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Restoration and wear resistance of electric transport sliding contacts

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Abstract

The electrical contact insert of the current-carrying suspension of the electric vehicle belongs to the fast-wearing elements that require frequent replacement and attention to ensure standard performance. The purpose of this study was to develop a technology for manufacturing graphite-filled electrical contact inserts from waste materials and by modifying the composition of the composite. As a result of difficult operating conditions, coal current collector inserts of electric transport are subject to considerable wear. The causes of increased wear are electrocorrosion in contact with the conductor under current, abrasive wear from sliding on the wire with increased dustiness and air humidity. The technological process of manufacturing graphite current-collecting inserts from used graphite components is proposed. To prove the functionality of the restored current-collecting inserts, the strength, electrical conductivity and tribological characteristics of the material were tested. The results of experimental tests showed a slight decrease in material hardness and an increase in electrical resistance within acceptable limits. Bench wear tests showed improved tribological properties of the restorative insert material with the addition of copper powder.

Keywords: electric transport, current collector, contact insert, graphite, recovery, sintering, wear resistance, electrical resistance

Introduction

Electric transport is an integral part of the unified transport system of many cities of Ukraine. Reliability and efficiency of the current collection system and current collector parts of the trolleybus is one of the important problems of operation of electric transport [1-10[. During operation, there is an intensive operation of the current collector head of the trolleybus, and a deterioration of the current collection process, which is affected by the state of the contact network, the quality of the used lubricants, and the operating conditions. The reliability of the contact "current receiver of electric rolling stock - contact suspension" is primarily determined by its service life and reliability during operation and depends on the state of operation of the interacting elements: the head of the current receiver and the contact wire. The wear resistance of the contact significantly depends on the physico-mechanical, electrical and tribotechnical properties of the materials of its interacting elements. In order to improve these characteristics, it is necessary to apply effective methods and technologies of manufacturing, strengthening or modification of the conjugated contact elements of the current collector.

The most responsible part of the current collector is the contact head (Fig. 1). It should provide stable current collection during movement at high speeds, on curves, as well as when the trolleybus deviates from the axis of the contact wire suspension.

The end of the rod of the current collector covers the insulating sleeve 2 (Fig. 1), on which the steel holder 1 is fixed with bolts. A spherical axis is installed in it in the upper part. On the axis is the rotating part of the contact head, which consists of a holder, a copper insert 3, two cheeks 5 and a replaceable, carbon insert 6. The upper part of the axis is located between the holder and the insert, which are rigidly connected by two screws. The presence of spherical surfaces of connected parts enables the variable insert to rotate around a vertical axis.

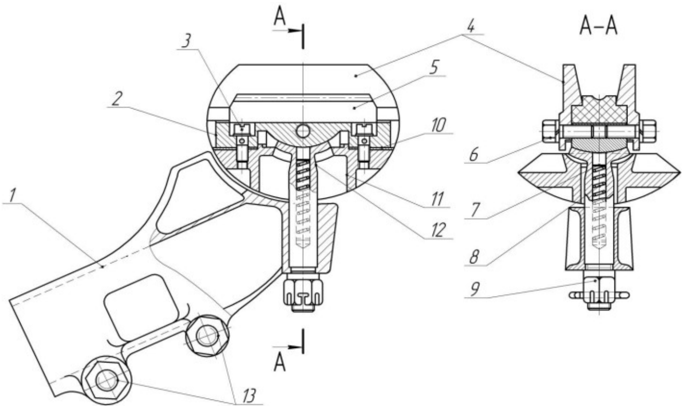

Fig. 1. Contact head of the current collector: 1, 11 – holders; 2 – insert; 3, 6, 13 – bolts; 4 – cheek; 5 – carbon insert; 7 – brush; 8 – spring; 9 – nut; 10 – gasket; 12 – the fifth.

The spherical surfaces of the contact head must be lubricated with a thin layer of grease (AeroShell Grease 7). To reduce the transition resistance between the insert and the holder, a copper graphite brush 8 with a spring is installed, which creates the necessary pressure of the brush on the insert. The insert is installed on the liner and fixed with bronze cheeks, which simultaneously act as guide ribs when the head moves along the contact wire. Cheeks are pressed to the insert with bolts 7. To prevent the contact head from falling to the ground when coming off the rod, a protective tape 16 is provided.

The weakest element of the current collector is the contact insert, which slides along the copper trolleys of the power supply. In fig. 2 presents various types of trolley bus inserts.

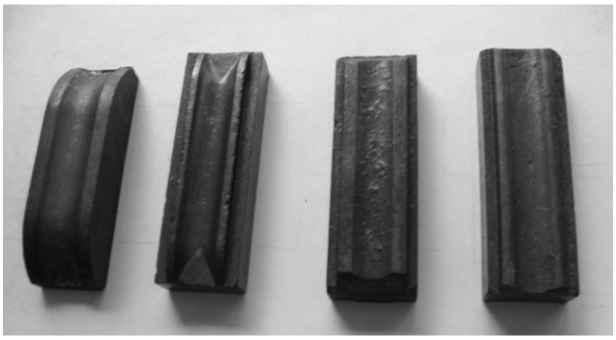

Fig. 2. Types of trolleybus inserts

As a result of friction and the formation of spark discharges, the inserts are subject to intense wear. Their regulatory term provides80 km. mileage Inserts also often fail due to mechanical damage. The operational characteristics of the inserts are presented in Table 1.

Table 1

Operating characteristics of inserts when working together with MF-100 copper wire

Indicator	State of sliding contact		
	Dry	Wet	Wet
Linear wire wear, µm/10,000 passes	0.00	0.20...0.25	0.25...0.30
Wire wear area in cross-section, mm2/10,000 passes	0.00	0.003...0.004	0.004...0.005
Coefficient of friction	0.13	0.05...0.06	
The decline of insult in contact, V	0.40...0.60	0.25...0.40	
Linear wear of inserts, mm/100 km of mileage	0.1...0.2	0.2...0.4	0.04...0.06

According to the technical conditions, the current collector removes a constant voltage of 550 V, while the permissible current should not exceed 170 A. The pressure of the current collector on the contact wire is up to 140 N. The contact insert is a part of the current collector head, which directly contacts the wire and carries out current collection. The quality of current collection largely depends on the insert: continuity of contact, amount of mechanical and electrical wear of the contact wire, sparks, radio interference, electrical losses.

The most common types of wear of the tribosystem "contact wire - insert" are abrasive, fatigue, oxidative and molecular-mechanical wear. Several types of wear may appear simultaneously, but one of them will always be dominant. Abrasive wear occurs as a result of products of wear and external dust falling into the friction plane, as well as in the presence of solid inclusions that form the basis of the material of the conjugated elements of the tribosystem. Most often, microchips, small particles torn from the friction surface, appear on graphite inserts, but at the same time the surface retains its polish. Characteristic wear damage of coal inserts in operation are shown in fig. 3.

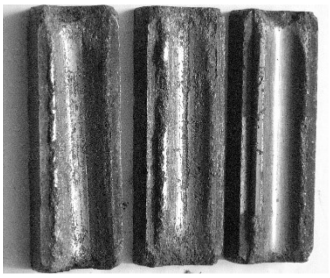

Fig. 3. Wear damage of coal inserts

In case of poor adjustment of the contact suspension, carbon inserts are characterized by damage and excessive activation or lateral wear. Chips occur only when the adjustment of the contact suspension elements is disturbed, cracks occur due to impacts on the insert and under conditions of impaired current collection, fires occur. Fatigue wear is associated with volumetric deformation of the friction surfaces and cracking of the over-riveted metal layer, followed by its removal. Oxidative wear is associated with the formation and destruction of thin oxide films on friction surfaces. Mechanical wear occurs as a result of the friction process and as a result of shocks of the current collector insert against the contact wire and depends on the characteristics of the contacting materials, the state of their surfaces, the pressure at the contact point, the sliding speed and the uneven height of the wire suspension.

Tribotechnical materials and technologies of sliding electrical contacts (inserts)

Graphite is the main material used in friction pairs operating in a sliding contact system, as it acts as a dry lubricant. Contacts of this type are a kind of friction pair in which the contacting elements slide one after the other without breaking the electrical connection. Therefore, along with the above-mentioned requirements, the contact material must also possess a complex of antifriction properties in relation to dry friction conditions, and the contact pair cannot consist of the same materials, because otherwise friction surfaces will seize even under normal operating conditions, not to mention about working in a vacuum. The hardness of the materials that make up the contact pair must be different. It is desirable that the counter-body (current-carrying element) is more solid (approximately 1.3-2 times) than the moving contact (current-collecting element), then the service life of the contact pair increases, and replacing the current collector is usually easier than other elements of the electrical circuit . The required hardness ratio is achieved by adding solid lubricants (molybdenum disulfide, zinc sulfide, selenides of some liquid metals, calcium fluoride, graphite, etc.) or low-melting metals (for example, gallium) to the corresponding contact material, which become liquid during the operation of the contact pair.

In this case, areas of solid lubrication perform anti-friction functions, and a metal base with low electrical resistance provides the main electrical connection in the connected contact node; in the presence of a low-melting metal in the material, together with the basis of the power transmission, wear is reduced due to the replacement of dry friction with liquid friction when the additive is melted. In the process of operation, when the contact surfaces are moved relative to each other, both the actual physical contact surface changes (frictional surfaces act unevenly) and the actual electrical contact surface (not the entire contact surface participates in electrical transmission due to roughness and the presence of non-conductive or low-conductivity phases on it) . In the process of commutation of an electric current, the wear of the contact surfaces of the friction pair, depending on the quality and material of the contacts, increases 10-100 times compared to the wear in the de-energized state: electric spark and arc processes destroy the friction surface, contributing to its mechanical wear, and heating also accelerates the interaction material with the surrounding external environment, causing a loss of their strength and hardness.

Sliding contacts are used in the form of plates, rods, cylinders, darts, etc. in electric motors, dynamos, potentiometers, current collectors, switches and other devices. The basis of the contact material is copper or silver, and graphite is most often used as a solid lubricant. Copper-graphite contacts contain 8-75% graphite, have good electrophysical properties, are cheap and work reliably in difficult operating conditions (brushes of electric motors and dynamos, magnetos, etc.). Bronze-graphite contacts contain 2-5% graphite, 70-80% copper, ost. - tin, iron, nickel. Such contacts are used as collector plates of pantographs for powering the motors of electric trains at speeds up to 1500 m/min and under the influence of relatively high pressures and shocks, and the current-carrying wire wears out minimally.

Silver-graphite contacts contain 2-50% graphite and work in precision measuring devices either dry or completely immersed in lubricant at speeds up to 20 m/min and a load of 0.05-0.07 MPa.

Silver-based sliding contacts are prepared from a mixture of powders of the corresponding components (for PDS-70 material, silver-palladium alloy powder is used, and for SNDSM-2.5 material, silver-palladium-nickel alloy powder is used). Large-sized blanks are pressed, sintered in the solid phase, pressed, annealed, extruded into a wire rod or tape (rolling and drawing are also possible) and contacts are stamped or planted. Contacts of the Sndsm-7.5 brand are pressed immediately from a mixture of powdered silver, nickel and molybdenum disulfide, solid-phase sintering of the blanks is carried out in argon, and then pressed and annealed. The same is done in the case of obtaining silver-graphite contacts.

When manufacturing copper-graphite electric brushes, which also include lead or tin additives, it is necessary to create a copper frame that gives the material maximum electrical conductivity. Technologically, this problem is solved in several ways. According to one of them, porous graphite is impregnated with molten copper, which turned out to be economically beneficial when the copper content in the composition is more than 50% (by mass). Porous graphite should have a through porosity of 20-35% and be strong. Impregnation with copper is carried out under pressure.

The most common method is the pressing and sintering of a mixture of copper powder with various carbon materials. Many companies make copper graphite brushes from mixtures of copper powders and natural graphite, but most of the brushes contain, in addition to graphite, other carbon components that are introduced to increase strength, improve wear resistance and reduce contact resistance. Such additives are pitch (increases strength and improves pressing of the mixture), or carbon black-coke fines (increases wear resistance), rubber (increases strength). When using a binder and other additives, an important role is played by the operation of mixing the initial powders, because in the final product the copper component should cover the particles of the carbon component as best as possible. As a rule, carbon components such as graphite, carbon black and pitch are mixed first. For this, heated mixers are used. After cooling, the mixture is ground into powder, the fines are sifted out and mixed with copper powder. The resulting charge is pressed (200-400 MPa) into a product or blank. Sintering is carried out at 700-800 ºC in continuous furnaces with a protective atmosphere. If the blanks contain connecting components, then sintering is reduced to coking the pitch with the formation of a strong coke backbone, in the pores of which particles of metal powders are held. After sintering, the blocks are cut into individual brushes, and the individually sintered brushes are machined and reinforced with conductive elements.

You can make electric brushes from graphite coated with copper or its alloys. In this case, graphite, zinc and lead powders are immersed in aqueous solutions of CuSO4 or CuCl4. At the same time, copper is deposited on the graphite surface, and part of the lead is mechanically captured. The best wear resistance, hardness and strength are achieved with a lead content of 1-2%. Such powders are sintered at 400 ºC, that is, 250 ºC lower than ordinary mixtures of copper, graphite and lead powders. The structure of the products is mesh, which provides them with high wear resistance and good electrical, thermal and mechanical properties.

Research on the reliability and wear resistance of working parts of sliding electrical contacts, especially electrical brushes, is carried out in three main directions:

- improvement of the structure of the material and the design of the working element;
- optimization of the choice of constituent and granulometric parameters of the composition of charge materials;
- optimization of technological modes of production of the working element.

Electric brushes based on carbon with various additives and layered brushes based on alternating layers of carbon fabrics and polymer binders with anti-friction additives do not ensure the creation of a continuous intermediate film (polish) between the collector and the brush material.

For direct current electric machines that work in a single-use mode and with high-density operating currents, in order to reduce the generation of sparks, current-collecting brushes are used, formed by sections of twists of insulated current-conducting cores from a metal wire of low electrical resistance, for example, beryllium bronze.

For electric machines, the operating conditions of which are characterized by the special tension of the current-collecting devices due to vibration and large currents, in order to increase the wear resistance of the brushes and the collector, brushes with different physical and mechanical characteristics and which are placed taking into account the polarity are recommended.

Each of the known measures of constructive implementation does not solve the problem of reducing the value of the transient resistance and the loss of current transmission capacity. It is possible to reduce and at the same time stabilize the transient resistance of sliding current collectors by additionally passing through the contact a low-frequency direct or alternating current of a high-frequency current [11].

Brushes based on crystalline graphite with anisotropy of electrical resistance, as well as brushes containing carbon fabrics, thermo-reactive binders and anti-friction components have high switching ability, wear resistance and minimal energy loss in contact.

Optimization of the composition and granulometric parameters of the composition of charge materials is the second direction of research into current-carrying sliding elements, which are carried out in order to improve their commutative properties and wear resistance.

A mixture of graphite and hardened coke, copper (introduced in the form of a coating layer on a coke particle) and binder [12], as well as a mixture of copper and graphite in the form of pressed powders, which represent a single matrix, are proposed for sliding elements of electromotive transport , and granular inclusions containing copper and molybdenum disulfide are evenly distributed in the volume of this matrix, and the copper in the granules is introduced in the form of a coating layer applied to molybdenum disulfide powder particles [13] according to the following ratio of components: copper 25 ... 33%, granules 25 ... 39%, graphite - the rest. Granules have dimensions of 80 ... 200 μm according to the following ratio of components in the body of the granule: copper 20 ... 31%, molybdenum disulfide - the rest. Granular inclusions strengthen the matrix and increase wear resistance. Copper-graphite and copper-copper interparticle contacts cause high electrical conductivity. To manufacture the sliding element, artificial graphite powder with a dispersion of 40 ... 200 µm was mixed with copper powder 40 ... 150 µm and molybdenum disulfide powder 150 ... 300 µm, on which a layer of electrolytic copper was applied. The resulting pressed powder was pressed and then sintered.

The composition of the carbon-containing material [14] includes a mixture of natural and artificial graphite, and copper is introduced in the form of a coating layer applied to the particles of natural graphite, which wets this graphite by spontaneously spreading over it. The ratio of components in the press powder is: natural graphite 50.0 ... 75.0%, artificial graphite 7.0 ... 35.0%, copper 5.0 ... 25%, binder - the rest. Natural graphite is the most inert carbon material to oxidation when heated and has the best self-lubricating properties. Due to the modification of natural graphite with niobium, copper enters into physical and chemical interaction, moistens and increases its electrical conductivity. At high currents, the sliding element heats up and electroerosion of graphite occurs, but the copper does not peel off from it. Powders of artificial graphite (40 ... 200 µm), copper (40 ... 150 µm), natural graphite (50 ... 200 µm) with a modifier and binder powder are mixed, pressed and sintered.

According to another method [15], pressing is carried out at a pressure of 5 ... 30 MPa at a temperature of 165 ... 210 °C, and heat treatment is performed at a temperature of 220 ... 600^0C. The content of a thermosetting binder, for example, phenol-formaldehyde resin, is 7...50%, metal materials, for example, copper - 0...70%, and carbon graphite materials, for example, natural and artificial graphite, carbon black, carbon fibers - 20 ...93%. The composition may also include known alloying, polishing, anti-friction, plasticizing and polymerization-accelerating binder additives. The method of manufacturing a current-carrying sliding element [16] from copper-plated graphite powder, on the surface of whose particles a protective layer of tin is applied, and an organic binder, is distinguished by the fact that a layer of copper and a layer of graphite are applied one after the other, along or across this element at an angle of 0 ... 90o to the working surface with the following ratio of components in the material: copper - 5 ... 48%; graphite - the rest. The layers are formed in the form of hollow cylinders inside each other, along this element or in the form of a combination of cylinder segments formed one on top of the other along or across this element. High hardness, strength and wear resistance, the highest electrical conductivity and good interparticle contacts between copper and graphite are ensured when copper is applied in layers on graphite. The pressed powder is applied in functional layers, pressed and sintered.

According to another [17] method, a mixture of graphite-containing material with a crushed binder is ground to particle sizes of 0.040 ... 0.071 mm and mixed with graphite-containing material powder with a fraction of 0.2 ... 1.0 mm, and heat treatment is carried out simultaneously with the pressing process with exposure under pressure Graphite electrode waste with an ash content of less than 0.5% is used as a graphite-containing material, and phenol-formaldehyde resin is used as a binder. When the graphite-containing material and resin are simultaneously crushed, a homogeneous powder-like mixture is obtained, in which the finely dispersed particles of the binder are evenly distributed in the volume of the finely dispersed graphitized material. After thorough mixing of the obtained mixture with the powder of graphitized material with a fraction of 0.2...1.0 mm, a composition is obtained in which, when pressed, finely dispersed particles fill the voids between coarsely dispersed particles, forming a uniform dense packing. Under the simultaneous action of pressure and temperature, the binder, melting and enveloping the particles of the graphitized material, penetrates into the pores, squeezing out air, and the particles of different fractions, clinging to each other and being incorporated into each other, form a homogeneous structure of the product with minimal porosity. Temperature exposure contributes to a more complete flow of these processes and their completion as a result of polymerization of the binder over the entire thickness of the product. The dense, uniform structure provides stable, low electrical resistance due to the increase in the contact surface between the particles, ensures good sliding of the moving collector on the stationary brush, and reduces sparking.

Technology of restoration of current collector inserts

The analysis of the defects of the inserts of the current collectors of the trolleybus showed that it is possible to restore its operability by restoring the surfaces under the contact wire. The technological operations of restoration are shown in Table 2. The amount of material of the worn insert, which is thrown into the scrap, is 35% of the total weight of the new coal insert. Therefore, it is rational to use the worn-out part of the carbon insert in the subsequent production of new carbon inserts of the current collector of the trolley bus.

Table 2

The technological process of restoring the current collector insert

The name of the operation	Performing the operation
Defective	Suitability of the insert for further operation
Grinding	Grinding of spent inserts of current collectors
Screening	Sifting of components of spent inserts
Preparatory	Preparation of the mixture
Pressing	Pressing new inserts
Heat treatment	Hardening of pressed inserts
Control	Product quality control

At the next stage, the selection of equipment and tools was carried out as the basis of the rationality and economy of the process of restoration of parts. In the conditions of repair enterprises, universal equipment is beneficial, which allows you to perform a large number of operations. Based on the conditions of the technological process and economy, we choose the equipment, cutting and measuring tools, with the help of which it is possible to perform all the necessary operations.

The technology involves the grinding of activated inserts of trolleybuses with the help of a rotary crusher (Fig. 4). Grinding is carried out in the crusher thanks to the rotor, on which the knives are fixed, which break the pieces of graphite against the baffle plates fixed in the housing. The elements of the inserts also break against each other after gaining acceleration from the rotor. Grinding is carried out until the powder cannot enter the lower chamber through the installed grate. The body is lined from the inside with wear-resistant metal. In the future, it is necessary to divide the obtained powder into fractions. It is proposed to do this with the help of a separator, which separates the graphite powder into two fractions: small and large. The principle of operation is based on the passage of a shallow fraction through a profiled disk under the action of air pressure and centrifugal force. Powder supply is carried out through one nozzle together with air. The rotor rotates and gives centrifugal force to the small fraction, due to this, it passes through the profiled disk and enters the outlet of the fine powder, while the large fraction remains at the bottom of the case.

The next technological operation is the mixing of components. Mixing is done in mixing drums. Additionally, PMS-1 copper powder (220μm) in the amount of 5% is added to the obtained graphite material.

The finished mixture is sifted and pressed in molds (200-400 MPa).Inserts are pressed on a hydraulic press. For the production of inserts, the mold shown in fig. was designed and manufactured. 5.

Fig. 4. Crushing of graphite inserts

Fig. 5. General view of the mold for graphite inserts

Sintering of experimental samples and full-scale inserts was carried out in a vacuum electric furnace at a temperature of 180...220ºC.

Samples of the obtained experimental compositions (Fig. 6) were examined for hardness and electrical conductivity.

Fig. 6. Research samples

The hardness of experimental and serial samples was measured by the Rockwell method on the TK-2 device on the B scale, provided there was no working load. The average results of hardness measurements are shown in Table 3.

Table 3

HRB hardness of experimental and serial samples

Sample	1	2	3	4	Serial sample
HRB	80	79.5	76.5	66.5	84

The obtained results show that the conventional hardness of experimental and serial samples differs slightly.

The electrical resistance of experimental and serial samples was measured with an ohmmeter with an accuracy of 0.05 Ohm. The specific resistance was calculated according to the formula:

$$\rho = \frac{RS}{l},$$

where R is the resistance determined by an ohmmeter, Ohm;
S is the cross-sectional area of the sample, mm^2;
l is the sample length, mm.

The results of determining the electrical resistance are shown in Table 4.

Table 4

Electrical resistance of experimental and serial samples

Sample	R, Ohm	ρ	l	S
1	1.4	7.02	25.5	128.2
2	1,2	6.41	23.7	126.6
3	1.1	5.84	23.8	126.4
4	1.0	5.36	23.6	126.6
Serial sample	1.1	6.07	23.0	127.0

The resistance of the serial samples is approximately 25% lower than the resistance of the experimental materials, which requires certain optimization of the chemical and granulometric composition and technologies of manufacturing inserts.

Results of tests on the wear of electrical contact inserts

Tests were carried out on a laboratory bench to check the functionality of restored copper-graphite inserts (Fig. 7).

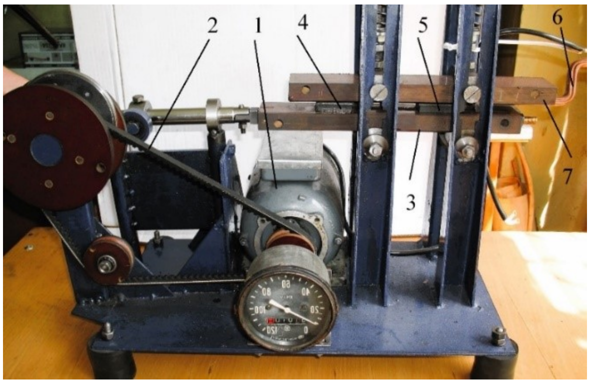

Fig. 7. Stand for testing trolley bus pantograph inserts: 1-electric motor, belt drive, 3-moving support, 4-test sample 1, 5-test sample 2, 6-pin wire, 7-wire clamp.

The test bench simulates the sliding contact of a natural graphite insert of a current collector with a current-conducting wire. Electric motor 1 serves as the drive for the reciprocating movement of the insert samples. The rotational movement is transmitted to the crank mechanism through the belt system 2. As a result, the support with the samples placed on it receives a reciprocating movement. Experimental 4 and serial 5 samples of the current collector insert are fixed on the support 3. The contact wire 6 is fixed in the upper clamp 7. The clamp 7 with the wire is pressed against the insert samples with the help of springs with a given force. In this way, a sliding mechanical contact is created between the insert and the wire. The amount of wear was determined by periodic measurement of the linear dimensions of the inserts. The results of wear determination are shown in the graph of fig. 8.

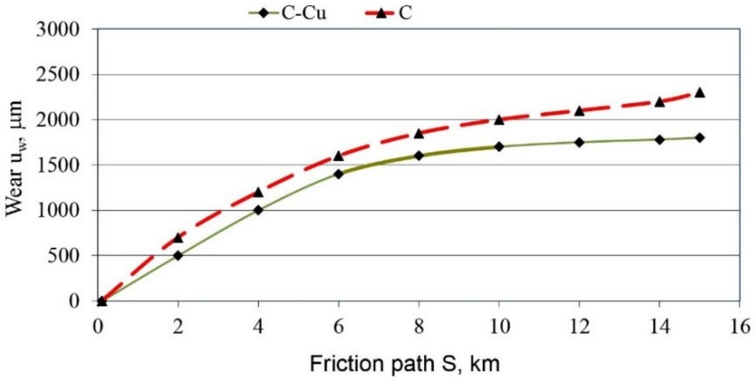

Fig. 8. Dependence of wear of the insert on the friction path

The change in the thickness of the insert in the center of the radial recess was taken as the wear criterion. The maximum wear of the insert was 2.5 mm on average for 15 km of the friction path. The insert restored without the addition of graphite powder and with the addition of 5% Cu powder was compared. From the results of wear tests, it can be seen that the insert with the addition of copper has an average of 10% less wear, which indicates the effectiveness of the proposed technology. Along with this, it should be noted that the wear resistance of restored inserts is 30% lower compared to new serial inserts (average literature data on the wear of serial inserts). At the same time, the economic efficiency of using restored bushings is determined by the lower cost of restoration technology.

The prospects of this research are the search for a more optimal phase and granulometric composition of the composition, as well as the application of more advanced technologies for the regeneration of spent coal inserts of current collectors of trolleybuses.

Conclusions

1. As a result of difficult operating conditions, coal current-carrying inserts of electric transport are subject to considerable wear. The causes of increased wear are electrocorrosion in contact with the conductor under current, abrasive wear from sliding on the wire with increased dustiness and air humidity.
2. Graphite is the main material used in friction pairs working in the sliding contact system, as it acts as a dry lubricant. Due to the limited wear resistance of pure graphite, there are many proposals for modifying the composition of contact sliding inserts in order to provide increased wear resistance, high anti-friction characteristics, and reduced electrical resistance.
3. One of the effective methods of introducing energy-saving technologies when using graphite inserts of electric transport is the secondary processing of the insert material for renewable use. The technological process of manufacturing graphite current-collecting inserts from spent graphite components has been developed. To improve the conductive properties of the inserts, it is suggested to add finely dispersed copper powder in the amount of 5% to the composition.
4. To prove the functionality of the restored current-collecting inserts, the strength, electrical conductivity and tribological characteristics of the material were tested. The results of experimental tests showed a slight decrease in material hardness and an increase in electrical resistance within acceptable limits. Bench wear tests showed improved tribological properties of the restorative insert material with the addition of copper powder.

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Ковтун О.С., Дитинюк В.О., Старий А.Л., Фасоля В.О. Відновлення та зносостійкість ковзних контактів електротранспорту

Електроконтактна вставка струмознімальної підвіски електротранспорту відноситься до швидкозношуючихся елементів, які потребують частої заміни і уваги щодо забезпечення нормативної працездатності. Метою цього дослідження була розробка технології виготовлення графітонаповнених електроконтактних вставок із відпрацьованих матеріалів та шляхом модифікації складу композиту. Внаслідок складних умов експлуатації вугільні струмознімальні вставки електротранспорту піддаються значному зносу. Причинами підвищеного зносу є електрокорозія в контакті із провідником під струмом, абразивний знос від ковзання по дроту із підвищеною запиленістю і вологістю повітря. Запропонований технологічний процес виготовлення графітових струмознімальних вставок із відпрацьованих графітових компонентів. Для доведення працездатності відновлених струмознімальних вставок були випробовані міцнісні, електропровідні та триболгічні характеристики матеріалу. Результати експериментальних випробувань показали незначне зменшення твердості матеріалу та збільшення електрично опору в допустимих межах. Стендові випробування на знос показали покращені трибологічні властивості відновного матеріалу вставок із додаванням порошку міді.

Ключьові слова: електротранспорт, струмознімач, контактна вставка, графіт, відновлення, спікання, зносотійкість, електричний опір