволяющий количественно оценивать качество лемехов и проводить корректное сравнение различных технологий упрочнения и восстановления. Методика апробирована на примере сравнительных испытаний лемехов, упрочнённых плазменной закалкой. Полученные результаты подтверждают возможность практического приме-

нения предложенного подхода для повышения эксплуатационной надёжности почвообрабатывающих машин и повышения эффективности использования сельскохозяйственных машин.

Ключевые слова: методика оценки износа, абразивный износ, износостойкость, упрочнение, плазменная закалка, лемех плуга.

Introduction and relevance. Agriculture plays an important role in ensuring long-term sustainable development, economic stability and improving the standard of living of the population in Kazakhstan. The main development potential of Kazakhstan lies in the vast agricultural territories and natural resources. Agriculture is one of the most important sectors of our country's development. In this regard agricultural machinery which is used to perform all necessary tasks requires constant development and improvement. Technology, in turn, contributes to a significant increase in labor productivity.

According to the agrotechnical requirements for the cultivation of crops, the most important aspect happens to be soil treatment. This process creates favorable conditions for plants which is a decisive factor in yields. Tillage is performed by tillage machines; they perform the most energy-intensive operations.

The most energy-intensive operations in tillage are performed by soil processing machines. Nowadays there is a tendency to increase the area planted in the Republic of Kazakhstan. According to the Bureau of National Statistics for 2024, the area occupied by crops increased from 22 135.8 thousand hectares in 2019 to 24 016.9 thousand hectares in 2023 [1]. [1, p.113].

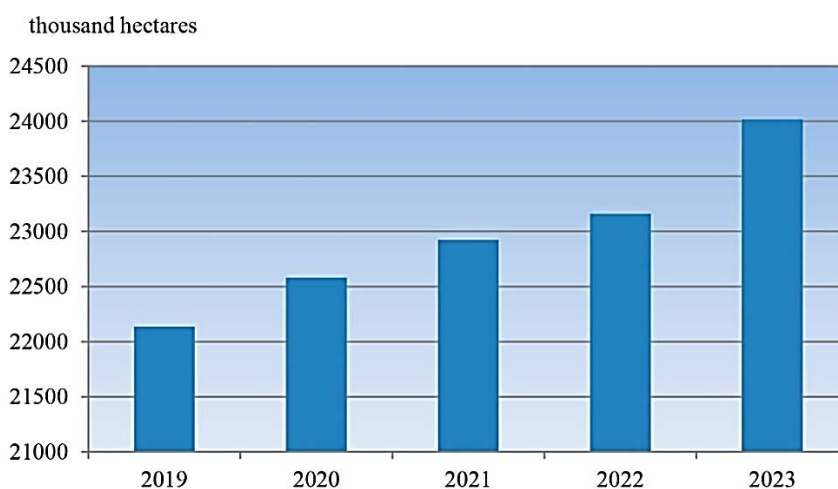


Figure 1 – Refined sowing area of major crops

The plough's function is to cut 20...35 cm thick soil layers by partially grinding them and feeding the soil to the plough body. According to the literature analysis, it can be seen that the average operation time rate of the plough share depending on the types of soils and their physical condition ranges from 5...10 hectares on sandy soils and 40... 60 hectares on black soil [2, p 23]. The key factor in this case is the diversity of soil types. The territory of our country is huge, but mostly we have sand, light loamy and light clay soil, among which brown, light and dark chestnut soils up to black soils are predominant [3, p 294], [4, p 112].

The working parts of agricultural machines are subjected to intensive abrasive wear during operation. One of these working tools is the plough sledge, so it should be wear-resistant, durable and have high impact strength. The analysis of the possible defects of the plough share has been conducted and presented in Figure 2. Some defects lead to the maximum state of wear, but are subject to recovery, except for splinters, bends and twisting. The condition of breakdowns, bends, and twists is critical and cannot be fixed.

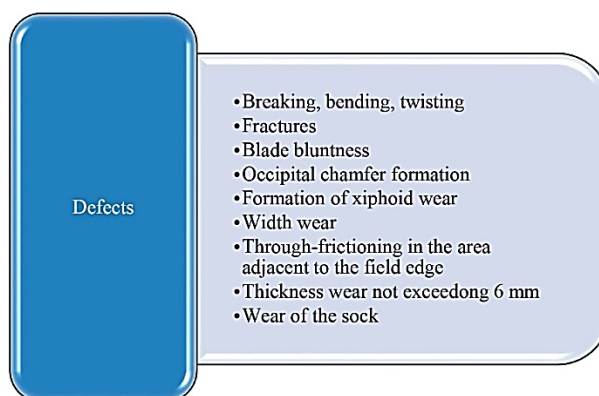


Figure 2 – Defects of the plough share

In the Republic of Kazakhstan, more than 300 thousand plough shares are operated which are made mainly of steels L65, L53, 65G and others [5, p 831], [6, p 160], [7, p 7], [8, p 92], [9, p 117]. According to the data, the loss of materials during the operation of agricultural aggregates is distributed as follows: moral wear accounts for 15%, breakdowns for another 15%, the remaining 70% are surface damage, 55% of which is wear 15% is corrosion.

Costs associated with abrasion elimination in our republic reach 50% of the cost of the new part [10, p 28]. Therefore, at the moment, strengthening agricultural machinery is quite an urgent task that requires scientific research [11, p 194, 12, p 164]. The main problem, however, is the lack of methodology for assessing the quality of work units, both new and those that have been restored or strengthened. In our opinion, it is the lack of a simple and reliable method of assessing the quality of the working bodies that is the main factor constraining the development of methods of strengthening and restoring soil-cutting parts.

Research objective. To substantiate the relevance and develop an objective and simple method for assessing the quality indicators of the working parts of tillage machines (ploughshares) to accurately compare new, hardened, and reconditioned parts using various restoration and hardening technologies.

Research tasks:

1. To analyze the factors influencing the wear and durability of the working parts of tillage machines under abrasive wear conditions.
2. To substantiate a system of indicators and criteria for assessing the quality of ploughshares, ensuring comparability of results using various restoration and hardening technologies.
3. To develop and test a method for comparatively assessing the quality of new and hardened ploughshares based on experimental and operational data.

Methods and results. We have conducted an expert survey «Cause-effect relationships of factors that influence the assessment of quality indicators (reliability) of a working body of a soil processing machine». The survey is a list of generalized factors that most strongly influence the stability of the plough share [13, p 44]. The experts included scientists, farm managers, chief engineers, heads of laboratories, etc.

The following factors were presented in the survey:

- Characteristics of a tractor driver.
- Working conditions.
- The material of the working body.
- The intensity of use and technology of field work performance.

As a result of processing the data of the expert survey, a graph depicting the weightiness of factors was obtained, which is demonstrated in Figure 3.

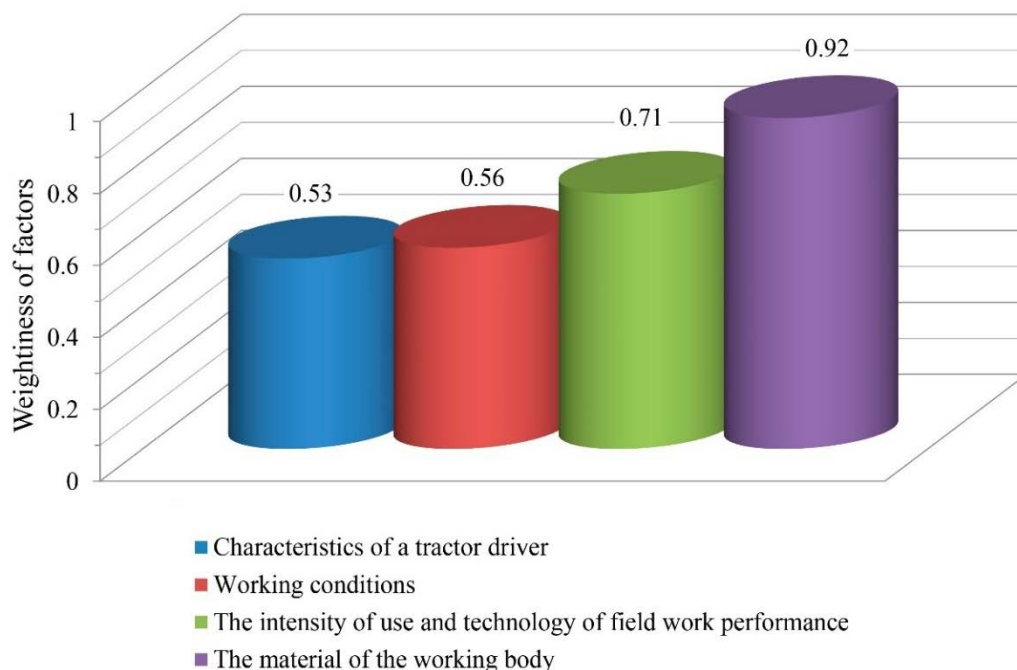


Figure 3 – Weightiness of factors after experts' assessment

The weighting factor is a quantitative characteristic of the significance of an indicator. The basic value of the product quality indicator is the value of the product quality indicator, taken as the basis for a comparative assessment of its quality. According to the results of the survey, the following factors were added that were not initially considered. These factors were revealed as a result of a survey of experts: 1. the quality of technologies and methods of making a ploughshare, 2. geometric parameters, type and shape of the

ploughshare, 3. Condition of tractor tools, 4. Storage conditions for spare ploughshares, 5. Wear and tear. Based on the results of the expert survey, an Ishikawa diagram of the cause-and-effect relationships of factors was compiled. The Fishbone diagram is one of the main tools for measuring, evaluating, controlling and improving the quality of production processes, which is shown in Figure 4 [14, p 60].

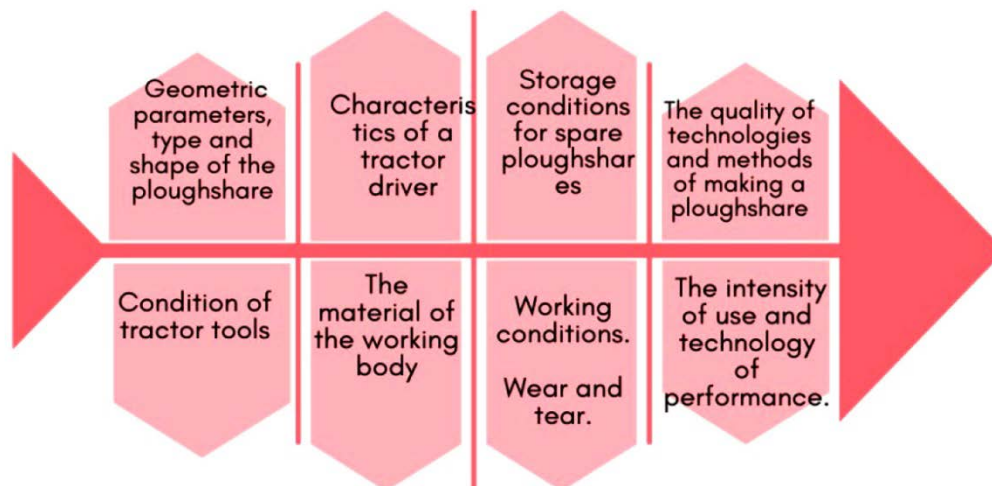


Figure 4 – Fishbone diagram for factors affecting the wear of a plough share

The hardness requirements for the ploughshare according to the standard ST RK STB 1388-2011 [15, p 5] in the hardened zone should be from 40.0 HRC to 54.0 HRC. The ploughshares must be made of 65G steel according to GOST 1577-93 [16, p 4] or of other materials that are not inferior in wear resistance and strength to 65G steel. In accordance with GOST 30480-97, wear resistance is the property of a metal to resist wear under certain friction conditions, estimated by the value of the reverse wear rate or wear intensity [17, p 4].

Wear resistance depends on the composition and structure of the material, the initial hardness, roughness and processing technology of a part. There is a wide variety of ways to strengthen the working bodies of tillage machines, such as welding, soldering, Sormite surfacing, plasma quenching, surfacing, galvanic processes, chemical-thermal processes, application of polymer materials, gasometric coatings, electromechanical processing and even acoustic ultrasonic hardening [18, p 186], [19, p 3], [20, p 75], [21, p 4], [22, p 5], [23, p 1674], [24, p 47], [25, p 583], [26, p 6], [27, p 856], [28, p 6].

The wear resistance of a metal is one of the most basic indicators of reliability, which depends on such properties as hardness, roughness, strength, surface pressure, interaction of contacting bodies, time and speed of interaction, etc. Strength is the ability of a metal to withstand the destructive force of the external environment. The hardness of metals is a quality that affects everything! From everyday objects to high-tech devices. From bridges to ploughshares. The hardness of metals plays an essential role in durability and functionality.

Hardness is the property of a metal to resist the introduction of another, more rigid body into it by a load [29, p 168].

Comparative tests of two surfaces treated with different hardening methods were carried out:

1. Sormite surfacing, U-653 welding machine [30, p 96].
2. Plasma hardening, UDGZ – 200 installations [31, p 51].

Table 1 – Comparative data on HRC hardness

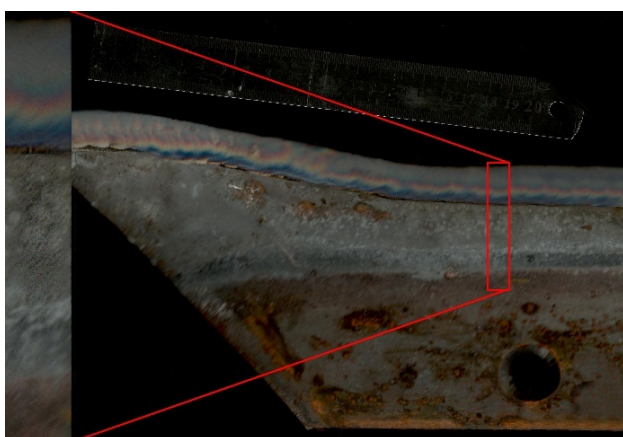
Hardening method	Coating hardness, HRC	Increase in durability compared to serial ploughshares, times
Sormite surfacing, U-653 welding	60...67	2
Plasma hardening, UDGZ– 200 installation	60...64	2

The presented hardening methods give identical proportional results. However, the advantage of plasma quenching is the economic efficiency justified by the lack of consumables for application. At the same time, the advantage of induction surfacing with Sormite alloys lies precisely in the consumption of materials, since surfacing can be used to restore the geometry of working bodies. That is, as a result, identical indicators are achieved, but at different costs. The evaluation and measurement of hardness indicators were carried out using ultrasonic and mechanical evaluation methods using UZET-3 [31, p 5] and TK-2M (ZEP) devices, shown in Figure 5 [33, p 4], [34, p 5].

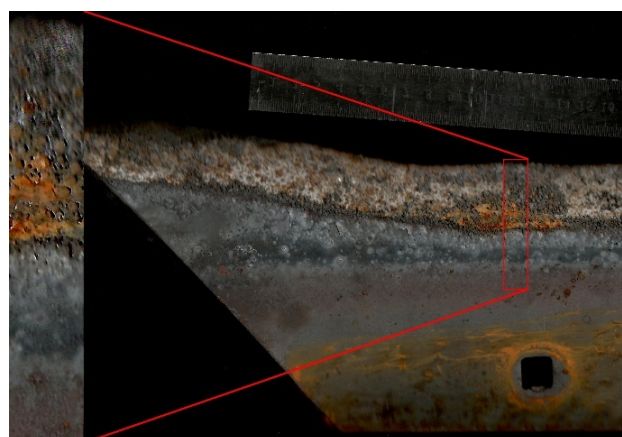


Figure 5 – The process of hardness evaluation

In the 60s, the Russian scientist Kragelskiy wrote that [35, p 54]. The smoother the surface, the lower the wear rate", so when treated with plasma hardening, the surface of the ploughshare remains almost unchanged and does not have such roughness as when treated with induction surfacing, shown in Figure 5.



a)



b)

Figure 6 – a) a ploughshare treated with plasma quenching.
b) a ploughshare treated with induction surfacing with Sormite alloys

However, in addition to plasma hardening, there are many methods for strengthening soil-cutting working parts; a comparative analysis of plasma hardening with other methods is presented in Table 2.

Table 2 – Comparison of plasma hardening technology with analogues

Indicator	Plasma hardening	Sormite (surfacing)	High-frequency hardening	Ceramic coating
Saving the geometry of the part	+	-	fractionally	-
Increase in service life, in comparison with the nominal non-hardened part, times	2-3	1,5-2	1,5-2	2-2,5
Cost price per 1 ploughshare, tenge	300	10 000 – 15 000	4 000 – 5 000	8 000-16 000
Operating restrictions	None	Increased soil resistance, increased fuel consumption, violation of agricultural requirements	Limitation on the shape of the part, fragility, residual stresses	Insufficient adhesion and high brittleness of the coating

We also plan to test ploughshares hardened by other methods to validate the methodology, but for further research at this stage, we have settled on the most promising and cost-effective hardening method – plasma hardening. We also conducted a field experiment to initially validate the methodology. Comparative testing of two sets of ploughshares (16 ploughshares, 2 plows) revealed that the average weight loss for plasma-hardened ploughshares was 700 grams, while for standard ploughshares (ploughshares manufactured by the Russian company Almaz without additional treatment) it was 990 grams per 300 hectares. To ensure the integrity of the experiment and the reliability of the wear assessment methodology, ploughshares were installed on the units in a staggered pattern, alternating between plasma-hardened and standard ploughshares. Figure 7 shows a general view of the installed ploughshare and the assembled unit (8-body mounted plough PLN-8-35).



Figure 7 – Mounted plow PLN-8-35 and general view of the installed share

Plasma-hardened shares demonstrated lower weight loss during operation over a 300-hectare area compared to standard shares made of grade 65G steel. Their wear resistance was 2.36 g/ha, significantly lower than that of the reference share (4.3 g/ha), confirming the effectiveness of plasma hardening.

Conclusions. There is a wide variety of ways to harden and restore the surfaces of soil-cutting machines. At the same time, plasma quenching and induction surfacing with Sormite alloys are the most widespread and promising. At the same time, plasma treatment benefits from its cost-effectiveness and simplicity of the technological process in comparison with induction surfacing with Sormite alloys. Toxic, flammable and explosive substances are not used in this treatment, which creates environmental safety and safety during use. As a result of the expert survey, factors that had not been considered before were identified: the quality of technologies and methods of manufacturing the ploughshare, geometric parameters, types and shapes of the ploughshare, the condition of tractor tools, storage conditions of spare ploughshares, wear. As a result, today there is a wide variety of defects and types of wear of soil-cutting parts as well as a wide variety of hardening technologies and a wide range of alloys that are used in the manufacture of soil-cutting machines. All this variety of factors affecting the process of wear of working bodies of tillage machines significantly complicates the process of creating a methodology for assessing the quality of working bodies. The lack of a

simple and reliable methodology for determining the wear rate and life of ploughshares itself constrains the development and justification of the use of new materials and technologies for strengthening working bodies in order to increase their durability.

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