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TRIBOLOGICAL AND CORROSION PROPERTIES OF 45 AND 65G STEELS USED IN AGRICULTURAL MACHINERY AFTER ELECTROLYTIC-PLASMA HARDENING

Annotation: *The article examines the effect of electrolytic plasma hardening on the wear resistance and corrosion resistance of steels 45 and 65G, which are used in the production of agricultural machinery components. The presented results demonstrate the improvement of the surface properties of steel through the application of electrolytic plasma hardening. This technology provides rapid heating and cooling, which contributes to the formation of a fine-grained and hardened surface layer, as evidenced by microstructural studies conducted using an optical metallographic microscope. Tribological tests showed an improvement in wear resistance after electrolytic plasma hardening: the wear volume for steel 45 was* $3{,}03\times10^{-4}$ *mm³, and for steel 65G it was* $6{,}17\times10^{-5}$ *mm³, which is 7 and 4,5 times less than the wear volume for the initial samples, respectively. The analysis of polarization curves showed that the corrosion current density decreased compared to the initial sample. For steel samples 45 and 65G after three cycles of electrolytic plasma hardening, the corrosion current densities were 6,87×10^-6 A/cm² and 1,61×10^-7 A/cm², respectively. Additionally, a shift in the corrosion potential towards more positive values was noted, indicating an increase in corrosion resistance. The results of the study demonstrate significant improvements in the tribological and corrosion properties of steels 45 and 65G after electrolytic plasma hardening, providing valuable data for industrial applications.*

Key words: *Electrolytic plasma hardening, quenching, steel 45, steel 65G, wear resistance, corrosion resistance, tribology, microstructure.*

Introduction

The working parts of soil cultivation machines undergo significant mechanical and corrosion wear, depending on the operating mode and the type of soil processed, which ultimately leads to considerable financial and material costs. The wear intensity of these working parts is determined by the soil type and depends on its composition of abrasive particles, density, moisture, processing speed, as well as the geometric shape of the working parts and the properties of the materials from which they are made. The soil's ability to cause wear on parts of soil cultivation machines is a primary reason for reducing the operational lifespan of these parts and the machines overall. Global expenditures on corrosion alone amount to approximately 2.5 trillion dollars, equivalent to 3.4% of the gross national product. However, effective methods to enhance corrosion resistance, such as improving the corrosion resistance of part surfaces and timely maintenance, can reduce these costs by 15-35%, amounting to 875 billion dollars annually [1-5].

Working parts for soil processing tools, operated under challenging conditions like deep loosening, continuous plowing of soils with high stone content, etc., are manufactured by modern producers using thick plate rolling of carbon and low-alloy steels with medium and high carbon content, such as grades 45, 70, 65G, 55C2. Most of these undergo preliminary surface or through hardening. Thanks to acceptable qualities such as high impact toughness and elasticity, as well as ease of processing, steels of grades 45 and 65G have gained widespread use in various industrial sectors.

Various methods of surface modification and engineering are used to ensure the necessary level of wear resistance during the manufacture and repair of agricultural machinery parts, differing in technology and the degree of improvement of individual physical, mechanical, and operational characteristics of surface layers [6-9].

The method of electrolytic deposition for working parts of agricultural machinery, including those based on iron, is attractive due to its low energy consumption and has gained widespread use and application in the restoration and hardening of worn parts. This method also has other advantages, including the ability to regulate physical and mechanical properties by changing electrolysis modes, small allowances for subsequent mechanical processing, no warping of parts, lower raw material consumption, and simple operation. However, iron and its alloy coatings obtained through the electrolytic method have a thin thickness, insufficient adhesion, increased electrolyte temperatures, and low wear resistance [10].

To enhance wear resistance and thereby extend the service life, most working parts are hardened by overlaying with hard alloy materials. This can involve the use of high-alloy cast irons such as PG-S27, PG-US25, PG-FBX-6-2, PR-FMI, PS-14-60. Despite good technological indicators after this hardening, the method itself has a number of disadvantages, including the need to overheat the base metal (steel), leading to an increase in the grains of the microstructure, and in some cases, due to magnetic properties, it is impossible to obtain a layer thicker than 1,6 mm. Moreover, the technology requires expensive equipment and its operation is energy-intensive [11-12].

Electrolytic-plasma hardening (EPH) represents an advanced method for improving the properties of steels, which are widely used in the production of working parts for soil cultivation machinery. This method significantly enhances the wear resistance and corrosion resistance of the material through optimal selection of electrolyte composition and precise adjustment of electrical processing parameters. The EPH process involves exposing the metal to concentrated energy flows in an electrolytic environment, leading to rapid heating and cooling. This promotes the formation of a hardened surface layer with a fine-grained structure, improving the physical and mechanical properties of the steel. It is important to note that the quality and characteristics of the resulting layer largely depend on the composition of the electrolyte, which can include various salts and additives to achieve desired properties.

Research shows that EPH increases the microhardness of steel, enhancing its resistance to wear and corrosion, which is particularly relevant for components operated in aggressive conditions such as agricultural equipment [13-16]. The use of EPH in the agricultural sector could solve the problem of rapid wear of machine working parts subjected to intense abrasive wear. Considering the environmental safety and the possibility of regenerating used electrolytes, this method also contributes to reducing the negative impact of technological processes on the environment.

It is known that the hardening of steels by changing the microstructure also changes the corrosion resistance of steels, which is an integral part of steel quenching, including during EPH. The change in the microstructure of steels 45 and 65G during thermal hardening involves phase transitions of austenite (α-phase) to martensite (γ-phase) and back ($\alpha \rightarrow \gamma$). This leads to a rearrangement of the crystalline lattice, where iron and carbon atoms redistribute. Properties such as high wear resistance, microhardness, and improved corrosion resistance make steel structures containing martensite desirable for many industrial applications. Numerous studies dedicated to the properties of hardened steels with a martensitic structure, including various technologies, emphasize the improvement of mechanical and corrosion characteristics.

Researchers D.I. Pantelis and others studied the influence of laser hardening on the corrosion resistance of CK60 steel using a CO-laser. The corrosion behavior of samples before and after hardening was assessed in a 3,5% NaCl solution by potentiodynamic polarization. It was found that samples with overlap coefficients of 0 and 9% demonstrated passivation at potentials from – 850 to – 550 mV and – 700 to – 500 mV, respectively, showing increased corrosion resistance compared to untreated samples and those with higher overlap coefficients. This behavior is associated with microstructural changes in the steel during laser processing, where higher overlap coefficients promote the formation of tempered martensite, unlike samples with lower coefficients [17].

In the work of A. Nasery and others, it is mentioned that the dissolution of carbides in the matrix, leading to a more uniform microstructure, is an important factor in reduction [18]. The work by authors Firas M. F. Al-Quran and others also confirms that annealing low-carbon steel after hardening, which results in a martensitic microstructure, improves the steel's corrosion resistance [19].

The positive influence of EPH on the tribological properties of 20GTL steel is dedicated to the work of Rakhadilov B. and others. In the course of the experiment, samples measuring 10×20×20 mm^3 were treated in an electrolyte with a 20% concentration of sodium carbonate. At a voltage of 320 V between the anode and cathode, an improvement in wear resistance was noted: the wear volume of samples before EPH was 0.076 mm^3, and after processing for 2 and 3 seconds it decreased to 0.065 mm^3 and 0.056 mm^3, respectively. The authors also indicate an increase in ferrite grains and, conversely, a decrease in perlite grains in the microstructure of the surface of samples after EPH for 2 seconds compared to the original sample. After 3 seconds of EPH processing, the steel structure predominantly contains needle-shaped martensite grains [20].

In the study by Toktarbaev G. and co-authors, the impact of electrolytic plasma hardening on 40KhN steel using electrolytes of various compositions was investigated. After EPH, a hardened layer with high wear resistance was obtained. It was also found that high surface hardness values were achieved using electrolytes containing 15% and 20% urea and 10% sodium carbonate. With these electrolyte contents, the best wear resistance values were also obtained in the "ball-on-disc" test method. Analysis of the microstructure of the cross-section of 40KhN steel after EPH showed the formation of 3 zones: a hardened zone, a thermal impact zone, and the base matrix of the sample. The microstructure profile changed from the hardened zone with a high martensite content to the matrix with a ferrite-pearlite structure [21].

In a recent study on the effect of EPH on the tribological properties of 65G steel, as presented in [22], a 15% sodium carbonate aqueous electrolyte solution was used. The heating of the samples was performed using four different methods, alternating between high, medium, and low voltage, along with the application of thermal cycling. The phase composition analysis revealed the formation of α'-iron phase and carbide compounds. The tribological test results showed a twofold increase in wear resistance and a 1,7-fold increase in resistance to abrasive wear.

Thus, EPH is a promising technology that can revolutionize steel processing methods, enhancing their operational characteristics and reducing the costs of manufacturing and maintaining agricultural equipment. Further research on wear and corrosion resistance is necessary to optimize processes and fully harness the potential of this technology.

The aim of this article is to systematically investigate the impact of EPH on the structure, tribological properties, and corrosion resistance of steels grades 45 and 65G. Thus, this study contributes to a deeper understanding of the mechanisms underlying this process, as well as to assess its effectiveness and applicability for improving the properties of soil-cultivating parts of agricultural equipment.

Materials and Methods

To conduct the EPU, samples of steels 45 and 65G measuring 15x15x20 mm were prepared. The surfaces of the samples were cleaned of contaminants and oxides manually using sandpaper with gradually increasing grit from P60 to P2500. The samples were polished to achieve a smooth and even surface using GOI polishing paste, which is a polishing compound based on hard abrasive chromium oxide (III) powder. The surfaces of the samples were also treated until they were uniform and free of visible defects, and no scratches should be visible under x100 magnification with an optical microscope. The chemical composition of steels grades 45 and 65G is shown in Figure 1.

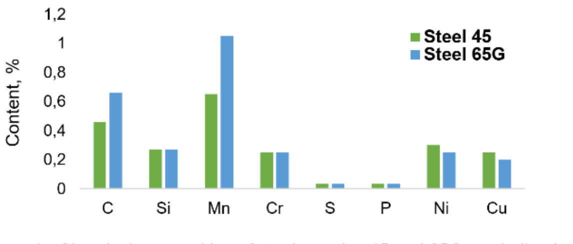

Figure 1 - Chemical composition of steels grades 45 and 65G, excluding iron

The chemical composition significantly influences the EPH process for steels grades 45 and 65G. Steel 45 contains a low amount of carbon, while steel 65G has a higher carbon content. The high carbon content in steel 65G contributes to the formation of harder and more brittle phases after thermal treatment at lower temperatures (carbon promotes the formation of carbon-rich phases, such as martensite), which can affect the mechanical properties [23]. Also, steel 65G features improved hardenability, which facilitates the quenching process. This indicator depends on the minimum cooling rate necessary to prevent the decomposition of austenite into a ferrite-carbide mixture, influenced by the alloy composition.

EPH, as mentioned above, is based on the use of electrolytic plasma for thermal treatment of the material's surface, followed by rapid cooling in the electrolyte medium, improving its hardness, wear resistance, and other characteristics. EPH was conducted in cathodic mode on a setup that includes a 50 kW constant current power source, an electrolytic bath, a pump, and a conical stainless steel anode. The cathode is the test sample made of steels grades 45 and 65G. The anode, made from a hollow stainless cone without a base, receives electrolyte, which overflows into the electrolytic bath. The sample is submerged in the electrolyte on the surface of the cone. Circulation of the electrolyte is ensured by an electric pump, and the flow rate of the electrolyte to the cone-anode is regulated by adjusting the proportion of flow into the anode-cone and the return feed into the electrolytic bath. Voltage from the power supply is applied between the anode and cathode, creating conditions for the hardening process.

Samples of steels grades 45 and 65G are submerged in the electrolyte in the cavity of the anode to a depth of 2-3 mm, and the application of constant current causes plasma formation on the surface of the samples, initiating the heating process to the austenitization temperature. After the electric current is switched off, the sample cools with the circulating electrolyte solution, resulting in the quenching of the steel. The plasma impact and subsequent cooling of the material surface by the electrolyte lead to changes in its structure, improving mechanical properties. During the EPH process, it is important to control parameters such as processing time, electrolyte temperature, and voltage to ensure optimal material hardening conditions. The appearance of the setup for conducting the EPH process is shown in Figure 2.

Figure 2 – External view of the EPH setup

Electrolytic plasma hardening of steel samples was conducted at the Engineering Center «Hardening Technologies and Coatings», Shakarim University of Semey, Kazakhstan.

Tribological tests were performed using an Anton Paar TRB3 tribometer with a «ball-on-disc» scheme. The test parameters included a wear radius of 3 mm, a friction path of 60 mm, a sample rotation speed of 2 cm/s, and a load of 6 N. A 6 mm diameter ball made of 100Cr6 material was used as the counterpart.

The wear volume of the steels before and after EPH was measured using a HY2300 profilometer. This device is equipped with a diamond probe, allowing for high measurement accuracy with a resolution up to 0,001 μm.

The corrosion resistance testing of the samples was conducted at a temperature of ±25°C using a potentiodynamic method on a CS300M potentiostat/galvanostat with a 3% NaCl solution. A protective coating was applied to the analyzed area. It is crucial that the tested samples have identical analysis areas, ensuring consistent comparison of the results obtained during potentiodynamic studies. In one cell, the reference electrode with a constant potential is a silver chloride electrode, while in the second cell, the auxiliary electrode is a platinum electrode, and the working electrode is the test samples of 45 and 65G steel with a surface area of 1 cm² (figure 3). The cells are connected by a salt bridge, sealed on both sides with filter paper to prevent mixing of the NaCl-filled solutions. Before conducting the tests, the test samples undergo preliminary preparation, which includes cleaning and degreasing using ethanol. The CS Studio6 software is used to determine the potential values, current density, corrosion rate, and Tafel slopes (ba, bc). The graphs obtained during the analysis are presented in logarithmic form (current density is logarithmic).

Optical images were obtained using a trinocular inverted metallographic microscope HL-102AW with a 3.0 MP digital camera and analysis software. This type of microscope has specific technical characteristics and capabilities that allow for more detailed and precise observations of the structure of metallic samples.

Experimental studies on the EPH of samples from steels grades 45 and 65G were conducted using a thermocyclic regime, which involves alternating high (U_H) and low voltages (U_L). This method allows for control of the heating process, avoiding the melting of the steel and ensuring the formation of a hardened layer with greater depth. The electrolyte for EPH consisted of 20% sodium carbonate and 80% distilled water. The anode area was 0,05 m², and the electrolyte flow rate was 100 liters per minute. Details of the EPH regime parameters are detailed in Table 1.

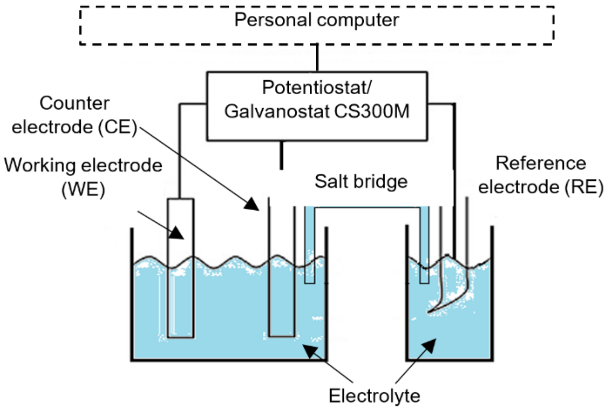

Figure 3 – Wiring diagram of the three-electrode electrochemical cell and potentiostat/galvanostat

Table 1 – Parameters of EPH modes for steels 45 and 65G

Sample	U_{H1}, V	t_{H1}, s	I_{H1}, A	U_{L1}, V	t_{L1}, s	U_{H2}, V	t_{H2}, s	I_{H2}, A	U_{L2}, V	t_{L2}, s	U_{H3}, V	t_{H3}, s	I_{H3}, A
Steel 45													
45_1	320	3	100	0	0	0	0	0	0	0	0	0	0
45_2	320	3	100	50	5	200	2	75	0	0	0	0	0
45_3	320	3	100	50	5	200	2	75	50	5	200	2	75
Steel 65G													
65G_1	320	3	100	0	0	0	0	0	0	0	0	0	0
65G_2	320	3	100	50	5	200	2	75	0	0	0	0	0
65G_3	320	3	100	50	5	200	2	75	50	5	200	2	75

Results and Discussion

Figure 4 illustrates the microstructural changes in steels grades 45 and 65G before and after EPH. The initial structures of both steels consist of ferrite and pearlite, typical for medium and high-carbon steels that have not undergone intensive heat treatments. After the EPH procedure, the microstructure of steel 45 transforms into martensite. This is explained by the high temperatures and rapid cooling during the EPH process, which correspond to quenching conditions. Martensite forms as a result of the instantaneous transformation of austenite, which occurs during rapid cooling, not allowing carbon sufficient time to diffuse, leading to the formation of a supersaturated solution of carbon in iron.

In the case of steel 65G, the microstructural changes after EPH are characterized by the formation of fine-grained pearlite. This can be explained by the chemical composition of the steel, which may facilitate the slow release of carbon and a more gradual transition from austenite to pearlite.

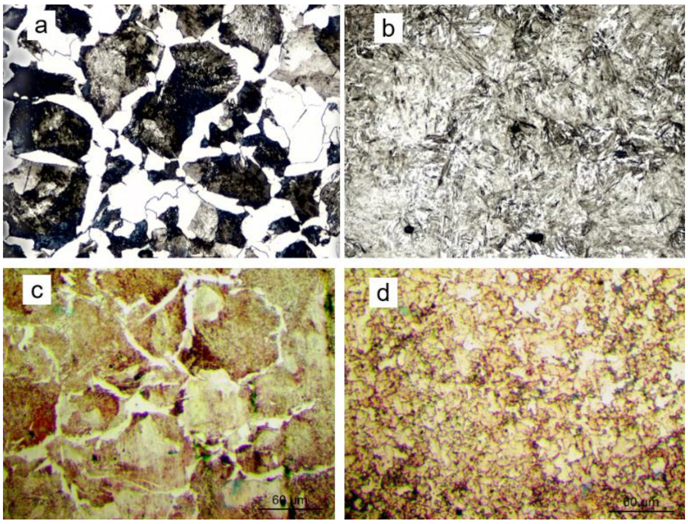

Figure 4 – Optical microphotographs of sample surfaces (×50):
a – Steel 45 before EPH, b – Steel 45 after EPH, c – Steel 65G before EPH,
d – Steel 65G after EPH

The tribological tests on wear volume have revealed a reduction in wear volumes for both 45 steel samples and 65G steel samples after EPH. For 45 steel, the wear volumes after hardening 1, 2, and 3 cycles of thermocycled EPH were respectively $1,11 \times 10^{-4}$ mm³, $4,41 \times 10^{-5}$ mm³, and $4,19 \times 10^{-5}$ mm³. It is noticeable that with increasing cycles, the wear resistance improves, and for the sample 45_3, this indicator improved 7 times compared to the initial sample with a wear volume of $3,03 \times 10^{-4}$ mm³. Similar indicators were obtained for 65G steel samples after thermocycled EPH, where the measurements of wear volume showed close values for samples 65G_1 and 65G_2. The most significant improvement in wear resistance was also noted in the sample that underwent EPH for 3 cycles, with a wear volume of 6.17×10^{-5} mm³, which is 4.5 times lower than the initial sample. The results on wear volumes before and after EPH for samples made from 45 and 65G steels are presented in Figure 5.

The reasons for the increase in wear resistance are the formation of a stronger and more stable surface structure, consisting of martensite. The plasma flow and electrolytic reactions contribute to the formation of solid solutions and dispersion particles on the steel surface, which increases its hardness and resistance to wear [24]. These wear volume data demonstrate the effectiveness of EPH technologies in enhancing the wear resistance of these types of steel, which is important for their application in conditions requiring increased durability and wear resistance.

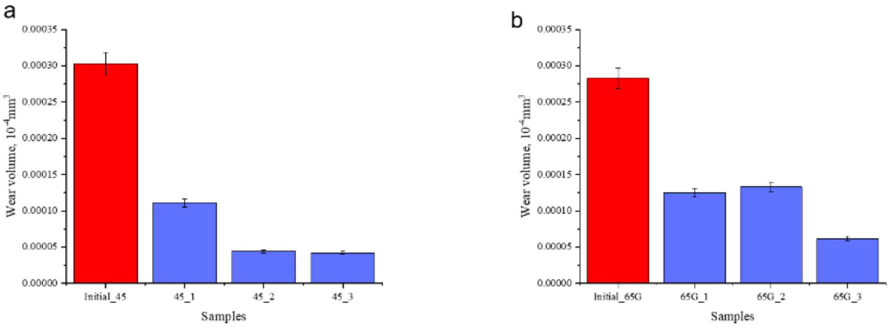

Figure 5 – Wear volume of: a – samples made of steel grade 45 before and after EPH,
b – samples made of steel grade 65G before and after EPH

Figure 6 shows the polarization curves in potential-current density coordinates (E – j) for corrosion measurement of 45 and 65G steel grades before and after electrolytic plasma hardening. The corrosion resistance test showed a significant reduction in corrosion rate after electrolytic plasma hardening of 45 and 65G steels. The analysis of the polarization curves, which show the dependence of corrosion potential on corrosion current, confirms that the corrosion potential for samples 45_3 and 65G_3 shifted to a more positive direction, and the corrosion current density decreased compared to the initial sample.

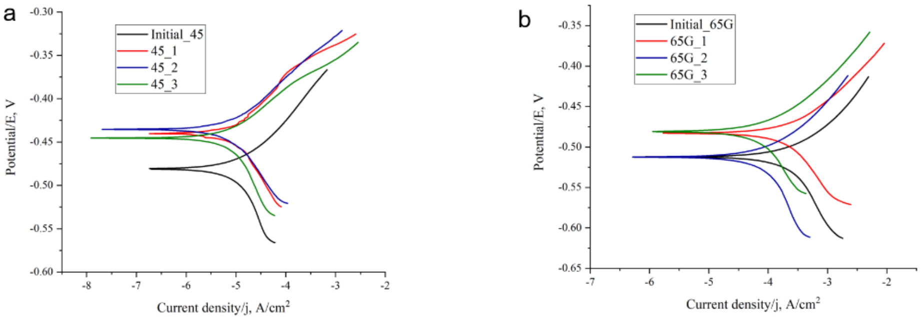

Figure 6 – Potentiodynamic polarization curves:
a – for steels 45 before and after EPH, and b – for steels 65G before and after EPH

The corrosion rate measurements showed that for samples 45_1 and 65G_1, the reduction in corrosion rate was less pronounced. For samples 45_2, 45_3 and 65G_2, 65G_3, the average corrosion rate was 2.49×10^{-4} mm/year, which is 7 times less compared to the initial sample, indicating increased corrosion resistance of the samples after EPH in 2 and 3 cycles.

Conclusion

The study of the influence of EPH on samples of 45 and 65G steel has led to several important conclusions. The martensitic transformation facilitated by EPH demonstrated great potential in improving the structural properties of these steels. This transformation process not only enhanced the mechanical characteristics of the material but also positively affected its corrosion properties. Wear resistance tests on 45 steel showed a 7-fold improvement: the wear volume after treatment decreased to 3.03×10^{-4} mm³. Similarly, for 65G steel, the wear volume decreased by 4.5 times to 6.17×10^{-5} mm³ compared to the initial sample. Additionally, the resistance of these steels to electrochemical corrosion has increased, which is crucial for components used in aggressive environments. The analysis of the polarization curves shows that the corrosion current density has decreased compared to the initial sample. For the 45_3 sample, the corrosion current density was 6.87×10^{-6} A/cm², and for the 65G_3 sample, it was 1.61×10^{-7} A/cm². There is also a shift in the corrosion potential to a more positive value, which further indicates improved corrosion resistance. The results demonstrate the formation of new phases in the surface layers after EPH, which enhances wear resistance, tribological characteristics, and corrosion resistance of 45 and 65G steels. Future studies will continue to explore the influence of various technological parameters on other properties of steels, which has significant practical importance for increasing the durability and efficiency of steel structures.

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ЭЛЕКТРОЛИТТІК-ПЛАЗМАЛЫҚ ҚАТАЙТУ КЕЗІНДЕ АУЫЛ ШАРУАШЫЛЫҒЫ ТЕХНИКАСЫНДА ҚОЛДАНЫЛАТЫН 45 ЖӘНЕ 65Г БОЛАТТАРЫНЫҢ ТРИБОЛОГИЯЛЫҚ ЖӘНЕ КОРРОЗИЯЛЫҚ ҚАСИЕТТЕРІ

Мақалада ауылшаруашылық техника бөлшектерін өндіруде қолданылатын 45 және 65Г болаттарының тозуға және коррозияға төзімділігіне электролитті-плазмалық шынықтырудың әсері қарастырылған. Келтірілген нәтижелер электролитті-плазмалық шынықтыруды қолдану арқылы болаттың беткі қасиеттерінің жақсарғанын көрсетеді. Бұл технология тез қыздыру мен салқындатуды қамтамасыз етіп, ұсақ түйіршікті және шынықтырылған беткі қабаттың пайда болуына ықпал етеді, бұл оптикалық металлографиялық микроскоппен жүргізілген микроқұрылымдық зерттеулермен расталады. Трибологиялық сынақтар электролитті-плазмалық шынықтырудан кейін тозуға төзімділіктің жақсарғанын көрсетті: 45 болаты үшін тозу көлемі $3,03×10^{-4}$ мм³, ал 65Г болаты үшін $6,17×10^{-5}$ мм³ құрады, бұл сәйкесінше бастапқы үлгілерге қарағанда 7 және 4,5 есе аз. Поляризациялық қисықтарды талдау коррозиялық ток тығыздығының бастапқы үлгімен салыстырғанда төмендегенін көрсетті. Электролитті-плазмалық шынықтырудың үш циклі өткізілгеннен кейін 45 және 65Г болат үлгілерінде коррозиялық ток тығыздығы сәйкесінше 6,87×10^-6 А/см² және 1,61×10^-7 А/см² болды. Сондай-ақ, коррозиялық потенциалдың оң мәндерге *қарай ауысуы байқалып, коррозияға төзімділіктің артқанын көрсетті. Зерттеу нәтижелері 45 және 65Г болаттарының электролитті-плазмалық шынықтырудан кейінгі трибологиялық және коррозиялық қасиеттерінің айтарлықтай жақсарғанын көрсетіп, өндірістік қолдану үшін құнды деректерді ұсынады.*

Түйін сөздер: *Электролиттік-плазмалық қатайту, шынықтыру, болат 45, болат 65Г, тозуға төзімділік, коррозияға төзімділік, трибология, микроқұрылым.*

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ТРИБОЛОГИЧЕСКИЕ И КОРРОЗИОННЫЕ СВОЙСТВА СТАЛЕЙ 45 И 65Г, ИСПОЛЬЗУЕМЫХ В СЕЛЬСКОХОЗЯЙСТВЕННОЙ ТЕХНИКЕ, ПОСЛЕ ЭЛЕКТРОЛИТНО-ПЛАЗМЕННОГО УПРОЧНЕНИЯ

В статье рассмотрено влияние электролитно-плазменного упрочнения на износостойкость и коррозионную стойкость сталей 45 и 65Г, которые используются в производстве деталей сельскохозяйственной техники. Представленные результаты показывают улучшение поверхностных свойств стали за счет использования электролитно-плазменного упрочнения. Данная технология обеспечивает быстрый нагрев и охлаждение, что способствует образованию мелкозернистого и упрочненного поверхностного слоя, о чем свидетельсьвуют микроструктурные исследования, проведенные с помощью оптического металлографического микроскопа. Трибологические испытания показали улучшение износостойкости после электролитно-плазменного упрочнения: для стали 45 объем износа составил 3,03×10-4 мм³, а для образца из стали 65Г – 6,17×10-5 мм³, что соотвественно на 7 и 4.5 раза меньше, чем объем износа для исходных образцов. Анализ поляризационных кривых показал, что плотность коррозионного тока уменьшилась по сравнению с исходным образцом. Для образцов сталей 45 и 65 Г после трех циклов электролитно-плазменного упрочнения плотности коррозионного тока составили 6,87×10-6 А/см² и 1,61×10-7 А/см² соответственно, также был отмечен сдвиг коррозионного потенциала в сторону более положительных значений, что указывает на увеличение коррозионной стойкости. Результаты исследования демонстрируют значительные улучшения трибологических и коррозионных характеристик сталей 45 и 65Г после электролитно-плазменного упрочнения, что представляет ценные данные для произведственного применения.

Ключевые слова: *Электролитно-плазменное упрочнение, закалка, сталь 45, сталь 65Г, износостойкость, коррозионная стойкость, трибология, микроструктура.*

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ХРИЗОТИЛ МЕН КҮКІРТ ҚЫШҚЫЛЫ ЖҮЙЕСІНДЕГІ ӘРЕКЕТТЕСУІНЕ ХРИЗОТИЛ КРИСТАЛДЫҚ ТОРЫНЫҢ ҚҰРЫЛЫМДЫҚ ЕРЕКШЕЛІГІНІҢ ӘСЕРІ

Аңдатпа: *Хризотил – $Mg_6[Si_4O_{10}](OH)_8$құрамындағы магнийдің мөлшеріне (мөлдік) қатысты есептелген күкірт қышқылының мөлдік стехиометриялық қажетті мөлшерлері (СҚМ) мен хризотил арасындағы өзара әрекеттесулерінің сипаты зерттелді. Құрамында күкірт қышқылының (0-0,3) СҚМ аралығындағы ерітінділерді қолданғанда, ерітіндіге хризотил құрамындағы магнийдің өту мөлшері алынған қышқыл мөлшеріне пропорционалды болатыны көрсетілді. Ерітіндіге магнийдің өту мөлшері, СҚМ (0,3-0,5) аралығында тежелетіні, ал СҚМ (0,5-0,7) аралығында пропорционалдық заңдылық қайта орнағанмен, магнийдің ерітіндіге өту шығымы оның хризотилдегі мөлшерінің 76%-нан аспайтыны анықталды. Қышқылдық ортада, хризотил-асбестен магнийдің еруімен қабаттаса түзілетін поликремний қышқылдары ($SiO_2·nH_2O$) магнийдің ерітіндіге өтуін тежейтін фактор болатындығы көрсетілді.*

Хризотил-асбест және күкірт қышқылы жүйесіндегі жүретін өзара әрекеттесулер барысында, хризотилден ерітіндіге өтетін магний мөлшері, оның қабатты құрылымының ерекшеліктеріне байланысты болатыны,өнімдерін химиялық және рентгенофазалық зерттеулер нәтижелерімен түсіндірілді.

Зерттеу нәтижелерінде, құрамы негізінен серпентинит тобының минералдарынан (хризотил, лизардит, антигорит) тұратын, құрылымы жалпы $Mg_6[Si_4O_{10}](OH)_8$ формуласымен өрнектелетін көп қабатты магнисиликаттардың қышқылдарда еру үрдісі тек осы кезде жүретін қышқылдық-негіздік әрекеттесулер заңдылықтарына ғана емес, сонымен қатар серпентиниттердің кристалдық торын түзетін құрылымдық ерекшеліктеріне де байланысты болатындығы көрсетілді.