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RESTORATION OF THE TRIBOTECHNICAL PAIRS IN EQUIPMENT OF MINING INDUSTRY

M. Biloshytskyi[1], H. Tatarchenko[1*], N. Biloshytska[1]
[1]*Volodymyr Dahl East Ukrainian National University, Sievierodonetsk, Ukraine*
**Corresponding author: e-mail tatarchenkogalina@gmail.com, tel. +380506069411*

ABSTRACT

Purpose. Substantiation of the possibilities and development of technology for the restoration of the worn-out tribotechnical pairs of mining equipment by methods of hot radial stamping in powder metallurgy using technogenic waste.

Methods. Powder for wear-resistant material was obtained from metal-abrasive sludge waste. The grinding sludge of 40X10C2M steel was used, which contains 65 – 70% of metal, 10 – 15% of non-metallic component and 20% of lubricating-cooling fluid by a special preparation: grinding, washing, dehydration, drying, magnetic separation, recovery annealing in a generator gas. The wear resistance of tribotechnical pairs of powder composite materials was assessed according to DSTU 2823-94. The wear resistance of the restored tribotechnical pairs has been determined by means of stand experimental research on the SMC-3 testing machine in the conditions of limited lubricants feeding. The reasons for improving the wear resistance have been revealed by means of metallographic studies, as well as the composition with higher properties has been set through the research of powder compactability.

Findings. The compositions of powder, composite materials for the restoration of tribotechnical pairs using technogenic wastes and the technology of their application to the surfaces of parts have been developed. A wear-resistant powder layer for the restoration of the "shaft"-type parts has been obtained, working in pair with a composite recovery layer of the "hub"-type part. The physical and mechanical characteristics of a recovery layer of worn-out surfaces of "shaft – hub"-type parts have been studied. The influence of the percentage anti-seize additive content on the wear resistance of the obtained materials under conditions of contamination with coal dust has been determined. The scheme for restoring worn-out surfaces of "shaft – hub"-type tribotechnical pairs has been proposed. The research results enable to extend the life of worn-out parts, which will result in savings to replace with new parts.

Originality. It has been found that the introduction of 15% copper into a composite recovery layer of a "hub"-type part leads to the formation on the surface of a partition of solid and strong non-metallic layer, which leads to increased wear resistance of the tribotechnical pair.

Practical implications. The proposed scheme for the restoration of worn-out surfaces by the method of hot radial stamping of powdered materials enables the utilization of technogenic waste and helps to extend the service life of worn-out parts, which leads to savings in their replacement.

Keywords: *tribotechnical pair, wear resistance, powder, bimetal, restoration, coal industry*

1. INTRODUCTION

The development and improvement in the coal mining industry of resource-saving technologies is a very acute and urgent problem of the Ukrainian economy (Piwniak, Bondarenko, Salli, Pavlenko, & Dychkovskiy, 2007; Vagonova, & Volosheniuk, 2012). In machine-building industries, the resource saving task is solved by improving and creating the latest advanced technological processes used in metal treatment under pressure.

Operation of units which pump water from quarries, coal mines, underground mines is accompanied by wear of centrifugal-type pumps, isolation valves, as well as suction and discharge pipelines. When operating with the water outlet equipment, one has to face mainly with abrasive wear, since when pumping the water there are always non-soluble dust-like solid particles of mineral origin in suspended state, which, when passing through the wet end of the pump, inevitably fall between the rubbing surfaces of bearings (Dolganov & Timukhin, 2016). The parts of machinery components: sleeve-type bearings, joint hinges, pusher gears, cams, operating under high dynamic loads in severe conditions with limited lubricant feeding, mine atmosphere contaminated with coal dust, are also exposed to intensive abrasive wear, which leads to the need for complete replacement of expensive parts of tribotechnical pairs.

Solving the issues on the restoration of tribotechnical pairs exposed to abrasive wear, which are included in the pumping equipment and rubbing machinery components working in a mine atmosphere, helps to increase their productivity, extend the life of their operation, resulting in higher efficiency, lower power consumption and, as a consequence, is one of the sources for savings funds for the replacement of worn-out components at the mining enterprises.

The expediency of restoring the worn-out parts means to reduce the cost of repairing the coupling pairs, assemblies and machines by reducing costs for the supply of new parts and reducing the production costs during their operation. The use of modern technological processes enables to reduce time of restoration by 10%, increase the operating time per a coupling pair by 22 – 25% and increase its productivity by 30 – 45% (Zhang, Zhang, Liu, & Miao, 2017), reduce, if compared with manufacturing, the number of technological operations by 5 – 8 times (Dudnikov, Belovod, Kanivets, & Dudnik, 2011), as a result of which a significant economic effect can be obtained. In many sector of national economy, including repairing of mining machinery and modes of transportation, a large number of various methods and methodologies for the restoration of parts are used (Voynash, Gaydukova, & Markov, 2017). The share of parts exposed to restoration at enterprises of heavy machine building by retailoring, gas-thermal, electrochemical and other most common methods is (Naumenko, 2004):

– by means of retailoring – 34.4%;
– methods of gas-thermal spraying – 26.1%;
– electrochemical coatings – 20.2%;
– other methods – 19.3%.

Restoration using retailoring and gas-thermal spraying methods occupies the first places among the widespread technologies.

The authors of the work (Luzan, 2014) have proposed a classification of coupling the tribotechnical pairs, which consists of 10 classes of modules and 8 subclasses, which account the types of wear, the material and structure of the parts surface layers, the material of the coupled parts and working conditions, as well as the type of load, velocity and degree of wear. The presented classification enables to group modules of coupled parts into 10 classes and 8 subclasses and, based on this, develop modular technological parameters for restoration.

According to many methods and ways for restoring worn-out surfaces, when applying the recovery layer, mainly pre-manufactured pure metals and their alloys, as well as solutions and molten salts are used.

In order to extend the service life, ensure reliability and durability of the used friction joints, which are mainly made of steel, it is necessary to study the possibilities of restoring worn-out tribotechnical friction pairs using technogenic industrial waste by pressure metal treatment methods using powder metallurgy, as the most economical sector contributing to utilization of valuable technogenic waste. A very effective way to reduce the expenditures for manufacturing the tribotechnical pairs used in the coal mining industries is to use advanced methods of plastic deformation (Aliieva, 2015; Aliieva, 2016).

The use of technogenic wastes, which include valuable alloying constituents, allows to obtain bimetallic products with a wear-resistant layer, which significantly reduces by 5 – 10 times the consumption of wear-resistant high-alloy steels used in retailoring and spraying, as well as reduce the factory labour hours for their manufacturing. Often the use of bimetallic compositions gives an economic effect not only by reducing the expensive metals consumption, but also as a result of simplifying the design, assembling of products (Maslyuk & Napara-Volgina, 2003; Varmazyar, Allahkaram, & Mahdavi, 2018).

High potential of opportunities to obtain this type of material is represented by Pressure Metal Treatment (PMT) in powder metallurgy, the methods of which enable to obtain coupled bimetal layers with predetermined composition and properties. One of the most promising directions of powder metallurgy is the hot stamping method, which provides obtaining high-dense and high-strength wear-resistant materials, including bimetallic ones, when restoring worn-out tribotechnical pairs (Pavlygo, Serdyuk, & Svistun, 2005).

Due to the processes occurring during joint plastic deformation of dissimilar metals, it is possible to influence the properties of the metal, which can significantly improve the operational characteristics of friction pairs restored after exceeding the permissible wear. The use of technogenic industrial waste will make it possible to make a reasonable selection of compositions of surfaces to be restored, taking into account the mechanical properties and the necessary wear resistance (Pavlygo, Serdyuk, & Svistun, 2005; Rud', Gal'chuk, & Povstyanoy, 2005).

Thus, the issue of restoring the expensive tribotechnical pairs of machinery parts components in coal mining industry is relevant and is of interest to solve the problem of the possibility of restoring worn-out parts using bimetallic materials, as well as using PMT methods in powder metallurgy.

2. PURPOSE AND OBJECTIVES OF RESEARCH

The work is aimed at solving the problem of restoring the worn-out expensive tribotechnical pairs of machinery parts components in coal mining industry using technogenic industrial wastes, by the methods of pressure metal treatment in powder metallurgy.

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

– to analyse the existing methods for the restoration of worn-out tribotechnical pairs;
– to develop the composition of powder, composite materials for the restoration of tribotechnical pairs using technogenic wastes, by the technology of applying them to the surface of parts;
– to determine the wear resistance of the obtained materials under the conditions of coal dust contamination;
– to develop a scheme for restoring the worn-out surfaces of "shaft – hub"-type tribotechnical pairs.

3. MATERIALS AND METHODS OF RESEARCH

Powder to obtain a wear-resistant material, which is used to restore the outer worn-out surface of the "shaft"-type parts and the wear-resistant frame of the composite material to restore the inner surface of the "hub"-type parts, was obtained from metal-abrasive sludge waste.

The grinding sludge of 40X10C2M steel was used, which contains 65 – 70% of metal, 10 – 15% of non-metallic component (products of destruction of an abrasive tool during grinding) and 20% of lubricating-cooling fluid (Rud', Gal'chuk, & Povstyanoy, 2005; Ryabicheva, Sklyar, & Beloshitskiy, 2005). More than 10 – 15% of the sludge is conglomerates, which are oxidized metal and non-metallic particles cemented with a lubricating-cooling fluid (LCF).

At the first stage, the sludge was subjected to treatment for 1.0 h in a globe mill with milling agents in hot water (temperature 60 – 80°C, the amount of water 2 – 3 l/kg of sludge, the mass of balls is 4 kg per 1 kg of sludge). As the milling media, metal balls made of ShKh15 steel with a diameter of 25 mm were used. After being settled, the milled, partially washed metal-abrasive sludge is treated by the mode: flushing for the final removal of LCF and oil, dehydration, drying, magnetic separation, recovery annealing in the generator gas.

Metallographic studies were performed on specially prepared microsections etched with a 3 – 5% solution of nitric acid (HNO_3) in ethyl alcohol (C_2H_5OH) using a MIM-7 microscope.

Anti-seize copper powder was obtained according to the technology described in the work (Biloshytskyi, Tatarchenko, Biloshytska, & Uvarov, 2017). Waste debris from the electrical engineering industry was sorted, as well as brazed sections were removed. Cable cuts were cleaned from rubber and glass insulation. Burnt sections of varnish insulation were removed by air-separation.

The purified current-carrying conductors with different cross sections and chip scrap were loaded into ceramic containers, covered with lids with openings for free access of atmospheric oxygen. Prepared containers were loaded into a chamber electric furnace heated to 650°C in order to heat to 900 – 920°C. Holding at this temperature was 30 minutes. Dispergation of oxidized copper wastes was carried out in a laboratory cutting mill of centrifugal type to a powder state with a fraction of less than 0.16 mm.

The reduction of copper oxide powder was carried out in a generator gas medium consisting of H_2 – 74%, CO – 25%, as well as a small amount of (CH_4 and CO_2) (Biloshytskyi, Tatarchenko, & Biloshytska, 2019), at a temperature of 350 – 380ºC and holding 25 – 30 min.

The wear resistance of tribotechnical pairs of powder composite materials obtained from technogenic industrial waste under the conditions of coal dust contamination was assessed according to DSTU 2823-94 (Wear resistance of products. Friction, wear and lubrication. Terms and definitions) by the shaft-hub scheme. The tests were performed on the SMC-3 testing machine in the conditions of limited lubricants feeding. The tests for wear resistance were conducted by the principle of "shaft – hub". Wear resistance was determined under conditions of limited feeding of MS-20 industrial oil. The maximum load before adhesion $P_{b.ad}$, as well as friction coefficient K_{fr} were determined. Rubbing velocity is 0.8 m/s. The linear wear of the shaft and hub after 100 hours of testing was investigated for a nominal load of 80% of $P_{b.ad}$. The study on wear resistance consisted of the following stages: breaking-in of the shaft and hub, flushing, weighing, testing, flushing and weighing.

Research of the powder compactability was performed on R-10 universal testing machine, according to GOST 25280-90 "Metal powders. Method for determination of compactability".

4. RESULTS

According to metallographic studies of 40X10C2M steel sludge, it has been found that the metal part consists of chip scrap with various shapes: thin curly turnings, elongated curved (scimitar-shaped) and in the form of fragmentation particles shown in Figure 1. The average chip scrap sizes are as follows: thin curly turnings – width 0.015 – 0.110 mm, length 0.5 – 2.5 mm; elongated – width 0.006 – 0.025 mm, length 0.05 – 0.20 mm, fragmentation particles – 0.015 – 0.110 mm.

(a) (b) (c)

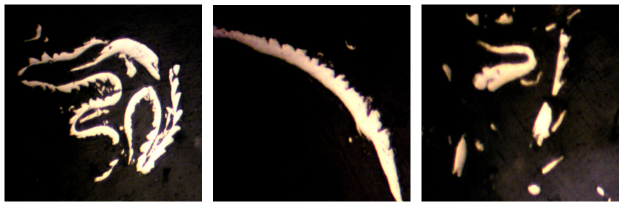

Figure 1. Shape of 40X10C2M steel chip scrap after grinding: (a) thin curly turnings; (b) elongated curved; (c) fragmentation particles

According to the developed technology by the authors of the work (Ryabicheva, Sklyar, & Beloshitskiy, 2005). When treating the sludge in a globe mill, the conglomerates are destroyed, partially LCF and oil contaminants are removed, and chip scrap is crushed. Small abrasive particles, which are the product of wheel disks' destruction, have a positive influence on the velocity and quality of the process, increasing attrition. High microhardness of the particles to be milled contributes to embrittlement. The chemical composition of the obtained powder from the sludge is presented in Table 1.

Table 1. Chemical composition of the powder from the 40X10C2M steel sludge, %

C	Cr	Si	Ni, Mo, V	Fe	Insoluble residue in HCl
0.85 – 0.87	9.4 – 9.6	2.10 – 2.17	abrasion	83.4 – 83.5	3.8 – 4.1

The chemical and granulometric composition of the obtained copper powder to prepare a composite material, by means of which to restore the inner worn-out surface of the 'hub' type parts, is presented in Table 2 (Biloshytskyi, Tatarchenko, & Biloshytska, 2018).

Table 2. Chemical and granulometric composition of the copper powder

Copper content, %	Tamped density, g/cm^3	Granulometric composition				
		Particle content, % with size, mm				
		< 0.16	< 0.14	< 0.1	< 0.063	< 0.045
99.4 – 99.7	2.3 – 2.6	9.5	—	40.7	35.4	14.4

The restoration of the "shaft" type parts was performed according to the following technology: a surface layer with thickness of not less than 3 mm was removed from the worn-out parts surface on metal-cutting machines, which is conditioned by the impossibility to obtain thin-walled compact from powder materials with satisfactory uniform density throughout the height.

A wear-resistant, recovery layer in the form of a cylinder powder liner, shown in Figure 2a, was made by pressing the powder obtained from metal-abrasive 40X10C2M steel sludge. The execution of the powder liner with a chamfer of 5×10° prevents the metal bead from leaking onto the body of the part being restored under radial plastic deformation.

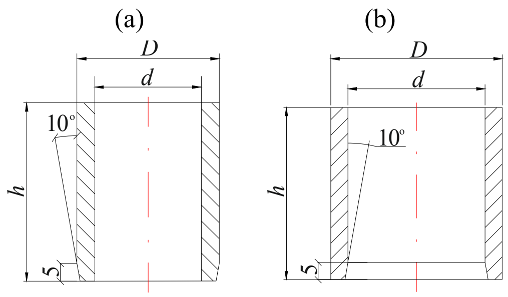

Figure 2. Powder cylinder-shaped liner: (a) to restore the "shaft"-type parts; (b) to restore the "hub"-type parts

It is known that the pressing process can be controlled using surface-active substance (surfactants) and plasticizers (Kostornov, 2002). In order to obtain strong and dense powder liners, a study has been conducted on the influence of a surfactant, a lubricant (zinc stearate) and a plasticizer (polyvinyl alcohol (PVA)) on the powder compactability.

A dry mix with surface-active substances was obtained by mixing the powder with 0.8% zinc stearate in a "drum tumbler" type mixer unit for 0.5 h. A dry mix with a plasticizer was prepared by mixing the powder with a PVA solution in the ratio of 8:1 by weight, using a 10% aqueous PVA solution, brought to a boil and cooled to room temperature. When pressing powder liners from a freshly prepared dry mix, after pressing they spontaneously were warmed up to a temperature of 45 – 55°C, which leads to intensive release of moisture and a significant increase in porosity caused by interparticle contacts disruption by flows of outgoing moisture vapours. To avoid this effect, the prepared dry mix was granulated by rubbing through a sieve with a mesh size of 1 mm, and then dried on sheets of stainless steel at room temperature for 24 hours. In terms of the equivalent amount of dry substance, the PVA concentration was 1%.

The results of determining the powder compactability, without additives and a dry mix with additives of surfactant and PVA, are presented in Figure 3. The best compactability and, consequently, the strength is characteristic to powder compacts with the PVA addition. The average density throughout the height of a compact is 5.6 – 5.8 g/cm^3, which corresponds to 18 – 20% porosity for the material under study.

The final stage of worn-out "shaft"-type parts restoration was performed by the method of hot metal treatment by pressure, joint stamping of the viscous shaft core and a wear-resistant recovery layer. The principal scheme of this stage is shown in Figure 4a.

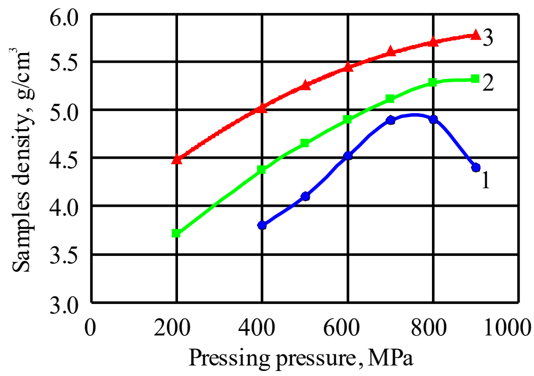

Figure 3. Dependence of samples density on pressing pressure: 1 – powder without additives; 2 – with the addition of 0.8% zinc stearate; 3 – with the addition of 1% PVA

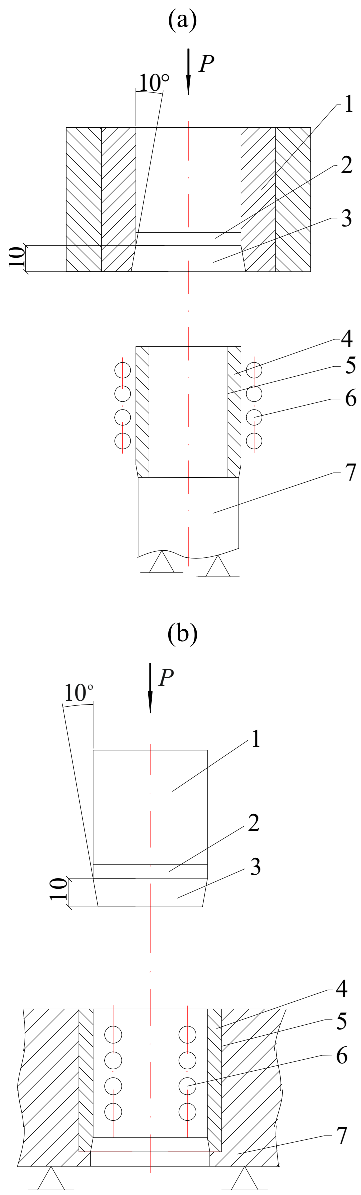

Figure 4. Principal scheme of hot stamping of the recovery layer of parts: (a) "shaft"-type; (b) "hub"-type; 1 – punch matrix (punch-mandrel); 2 – calibration parallel; 3 – lead-in cone; 4 – powder cylinder-shaped liner forming a recovery, wear-resistant layer; 5 – interlayer of copper; 6 – inductor; 7 – restorable part

To improve the mechanical adhesion of a part with a cylinder-shaped powder liner, a layer of powder copper is applied to the surface being restored by the method of electrolysis. The layer thickness is – 0.10 – 0.15 mm. Then the shaft is fixed in the bottom plate of the press, a cylinder-shaped powder liner is put on the coppered surface, wherein, on the outer surface in the lower part of the liner a chamfer is made with an inclination of 10° from the vertical and with a height of 5 mm. The purpose of the chamfer is to prevent possible leakage of wear-resistant material on the untreated shaft surface during hot plastic deformation. The recovery layer was heated to a temperature of 1125 ± 50°C using an inductor. To prevent surface oxidation of the powder liner, a protective-reducing gas was supplied to the heating zone. When the required temperature was reached, the inductor was removed and a hot radial compaction of the powder layer was performed with a punch matrix.

Thus, the restoration of surfaces by a deforming tool with a calibration parallel, by the PMT method with the use of powder material obtained from technogenic wastes, makes possible to achieve the required accuracy degree for the tribotechnical pairs of coupling without using the final finishing machining (Skvortsov & Okhotin, 2007).

The restoration of “hub”-type parts was performed according to the same technology as the “shaft”-type parts at a heating temperature for stamping – 1090 ± 10°C. For the recovery layer, cylinder-shaped powder liners were made (Fig. 2b), and a composite material was used, the composition of which included powder obtained from metal-abrasive 40X10C2M steel sludge with the anti-seize addition. The scheme of restoration is shown in Figure 4b.

To comply with the conditions for creating reliable tribotechnical pairs of coupling, finely-dispersed copper powder obtained from cabling and wiring industry waste is used as an anti-seize additive (Table 2).

Copper powder in the amount of 10, 15 and 20% was added to the dry mix used to restore the “shaft”-type parts. Cylinder-shaped powder liners were pressed from the resulting composite dry mix to restore the worn-out surfaces of “hub”-type parts.

5. RESULTS AND DISCUSSION

The research results of the mechanical properties of the recovery layer material of a “shaft”-type part have revealed that the steel obtained immediately after hot stamping has high hardness and strength with a sufficient level of impact hardness. To compare, the properties of the recovery layer steel and the powder ZHCH20H3 steel, which has high wear resistance and is widely used for movable parts are presented in Table 3 (Radomysel’skiy, Serdyuk, & Shcherban’, 1985).

Table 3. Physical and mechanical properties of steels

Material	ρ, g/cm^3	σ, MPa	KC, kJ/m^2	HRC
ZHCH20H3	6.8 – 7.0	550 – 600	120 – 140	40 – 45
ZHCH20H3	7.5 – 7.6	1100	150	50 – 57
recovery layer	7.0 – 7.1	1810 – 2000	87 – 94	51 – 56

The high level of the recovery layer properties is explained by the structural peculiarities of steel. Caused by the high cooling rate in the punch matrix and immediately after stamping with rapid heat removal into the shaft body, thermomechanical hardening of steel occurs with the formation of a finely dispersed martensite structure. A small reduction in impact hardness is explained by the presence of residual porosity after hot radial compaction and is – 2 – 3%, which when manufacturing the tribotechnical pairs, in conditions of limited feeding of lubricant, leads to an improvement in their operational properties. Moreover, steel contains about 4% of an insoluble residue (Table 1), which is microparticles of abrasive wheels, destroyed during grinding and embedded in a metal base, which cannot be removed by magnetic separation. It can be assumed that small particles having high hardness lead to steel hardening, which increases the level of strength properties as it was noted by the authors (Ryabicheva & Tsyrkin, 2004; Ryabicheva, Tsyrkin, & Beloshitskiy, 2007).

The research results of the physical and mechanical properties of the composite material of the “hub”-type parts recovery layer with different copper contents have shown that the obtained composites immediately after hot stamping have good characteristics, presented in Table 4.

Table 4. Physical and mechanical properties of the composite of recovery layer

Addition of copper, %	σ, MPa	KC, kJ/m^2	HRC
10	1700 – 1780	110 – 120	47 – 50
15	1610 – 1670	120 – 130	40 – 45
20	1270 – 1310	140 – 150	33 – 38

When heating the wear-resistant layer to a temperature of 1090°C, finely dispersed copper particles turn into liquid state and the radial compaction of recovery layer occurs in the presence of a liquid phase, which promotes reduction of deformation loads and, most importantly, achieving a practically non-porous state of the composite. Therefore, an increase in the impact hardness of the reduction layer composite occurs thanks to structural changes.

The main parameters for determining the wear resistance of tribotechnical pairs with different content of copper additive in the composite material of the “hub”-type parts are presented in Table 5.

Table 5. Tribotechnical pairs wear resistance

Addition of copper, %	Friction coefficient, K_{fr}	Maximum load before adhesion, $P_{b.ad}$, MPa	Linear shaft wear, nm/m	Linear hub wear, nm/m
10	0.08	10.0	0.94	1.92
15	0.04	13.0	0.34	1.25
20	0.05	11.7	0.30	2.10

The research of wear resistance of the obtained tribotechnical pairs preliminarily once lubricated with a graphite-oil suspension under conditions of coal dust contamination has revealed that with the addition of 10% copper to the recovery layer of “hub”-type parts, with an increase in load $P_{b.ad}$ on the machine’s spindle to 10 MPa, the friction tracks formation is observed.

This phenomenon over time leads to the formation of seizes and, as a consequence, to seizure, which is conditioned by the high hardness of the composite layer of the hub, the insufficient content of anti-seize copper additive, which does not separate the microasperities of the same particles of the solid phase.

An increase in copper in the composite layer to 15% leads to a sharp increase in wear resistance. The formation of friction tracks, seizes and seizure were not observed until the load on the machine's spindle was increased to 13.0 MPa. A sharp increase in the wear resistance of the specified tribotechnical pair was explained by means of metallographic examination of the surface after a wear test, the cross section of which is presented in Figure 5.

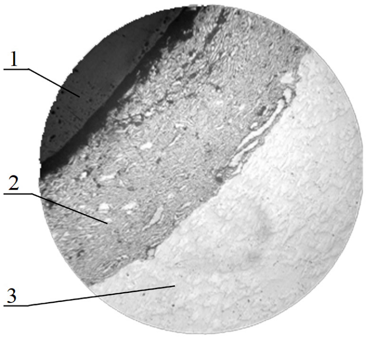

Figure 5. Cross sectional structure of the friction zone: 1 – shaft surface; 2 – partition surface; 3 – hub surface

In the course of metallographic studies, it has been revealed that at high loads, a graphite-oil suspension, having mixed with coal dust, is embedded into the surface layer of the composite material of the hub. As a result, a solid and strong non-metallic layer is formed that separates the surfaces of friction pairs, which increases the efficiency of the component, moreover, under conditions of limited lubricant feeding.

The introduction of copper into the surface layer of the hub in an amount of 20% led to a deterioration in the wear resistance of the tribotechnical pair, compared with a 10% content. In studies during the tests, it has been revealed that the formed graphite-carbon film, which is a partition surface, is not able to stay on a surface with a 20% copper content, due to its low hardness. When the load is increased to 11.7 MPa, the film is sheared, fallen into the friction zone, then seizes appear on the surface of the hub, which over time leads to seizure.

6. CONCLUSIONS

Thus, as a result of conducted research:

– the composition of powder, composite materials for worn-out tribotechnical pairs restoration using technogenic wastes has been developed;

– it was determined that the recovered layer has high physical-mechanical properties as a consequence of thermomechanical hardening of the surface layer during hot radial stamping;

– the wear resistance of the obtained tribotechnical pairs of coupling under conditions of coal dust contamination is determined;

– it has been revealed that the introduction of 15% copper into the composite recovery layer of a "hub"-type part leads to the formation of a solid and strong non-metallic layer on the surface of the partition, which leads to an increase in the wear resistance of the tribotechnical pair as a whole;

– a scheme has been developed for the worn-out surfaces restoration of the "shaft – hub"-type tribotechnical pairs, which enables to use technogenic wastes and to achieve the required accuracy degree for the tribotechnical pairs of coupling without using the final finishing machining.

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ВІДНОВЛЕННЯ ТРИБОТЕХНІЧНИХ ПАР ОБЛАДНАННЯ ГІРНИЧОДОБУВНОЇ ПРОМИСЛОВОСТІ

М. Білошицький, Г. Татарченко, Н. Білошицька

Мета. Обґрунтування можливостей та розробка технології відновлення зношених триботехнічних пар обладнання гірничодобувної промисловості методами гарячої радіальної штамповки у порошковій металургії із використанням техногенних відходів.

Методика. Порошок для отримання зносостійкого матеріалу отримували з відходів металоабразивних шламів. Використовували шліфувальний шлам сталі 40Х10С2М, який містить 65 – 70% металу, 10 – 15% неметалічної складової і 20% мастильно-охолоджувальної рідини за спеціальної підготовки: подрібнення, промивання, зневоднення, сушка, магнітна сепарація, відновлювальний відпал у генераторному газі. Зносостійкість триботехнічних пар порошкових композиційних матеріалів оцінювали за ДСТУ 2823-94. Стендовими експериментальними дослідженнями в умовах обмеженої подачі мастила на випробувальній машині марки СМЦ-3 визначена зносостійкість відновлених триботехнічних пар; металографічними дослідженнями з'ясовані причини підвищення зносостійкості; дослідженнями ущільнення порошків визначено склад з більш високими властивостями.

Результати. Розроблено склади порошкових, композиційних матеріалів для відновлення триботехнічних пар із використанням техногенних відходів та технологія їх нанесення на поверхні деталей. Отримано зносостійкий порошковий шар для відновлення деталей типу "вал", що працює у парі з композиційним відновлювальним шаром деталі типу "втулка". Вивчено фізико-механічні характеристики відновного шару зношених поверхонь деталей типу "вал – втулка". Визначено вплив процентного вмісту протизадирної добавки на зносостійкість отриманих матеріалів в умовах забруднення вугільним пилом. Запропоновано схему відновлення зношених поверхонь триботехнічних пар типу "вал – втулка". Результати досліджень дозволять продовжити термін експлуатації зношених деталей, що призведе до економії коштів на заміну новими.

Наукова новизна. Виявлено, що введення 15% міді в композиційний, відновлювальний шар деталі типу "втулка" призводить до утворення на поверхні розділу твердого та міцного неметалічного шару, що веде до підвищення зносостійкості триботехнічної пари.

Практична значимість. Запропонована схема відновлення зношених поверхонь методом гарячої радіальної штамповки порошкових матеріалів дає можливість утилізації техногенних відходів, продовження терміну експлуатації зношених деталей, що призводить до економії коштів на їх заміну.

Ключові слова: *триботехнічна пара, зносостійкість, порошок, біметал, відновлення, вугільна промисловість*

ВОССТАНОВЛЕНИЕ ТРИБОТЕХНИЧЕСКИХ ПАР ОБОРУДОВАНИЯ ГОРНОДОБЫВАЮЩЕЙ ПРОМЫШЛЕННОСТИ

Н. Белошицкий, Г. Татарченко, Н. Белошицкая

Цель. Обоснование возможностей и разработка технологии восстановления изношенных триботехнических пар оборудования горнодобывающей промышленности методами горячей радиальной штамповки в порошковой металлургии с использованием техногенных отходов.

Методика. Порошок для получения износостойкого материала получали из отходов металлоабразивных шламов. Использовали шлифовальный шлам стали 40Х10С2М, который содержит 65 – 70% металла, 10 – 15% неметаллической составляющей и 20% смазочно-охлаждающей жидкости по специальной подготовке: измельчение, промывка, обезвоживание, сушка, магнитная сепарация, восстановительный отжиг в генераторном газе. Износостойкость триботехнических пар порошковых композиционных материалов оценивали по ДСТУ 2823-94. Стендовыми экспериментальными исследованиями в условиях ограниченной подачи смазки на испытательной машине марки СМЦ-3 определена износостойкость восстановленных триботехнических пар; металлографическими исследованиями выяснены причины повышения износостойкости; исследованиями уплотняемости порошков определен состав с более высокими свойствами.

Результаты. Разработаны составы порошковых, композиционных материалов для восстановления триботехнических пар с использованием техногенных отходов и технология их нанесения на поверхности деталей. Получен износостойкий порошковый слой для восстановления деталей типа “вал”, работающий в паре с композиционным восстановительным слоем детали типа “втулка”. Изучены физико-механические характеристики восстановительного слоя изношенных поверхностей деталей типа “вал – втулка”. Определено влияние процентного содержания противозадирной добавки на износостойкость полученных материалов в условиях загрязнения угольной пылью. Предложена схема восстановления изношенных поверхностей триботехнических пар типа “вал – втулка”. Результаты исследований позволят продлить срок эксплуатации изношенных деталей, что приведет к экономии средств на замену новыми.

Научная новизна. Выявлено, что введение 15% меди в композиционный, восстановительный слой детали типа “втулка” приводит к образованию на поверхности раздела твердого и прочного неметаллического слоя, что ведет к повышению износостойкости триботехнической пары.

Практическая значимость. Предложенная схема восстановления изношенных поверхностей методом горячей радиальной штамповки порошковых материалов дает возможность утилизации техногенных отходов, продления срока эксплуатации изношенных деталей, что приводит к экономии средств на их замену.

Ключевые слова: *триботехническая пара, износостойкость, порошок, биметалл, восстановление, угольная промышленность*

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ABOUT AUTHORS

Mykola Biloshytskyi, Candidate of Technical Sciences, Associate Professor of the Department of Building, Urban and Spatial Planning, Volodymyr Dahl East Ukrainian National University, 59a Tsentralnyi Ave., 93400, Sievierodonetsk, Ukraine. E-mail: beloshitskiynik@ukr.net

Halyna Tatarchenko, Doctor of Technical Sciences, Head of the Department of Building, Urban and Spatial Planning, Volodymyr Dahl East Ukrainian National University, 59a Tsentralnyi Ave., 93400, Sievierodonetsk, Ukraine. E-mail: tatarchenkogalina@gmail.com

Nataliia Biloshytska, Candidate of Technical Sciences, Associate Professor of the Department of Building, Urban and Spatial Planning, Volodymyr Dahl East Ukrainian National University, 59a Tsentralnyi Ave., 93400, Sievierodonetsk, Ukraine. E-mail: beloshitska@ukr.net