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PROBLEMS OF TRIBOLOGIC CHARACTERIZATION OF SHOE – WALKING SURFACE FRICTION PAIRS

PROBLEMY TRIBOLOGICZNEGO CHARAKTERYZOWANIA SKOJARZEŃ OBUWIE–PODŁOŻE

Key words: friction coefficient, functional additives, shoe sole, surface free energy.

Abstract Tribological characteristics of shoe sole in a friction pair with the walking surface are important parameters due to the safety of shoe exploitation and time of its durability. The footwear industry methods of analysing friction coefficient are obsolete, and, on the other hand, modern tribological equipment that allows credible results requires long data processing. The authors suggest using a previously developed formula that binds tribological characteristics with energetic condition of the walking surface. By doing so, this formula evaluates the force of friction and wear of shoe – walking surface pair. It may shorten the time needed to evaluate the basic parameters of shoe exploitation in variable conditions of their utilization and, thus, contribute to the formulation of material resolutions aiming to improve the quality of shoe usage while reducing the costs of performing required examinations.

Słowa kluczowe: współczynnik tarcia, dodatki funkcjonalne, materiał spodowy, swobodna energia powierzchniowa.

Streszczenie Charakterystyki tribologiczne podeszew obuwia w skojarzeniu z podłożem są parametrami istotnymi z punktu widzenia bezpieczeństwa jego użytkowania oraz czasu eksploatacji. Metody badania współczynnika tarcia i zużycia stosowane w przemyśle obuwniczym są przestarzałe, natomiast nowoczesne urządzenia tribologiczne pozwalające na otrzymywanie wiarygodnych wyników badań wymagają długich, wielogodzinnych biegów badawczych. Autorzy sugerują wykorzystanie reguły wiążącej charakterystyki tribologiczne z energetycznym stanem powierzchni trących do określania wielkości siły tarcia i zużycia skojarzenia podeszwy obuwniczej z podłożem. Może to pozwolić na skrócenie czasu potrzebnego do określenia podstawowych parametrów eksploatacyjnych obuwia w zmiennych warunkach eksploatacji, przyczyniając się do opracowywania rozwiązań materiałowych ukierunkowanych na poprawę jakości obuwia przy znaczącej redukcji niezbędnych do tego kosztów badań.

INTRODUCTION

Friction between a shoe and walking surface is quite commonly neglected when choosing materials for the shoe sole. The reason behind that is the lack of fast and reliable methods of the evaluation of friction characteristics of consumable shoe sole materials in a friction pair with the walking surface. The possible consequence includes the lack of effective counteracting slippage, which decreases comfort of the shoe usage, but also impedes its safety [**L. 1–7**].

The process of friction between a shoe and a walking surface depends on shoe sole material, specifically, its chemical and physical structure, physical properties, surface structure, temperature, type of walking surface, as well as the type and thickness of the layer separating rubbing surfaces, e.g., water, ice, snow, dust, or oil. Friction also depends on shoe construction, particularly the profile of the shoe sole, the shape of the heel, and thickness of the sole, and also on the type of exploitation (speed of movement and weight of the load) [**L. 6–9**]. This great number of factors affecting a shoe during

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its use sets the importance of methods of evaluation of tribological characteristics of shoe sole materials in pair with a walking surface. Currently used analysis equipment in the footwear industry is characterized by low accuracy, and modern and precise apparatus employed in different fields requires long-term measurements. In this case, the formula developed by authors may be advantageous. It describes the activity of polymer – metal friction knots based on composites of their surface free energy. Using this formula to determine tribological characteristics of shoe sole – walking surface pair may contribute to the dissemination of an easy-to-use method of the optimization of the process of the choice of materials for shoe soles. It may also provide a basis for systematic approach to the friction-usage research of shoe materials.

MATERIAL AND METHODS

Test samples, which were the subjects of evaluation, were made of natural leather cut from industrial shoe soles from locations of equal thickness, and they were fixed to the sample holder. Counter-samples, made of concrete, were cut from usual walking surface materials used in architecture.

Tribological evaluations were made on a testing rig T-15 (**Fig. 1**) and consisted of rubbing the samples and counter-samples on a defined path in specific conditions (load and sliding speed) in dry friction, and in presence of water (submersion lubrication), while continuously registering movement resistance.

Control was made by tribological experiments with the use of samples made from evaluated materials and counter-samples that were ceramic and wooden. Experiments were conducted at room temperature in the following parameters of friction knots:

- Sliding speeds = 27m/s, 0.40 m/s, and 0.53 m/s;
- Friction distance = 250 m; and,
- Load of friction knot = 0.06 MPa.

The following parameters were registered during test runs:

- The force of friction, and
- The distance of friction (time).

The arithmetic mean of at least three tests composed a basis for the evaluation of friction-usage endurance. Results requiring exclusion due to Dixon statistic tests were not included.

Sliding speed of the evaluated pair depends on rotation speed, which was chosen so that linear speed corresponds to the speed of movement of people with motor organ injuries (minimal sliding speed) as well as people walking in a regular fashion (maximal sliding speed). The load of a friction knot corresponds to the usual surface pressure applied by a human on a walking surface.

Fig. 1. T-15 Testing rig
Rys. 1. Stanowisko badawcze T-15

RESULTS AND DISCUSSION

Results of tribological evaluations of analysed pairs in different sliding speeds are presented in **Figs. 2** through **5**. It is worth mentioning that, for a friction pair in dry conditions, increase of sliding speed was associated with the increase of the friction coefficient (**Fig. 2**). Only sole material has such a feature. It is observed that, for all types of artificial sole materials, the coefficient of friction decreases with the increase in sliding speed, which impedes the safety of shoe usage. [**L. 1**]. In case of leather and walking surface friction pair in wet conditions, the increase in sliding speed resulted in a decrease in the friction coefficient **(Fig. 3)**.

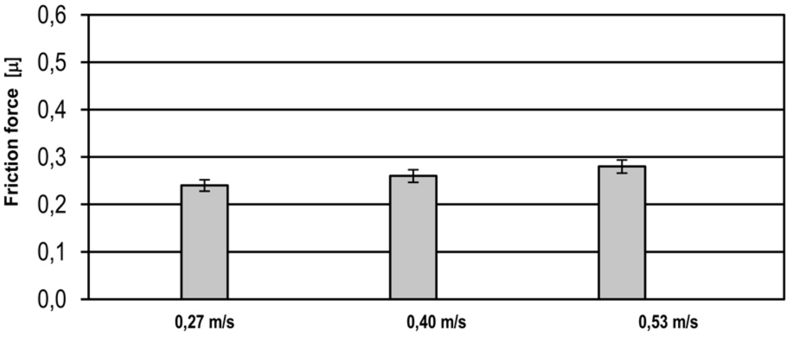

Fig. 2. Average values of friction force for dry tested pairs natural leather -concrete for three sliding speed

Rys. 2. Średnie wartości współczynnika tarcia skojarzenia spodowej skóry naturalnej z betonem w warunkach tarcia technicznie suchego dla trzech prędkości poślizgu

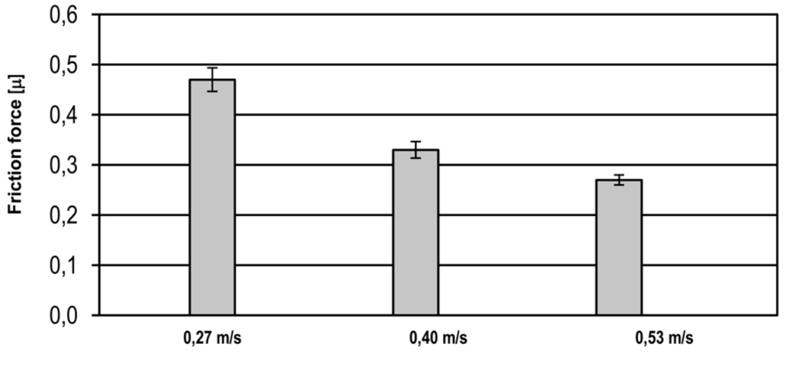

Fig. 3. Average values of friction force for wet tested pairs natural leather - concrete for three sliding speed

Rys. 3. Średnie wartości współczynnika tarcia skojarzenia spodowej skóry naturalnej z betonem w obecności wody dla trzech prędkości poślizgu

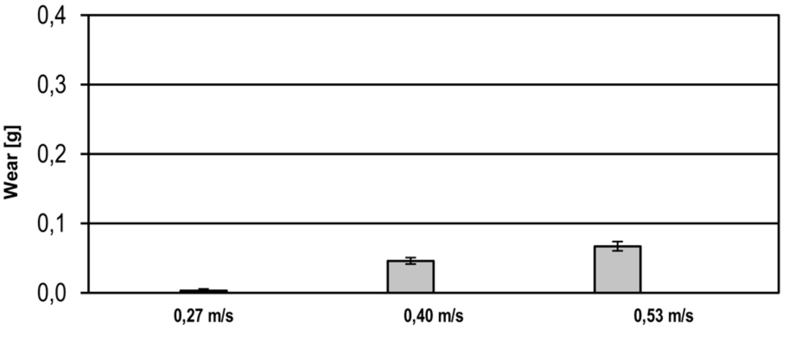

Fig. 4. Average values of wear for dry tested pairs natural leather - concrete for three sliding speed

Rys. 4. Średnie wartości zużycia wagowego skojarzenia spodowej skóry naturalnej z betonem w warunkach tarcia technicznie suchego dla trzech prędkości poślizgu

The smallest wear was present in dry conditions with minimal speed, and the highest was found with the equal speed in wet conditions **(Fig. 4** and **Fig. 5)**.

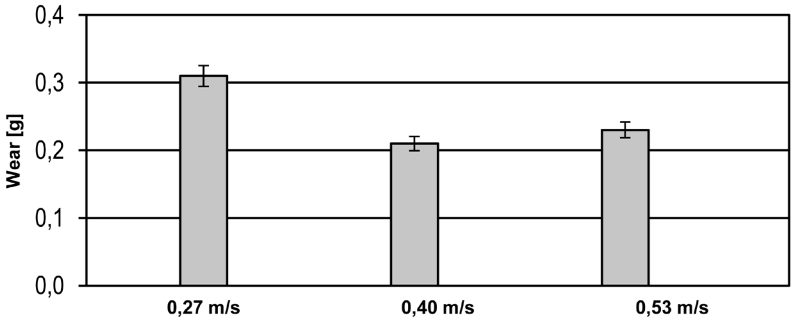

Fig. 5. Average values of wear for wet tested pairs natural leather – concrete for three sliding speed

Rys. 5. Średnie wartości zużycia wagowego skojarzenia spodowej skóry naturalnej z betonem w obecności wody dla trzech prędkości poślizgu

Conducted tribological evaluations are time-consuming and require tests that last for many hours Due to large number of variations of pairs of artificial shoe sole materials and different types of walking surfaces, evaluating all of them is an expensive and meticulous process. The authors suggest using an earlier described formula that binds tribological characteristics (wear and force of friction) with the sum of polar compositors of surface free energy, with the latter being tested for polyamide-metal friction knots. Exemplary results, demonstrating this relationship, are illustrated in **Fig. 6**, according to [**L. 10**].

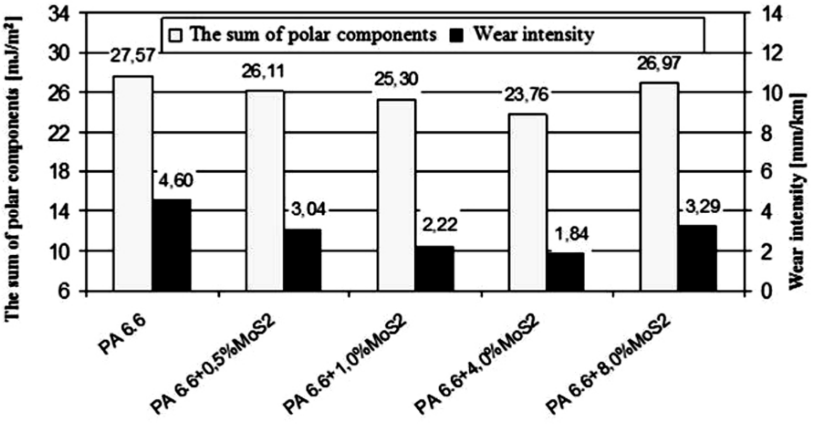

Fig. 6. The sum of polar components and wear intensity for tested polymers PA6.6 with modified MoS2 and 56100 steel

Rys. 6. Zestawienie składowej polarnej i intensywności zużycia dla badanych polimerów PA6.6 z dodatkiem MoS2 współpracujących ze stalą ŁH15

Using previously described formulae would allow one to preliminarily select materials for shoe sole based on relationship between tribological characteristics and energy state surface friction knots on the basis of quick and affordable (as compared to tribological evaluations) tests of wetting angle. Previous results indicate that further research may validate the proposed approach.

CONCLUSIONS

Based on conducted tribological evaluations, wear and mean friction coefficients for leather shoe sole and concrete friction pair were evaluated. Tests were undertaken in technically dry conditions and water lubricated conditions for three sliding speeds. Results confirmed that natural leather is a very good material for shoe sole. For instance, in presence of water, it had a similar or even higher friction coefficient, as compared to dry friction, for the whole spectrum of analysed sliding speeds. It is a key characteristic impacting the safety of shoe exploitation, especially crucial for elderly people or those with motor organ injuries.

The intensity of wear of natural leather in a friction pair with a concrete surface is minor at small sliding speeds but increases quickly at higher speeds. The presence of water negatively affected the wear of natural leather in the friction pair with concrete.

Safety and comfort of usage of shoes requires sole materials to be characterized by high friction coefficients regardless of the conditions of exploitation. Type of sole material should be chosen for a walking surface with a purpose and an age group of intended users in mind. It requires many tests to select the most advantageous material pair. For that reason, the method suggested by the authors for the preliminary choice of material for a shoe sole may be very useful in shoe sole evaluations. It includes the specific type of walking surface, based on formulae that binds tribological characteristics with energetic condition of the surface friction knots, on the basis of quick and affordable (as compared to tribological evaluations) tests of wetting angle.

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