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THE TRIBOLOGICAL CHARACTERISTICS OF THE POLYMER COMPOSITION IN THE RECIPROCATING MOTION IN THE PRESENCE OF ABRASIVE MATERIALS

CHARAKTERYSTYKI TRIBOLOGICZNE KOMPOZYTU P OLIMEROWEGO W RUCHU POSUWISTO-ZWROTNYM W OBECNOŚCI MATERIAŁÓW ŚCIERNYCH

Key words: polymer composite, solid lubricants, regeneration, sliding guides, abrasive wear.

Abstract The article presents the results of the studies of resistance to abrasive wear of regenerative chemically curable a metal–polymer composite. The metal–polymer composite is used for the regeneration of guide systems of cutting machines and the classical construction association in steel-steel sliding guides. The tribological tests were carried out using a T–17 tester in reciprocating motion for various friction node loads of the 100 N, 150 N, and 200N. The studied combinations of machine oil contaminated by grinding dust of different chemical compositions were lubricated. Based on the studies carried out, it was found that the combination of polymer-steel composite is characterized by greater abrasive wear resistance in the accepted study conditions than the steel-steel combination.

Słowa kluczowe: kompozyt polimerowy, smary stałe, regeneracja, prowadnice ślizgowe, zużycie ścierne.

Streszczenie W artykule przedstawiono wyniki badań odporności na zużywanie ścierne regeneracyjnego chemoutwardzalnego kompozytu metalopolimerowego stosowanego do regeneracji układów prowadnicowych obrabiarek skrawających oraz klasycznego skojarzenia konstrukcyjnego w prowadnicach ślizgowych stal–stal. Testy tribologiczne przeprowadzono z wykorzystaniem testera T-17 w ruchu posuwisto-zwrotnym dla różnych obciążeń węzła tarcia 100 N, 150 N i 200 N. Badane skojarzenia smarowano olejem maszynowym zanieczyszczonym pyłem szlifierskim o zróżnicowanym składzie chemicznym. Na podstawie przeprowadzonych eksperymentów stwierdzono, że skojarzenie kompozyt polimerowy–stal charakteryzuje się większą odpornością na zużycie ścierne w przyjętych warunkach badań niż skojarzenie stal–stal.

INTRODUCTION

Machine tools still dominate in the process of manufacturing machine elements. It is primarily associated with the possibility of obtaining a high accuracy of objects by cutting methods. The decisive element of machine tools is the system of forced guiding of the tool in relation to the workpiece through the use of a fence guide system.

The fence guides with the corpus are made of grey cast iron. It is the most commonly used material to produce the guides. The non-hardened cast iron guides should have a hardness of 210–240 HB. In order to increase the abrasion resistance, cast iron fence guides are surface hardened to a hardness of not smaller than 40 HRC and then ground. The machine tool construction also uses guides that are superimposed from steel slats welded to or screwed on the cast iron corpus. The guides are superimposed from 15H or 20H steel after carburizing and an achieved surface hardness of 56–62 HRC [**L. 1–5**].

In order to reduce the frictional resistance, improve the uniformity of movement (to prevent friction vibrations), and reduce the wear of sliding surfaces

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by abrasion, various types of lubrication are used. On the low sliding velocities (< 0.025 m/s) and not too abundant lubrication (e.g., capillary) in the fence guide connections, there is usually mixed friction (fence guides of feed movements). The liquid friction can only be achieved at higher sliding speeds (e.g., in the fence guides of the longitudinal planing table), provided that the lubricating grooves are properly formed. Assurance of adequate lubrication does not protect the elements of the guide pair from excessive damage. The cavities of metal processing are related to the formation of shavings and dusts, which affect the process of fence guide connections of machine tools. The result of using sliding fence guides of machine tools is the cavities of material and the accompanying change in the geometry of the system and the movement of the machine tool in relation to the workpiece. As a result, the machining accuracy and working conditions of the machine are reduced. The effects of using tribological sliding fence guides can be compensated by using plastic strips (polytetrafluoroethylene) or using shape remapping using chemically curable polymer composites [**L. 6–10**].

The aim of the work was to examine the wear resistance of polymer–steel composite and steel–steel combinations under variable load conditions lubricated with lubricating oil containing impurities in the form of grinding dust.

MATERIALS AND METHODS

The subject of the study was a metal–polymer composite on the basis of a chemically hardening epoxy resin (100 parts by weight), the filled with iron powder (Fe) with a specific chemical and granulometric composition (250 parts by weight), polyamide fibres (1 part by weight), and lubricating additives. As modifiers of tribological characteristics, composites graphite and molybdenum disulphide in a binary system were used. The selection of sliding additives with a layer structure resulted from their good tribological and physicochemical properties (they show chemical inertness, do not affect the cross–linking process of the composite, and are well wettable by the liquid polymer matrix).

The frictional-wear characteristics of the studied associations in reciprocating motion were determined using the T-17 tester (**Fig. 1**). The basic element of the tester is the model friction node shown in **Figure 1b**. This tester consists of a fixed steel mandrel with a hardness of 30 HRC, pressed by normal force FN to the plate performing a reciprocating motion with a specific frequency and amplitude. A metal–polymer composite layer was applied and hardened on the metal plate and then shaped by grinding to the specified size required for the tester. The device is equipped with a computer system for recording and archiving

a) b)

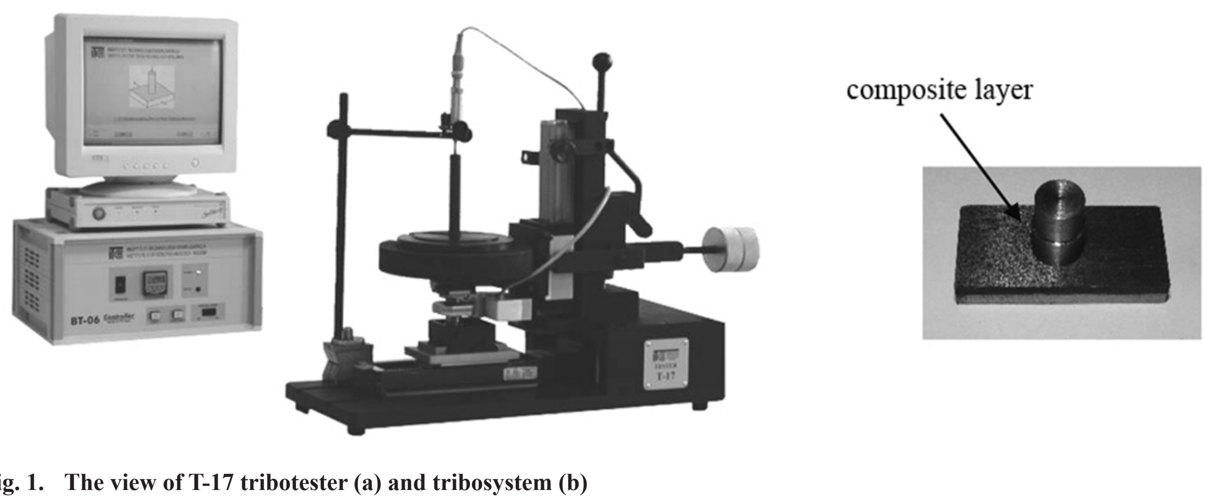

Fig. 1. The view of T-17 tribotester (a) and tribosystem (b)
Rys. 1. Widok testera tribologicznego T-17 (a) i skojarzenia badawczego (b)

measurement results. The assessment of the durability of the model friction node was based on the measurements of the total linear wear of the model friction node.

The methodology of tribological tests consisted of the following: cooperation of steel plate (size 36×17 mm) with applied, hardened, and processed layer of a metalopolymer composite (thickness 2 mm) with a steel mandrel (ø9 mm) with a hardness of 30–40 HRC. The study was carried out in the following conditions: sliding reciprocating motion, decomposed contact, constant pressure during the tests, amplitude 25 mm, frequency 1 Hz, the number of cycles 20 000, lubrication with machine oil contaminated with grinding dust coming from the machining of metal elements. The concentration of dust in the lubricating oil was 1% m/m. During the tests, the following data was recorded: the friction force, the ambient temperature of the friction node, the number of cycles (friction path), and the linear wear of the friction node. The studies were carried out for the loads of friction node characteristic for the fence guide systems of machine tools of 100 N, 150 N, and 200 N. For comparative purposes, the frictional and wear characteristics were also determined under the same conditions. The associations of steel and steel elements are made of alloy steel thermally improved to 30 HRC hardness.

RESULTS

A scanning electron microscope was used to determine the morphology and elemental composition of metallic dust coming from the machining of grinding of metal elements (**Table 1**). On the basis of the presented photograph (**Fig. 2**), we can declare that they mostly are multi–walled shapes with irregular shape, and there are also balls with different radii.

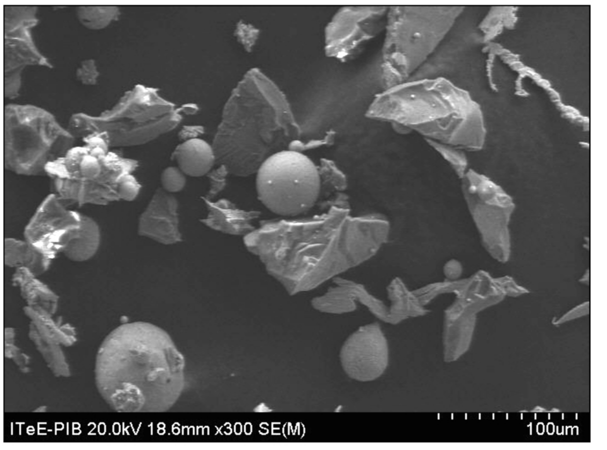

Fig. 2. The microscopic photograph of the grinding dust used in the tests
Rys. 2. Obraz mikroskopowy pyłu szlifierskiego zastosowanego w badaniach

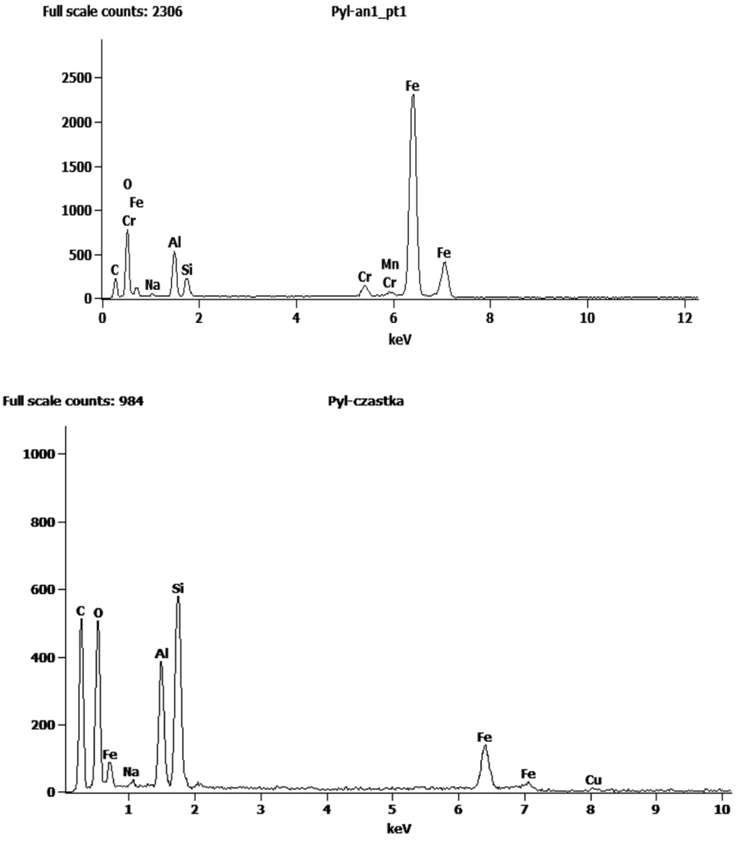

Fig. 2a. The EDS spectra of grinding dust used in tests
Rys. 2a. Widma EDS pyłu szlifierskiego zastosowanego w badaniach

The main components of metallic contaminations are iron, carbon, silicon, and oxygen. However, there are also soft metals such as copper and aluminium, which may come from the machining of parts or are the product of grinding wheels. The main component of the grinding wheels next to the silicon carbide is corundum (aluminium oxide) and an organic adhesive in the form of synthetic resin. In the spectrum of EDS (**Fig. 2a**), there are also peaks characteristic of chromium and manganese.

Table 1. The chemical composition of the grinding dust used
Tabela 1. Skład chemiczny zastosowanego pyłu szlifierskiego

Element	C	O	Na	Al	Si	Fe	Cu	Amount
Contents [%]	32.1	36.9	0.5	6.9	11.7	10.8	1.1	100

Figures 3–6 present exemplary courses of changes in the coefficient of friction and wear of the polymer–steel composite and steel–steel associations.

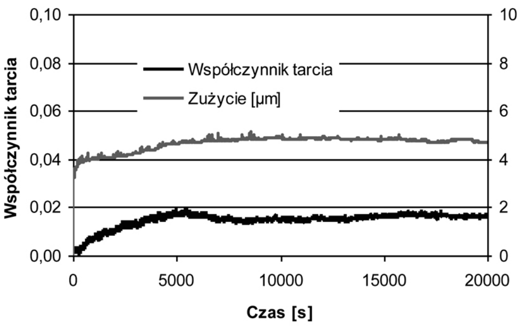

Fig. 3. The course of changes in coefficient of friction and wear of the composite – steel associations, lubricated with oil contaminated with grinding dust, the load of the node 150 N
Rys. 3. Przebieg zmian współczynnika tarcia i zużycia skojarzenia kompozyt–stal, smarowanego olejem zanieczyszczonym pyłem szlifierskim – obciążenie węzła 150 N

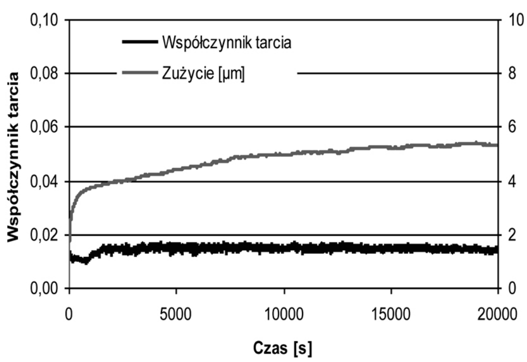

Fig. 4. The course of changes in the coefficient of friction and wear of the composite – steel associations, lubricated with oil contaminated with grinding dust, the load of the node 200 N
Rys. 4. Przebieg zmian współczynnika tarcia i zużycia skojarzenia kompozyt–stal, smarowanego olejem zanieczyszczonym pyłem szlifierskim – obciążenie węzła 200 N

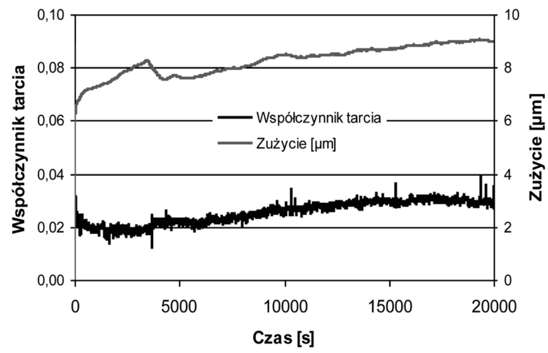

Fig. 5. The course of changes in the coefficient of friction and wear of the steel – steel association, lubricated with oil contaminated with grinding dust, the load of the node 150 N
Rys. 5. Przebieg zmian współczynnika tarcia i zużycia skojarzenia stal–stal, smarowanego olejem zanieczyszczonym pyłem szlifierskim – obciążenie węzła 150 N

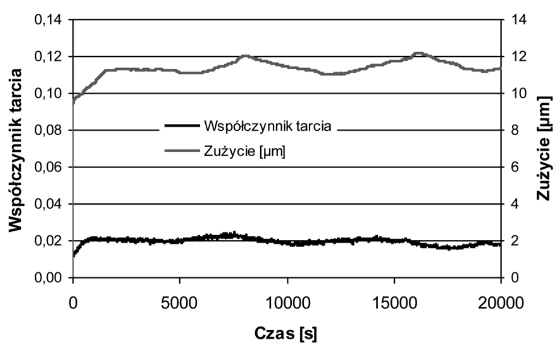

Fig. 6. The course of changes in the coefficient of friction and wear of the steel – steel association, lubricated with oil contaminated with grinding dust, the load of the node 200 N
Rys. 6. Przebieg zmian współczynnika tarcia i zużycia skojarzenia stal–stal, smarowanego olejem zanieczyszczonym pyłem szlifierskim – obciążenie węzła 200 N

On the basis of the frictional wear characteristics, it can be concluded that the combination of polymer composite–steel is characterized by a stabilized and lower coefficient of friction in all test ranges than the steel–steel association. In the case of a polymer composite, the increase of load friction node does not change the resistance to motion.

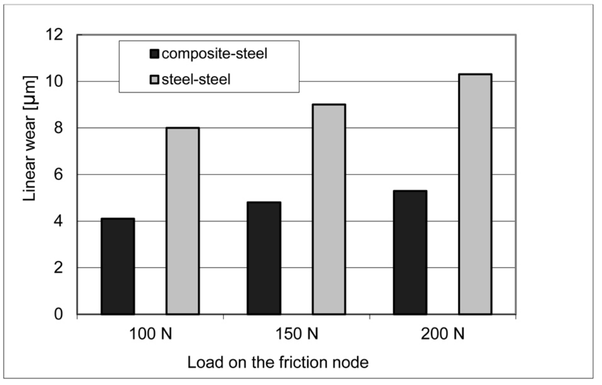

Fig. 7. The linear wear of the composite polymer–steel association and steel–steel lubricated with oil contaminated by grinding dust

Rys. 7. Zużycie liniowe skojarzenia kompozyt polimerowy–stal oraz stal–stal smarowanego olejem zanieczyszczonym pyłem szlifierskim

Figure 7 graph shows that the linear wear of friction is apparent and that the association of a steel plate with a regenerative layer of a polymer composite and the mandrel steel has higher (about 2 times) resistance to wear in the presence of abrasive material suspended in the lubricating oil than conventional association of steel–steel. The 200% increase in the load on the friction node does not cause a sudden increase in wear both for the associations of the polymer composite and the steel as well as the steel–steel associations.

THE RESULTS OF SURFACE MICROSTRUCTURE TESTS

The scanning electron microscope was used to assess the state of the surface layer of the composite and steel after their friction cooperation. **Figs. 8** and **9** show a photograph of the surface of the tile with applied composite layer and steel tile after friction – wear tests. The area on the right side of the line shows the area covered by the friction. On the left, the photograph shows the surface of the samples outside the friction area.

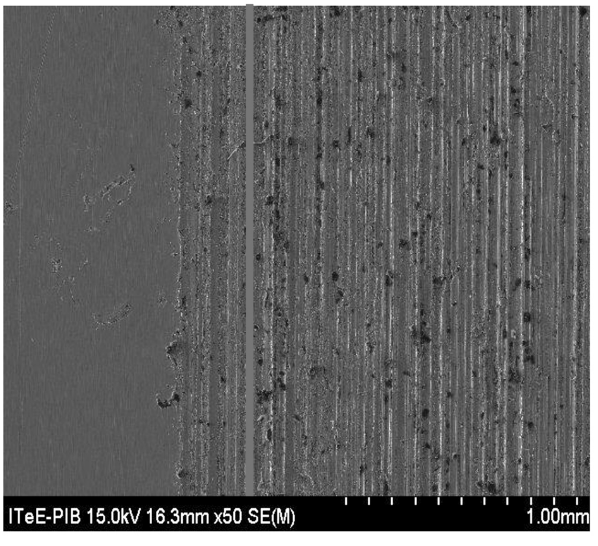

Fig. 8. The photograph of the steel plate surface after tribological tests

Rys. 8. Obraz powierzchni płytki stalowej po badaniach tribologicznych

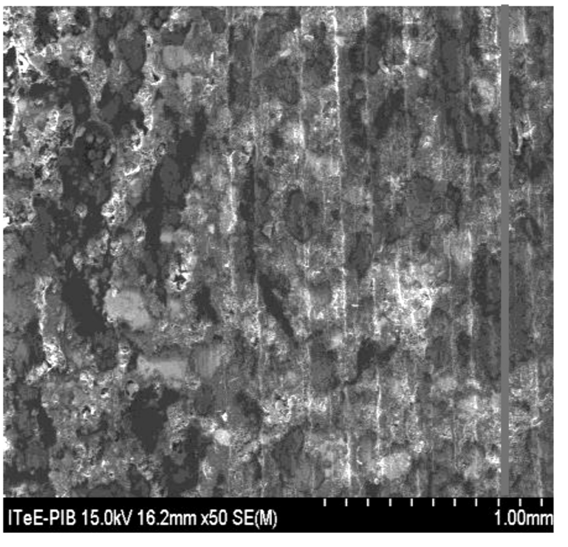

Fig. 9. The photograph of the composite surface after tribological tests

Rys. 9. Obraz powierzchni kompozytu po badaniach tribologicznych

Distinct cracks characteristic of the abrasive wear are apparent in the microscopic photograph of both the steel plate surface and the composite material. However, loose abrasive particles are found in the area of friction. On the microscopic photograph of the surface of the polymer composite, the size of the traces of the action of the abrasive particles is smaller than in the case of the steel plate. The polymer composite material has a much lower hardness than steel plates.

CONCLUSIONS

The resistance to abrasive wear of typical construction materials depends mainly on their hardness. The increased hardness means better wear resistance. The polymer composites are characterized by much lower hardness than steel. However, their wear is smaller in the presence of abrasive materials as demonstrated in the study than the steel sample. This effect results from the considerable difference in the hardness of the composite material layer on the steel plate and the steel mandrel cooperating with it. The lower hardness of the composite causes the abrasive particles to attach to its surface layer. The particles form a layer consisting of composite components and abrasive particles with relatively high wear resistance. The composition of grinding dust is very diverse. It also contains particles of soft metals or their alloys that may additionally have a positive effect on the process of friction and the wear of composite–steel.

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