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IMPACT OF SLIP SPEED ON THE WEAR INTENSITY OF 38GSA AND HARDOX 500 STEELS

WPŁYW PRĘDKOŚCI POŚLIZGU NA INTENSYWNOŚĆ ZUŻYWANIA ŚCIERNEGO STALI 38GSA I HARDOX 500

Key words: slip speed, abrasive wear, wear intensity.

Abstract The study shows the results of experimental tests on the wear intensity of 38GSA and Hardox 500 steels in combination with a silicate material in relation to the slip speed. In order to reflect the actual working conditions, the counter sample was cut out of a 1NF class 15 silicate brick. The granulometric composition of the sand-lime mixture ranges from 0.1 to 5 mm. Slip speeds were selected to be close to the real conditions in which construction products and aggregates are transported.

Słowa kluczowe: prędkość poślizgu, zużycie ścierne, intensywność zużywania.

Streszczenie W pracy przedstawiono wyniki badań eksperymentalnych dotyczących intensywności zużywania stali Hardox 500 i 38GSA w skojarzeniu z materiałem silikatowym w zależności od prędkości poślizgu. Aby oddać rzeczywiste warunki pracy, przeciwpróbka została wycięta z cegły silikatowej 1NF klasy 15. Skład granulometryczny mieszanki wapienno-piaskowej zawiera się w przedziale od 0,1 do 5 mm. Prędkości poślizgu dobrano tak, aby były zbliżone do realnych warunków, w których transportowane są wyroby budowlane i kruszywa.

INTRODUCTION

Abrasive wear processes are present in many industrial fields. They have a significant influence on production profitability and reliability of technological lines **[L. 1]**. One of the examples is the production of construction products (i.e. silicate bricks) or the transportation of different types of aggregates, gravels, and sands. Small grains of sand or sand-lime mixtures (in case of silicate products) coming into contact with steel cause intensive abrasion **[L. 12]**. There are many methods of increasing the resistance to abrasive wear, such as **[L. 2, 5, 8, 10]**: thermochemical treatment, hardfacing, using wear-resistant steel, and lubrication. However, they cannot be used in all cases. Some production processes can be optimized in terms of abrasion intensity by changing parameters (i.e. slip speed), which will not significantly affect the capacity in a negative way, but it can reduce the wear intensity **[L. 7, 11]**.

The study shows the influence of slip speed on abrasive wear intensity. A friction pair consisted of steels from a wear-resistant family (38GSA, Hardox 500) and silicate, which is a material produced from a concentrated sand-lime mixture in an autoclaving process. These combinations occur, e.g., in facade facing tile production, or in building material transportation (**Fig. 1**).

Fig. 1. View of transporting the building materials
Rys. 1. Widok linii transportującej wyroby budowlane

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The tests performed gave us new knowledge on the influence of slip speed on the wear intensity of the tested steels. Using proper materials and slip speed may allow working elements to work longer without introducing design changes.

TESTING METHODOLOGY

The steels selected for testing were 38GSA and Hardox 500. They are a part of a wear-resistant family **[L. 3, 4]**. For an accurate characterization, tensile tests were performed using a durability testing machine MTS 322 Test Frame located at the Faculty of Mechanical Engineering in Bialystok University of Technology. Three samples of each type of steel were used for tensile testing. The average results are shown in **Table 1**.

Table 1. Mechanical properties of tested materials
Tabela 1. Właściwości mechaniczne badanych materiałów

No.	Tested materials	Mechanical properties			
		R_e [MPa]	R_m [MPa]	E [GPa]	Hardness HV20
1	38GSA	426	723	205	221
2	Hardox 500	1336	1623	204	511

The mechanical properties of both steels are different. The yield strength of Hardox 500 steel is approximately 3 times higher than the yield strength of 38 GSA steel.

To represent the real working conditions, a disc cut out of a silicate brick was used as a counter sample, type 1NF class 15 (**Fig. 2a**). A view of a brick and a counter sample cut out of it is shown in **Fig. 2b**.

a) b)

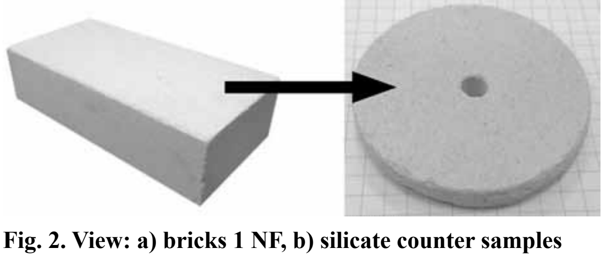

Fig. 2. View: a) bricks 1 NF, b) silicate counter samples
Rys. 2. Widok: a) cegły 1 NF, b) przeciwpróbki silikatowej

The surface of the counter sample touching the steel sample was the external wall of the silicate brick. The granulometric composition of the sand-lime mixture used to produce the brick ranged from 0.1 to 5 mm.

Tests were performed on a T-11 pin-on-disk testing machine (**Fig. 3**). It allows determining the basic tribological characteristics (friction force, friction coefficient, wear intensity).

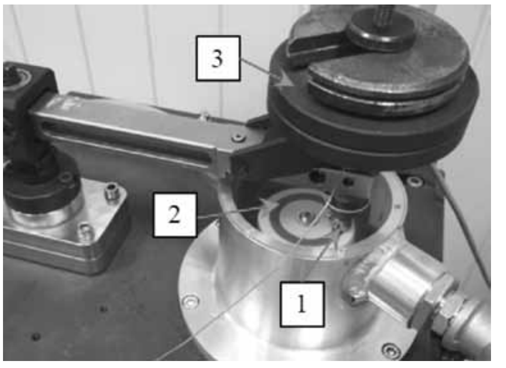

Fig. 3. Tribological, pin-on-disk test stand type T-11: 1 – steel sample, 2 – silicate counter sample, 3 – load
Rys. 3. Stanowisko do badań tribologicznych typu trzpie––tarcza T-11: 1 – próbka stalowa, 2 – przeciwpróbka silikatowa, 3 – obciążenie

Due to a brief contact of transported building materials with the wearable surfaces, the test time was set to 20 minutes. Three different slip speeds were assumed: v_p = 0.15 m/s, 0.3 m/s, and 0.45 m/s. In all tests, the sample was loaded with the force P = 10 N. The friction force T was recorded during the experiment, which allowed the friction coefficient μ to be determined.

$$\mu = \frac{T}{P} \tag{1.1}$$

where T – friction force, P – load of a steel sample, perpendicular to the silicate disc surface (counter sample shown on **Fig. 4b**).

The steel sample (**Fig. 4a**) had a diameter of 6 mm, and the silicate counter sample (Fig. 4B) had a diameter of 55 mm.

a) b)

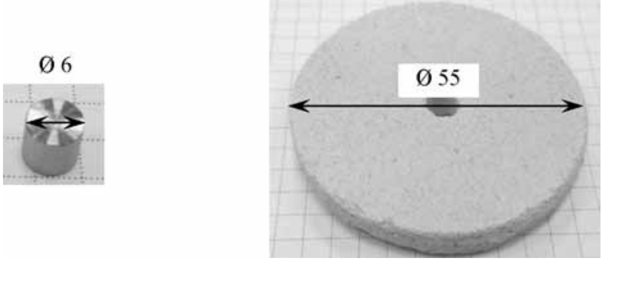

Fig. 4. View before the test: a) samples, b) counter samples
Rys. 4. Widok przed testem: a) próbki, b) przeciwpróbki

Measurements of sample mass before and after testing allowed the determination of wear intensity according to the following formula:

$$I = \frac{M_1 - M_2}{SF} \left[\frac{mg}{m^3}\right] \tag{1.2}$$

where M_1 and M_2 – sample mass before and after friction testing [mg], S – friction distance [m], F – sample section surface [m^2].

A photograph of the sample and counter sample after testing is shown in **Fig. 5**.

a) b)

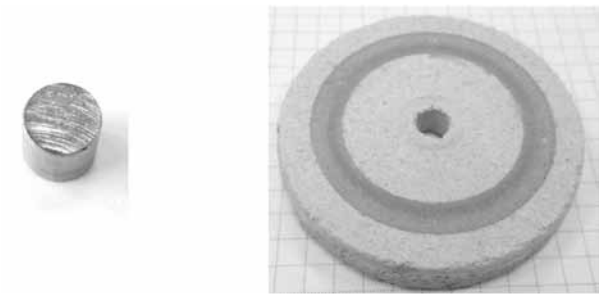

Fig. 5. View after the test: a) samples, b) counter samples
Rys. 5. Widok po teście: a) próbki , b) przeciwpróbki

TEST RESULTS AND ANALYSIS

There were three friction trials of the tested steels for three slip speeds (0.15 m/s, 0.3 m/s, 0.45 m/s). Based on the results, an average value of friction coefficient was established **[L. 6, 9]**. **Figures 6** to **11** show example graphs presenting a curve of the friction coefficient of the tested steels for different slip speeds.

Average values of coefficients obtained from tests are shown in **Table 2**.

During the experiment, the (steel) samples were weighed before and after testing. Based on the mass loss, the wear intensity of the tested materials depending on the slip speed was determined (Formula 1.2). A comparison of the obtained values is shown in **Fig. 12**.

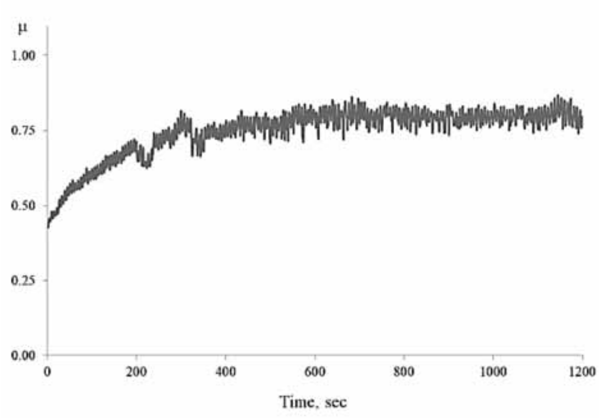

Fig. 6. Friction coefficient graph, Hardox 500, v_p = 0.15 m/s
Rys. 6. Wykres współczynnika tarcia, Hardox 500, v_p = 0,15 m/s

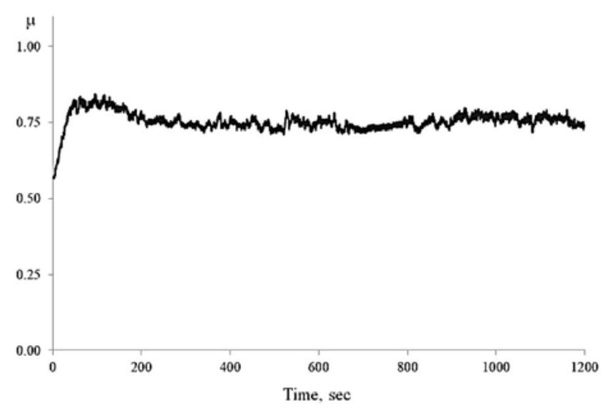

Fig. 7. Friction coefficient graph, 38GSA, v_p = 0.15 m/s
Rys. 7. Wykres współczynnika tarcia, 38GSA, v_p = 0,15 m/s

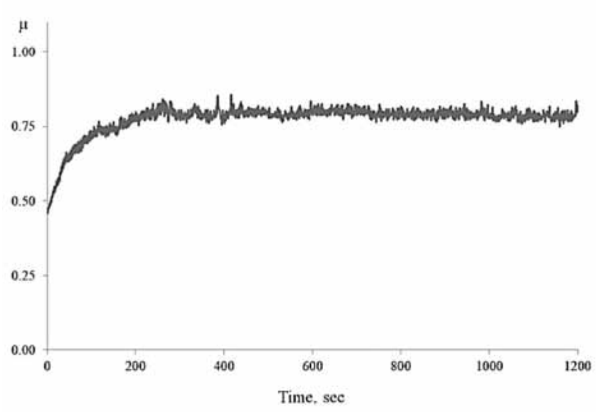

Fig. 8. Friction coefficient graph, Hardox 500, v_p = 0.3 m/s
Rys. 8. Wykres współczynnika tarcia, Hardox 500, v_p = 0,3 m/s

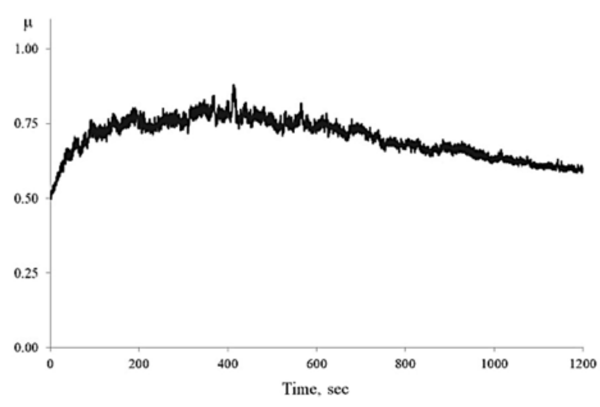

Fig. 9. Friction coefficient graph, 38GSA, v_p = 0.3 m/s
Rys. 9. Wykres współczynnika tarcia, 38GSA, v_p = 0,3 m/s

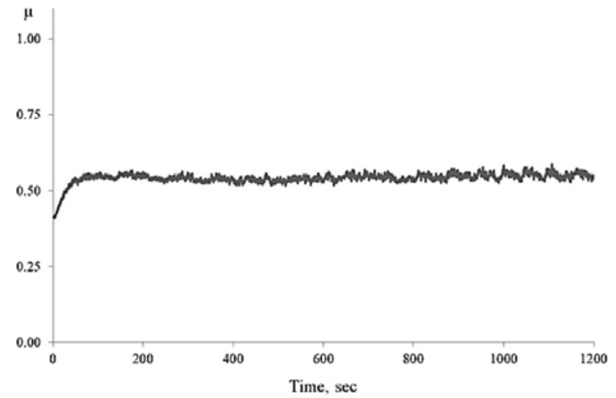

Fig. 10. Friction coefficient graph, Hardox 500, v_p = 0.45 m/s
Rys. 10. Wykres współczynnika tarcia, Hardox 500, v_p = 0,45 m/s

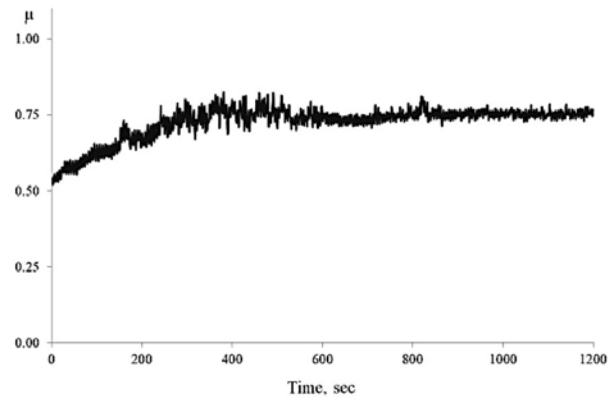

Fig. 11. Friction coefficient graph, 38GSA, v_p = 0.45 m/s
Rys. 11. Wykres współczynnika tarcia, 38GSA, v_p = 0,45 m/s

Table 2. A comparison of the friction coefficients of the tested steels depending on the slip speed
Tabela 2. Zestawienie współczynników tarcia badanych stali dla różnych prędkości

		v_p = 0.15 m/s	v_p = 0.3 m/s	v_p = 0.45 m/s
Hardox500	Friction coefficient, μ	**0.75**	**0.77**	**0.54**
38GSA		**0.75**	**0.70**	**0.72**

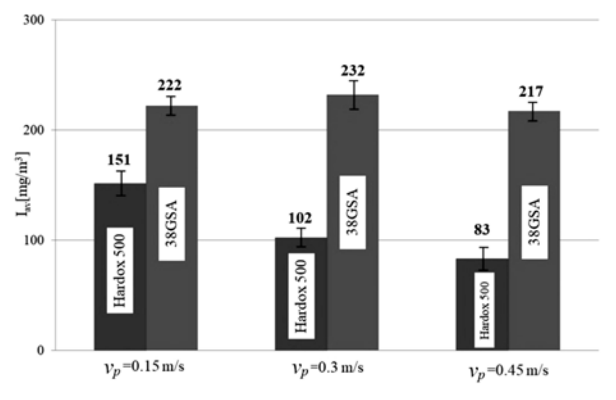

Fig. 12. Composition of wear intensity with standard deviation of steel: Hardox 500 and 38GSA
Rys. 12. Zestawienie intensywności zużywania z odchyleniem standardowym dla stali: Hardox 500 i 38GSA

The increase of slip speed results in an increase in friction distance and mass loss. Formula 1.2 allows one to determine the wear intensity taking both of these factors into account. It was observed that, for Hardox 500 steel, the increase of slip speed results in a decrease in wear intensity. A triple increase in slip speed results in a wear intensity decrease of approximately 45%. For 38GSA steel, the wear intensity is on a similar level regardless of slip speed. For the highest tested slip speeds, v_p = 0.45 m/s, the wear intensity of 38GSA steel is over two times higher than of Hardox 500 steel.

CONCLUSION

The results obtained show that, for Hardox 500 steel, for the applied slip contact parameters, the increase in slip speed results in a decrease in wear intensity. A double increase in slip speed results in a wear intensity decrease of approximately 30%, and triple increase in slip speed results in a wear intensity decrease of approximately 45%. For 38GSA steel, the wear intensity is similar regardless of slip speed.

Hardox 500 steel is characterized by its high hardness (511 HV20) and higher values of yield strength and tensile strength. During the tests, Hardox steel was subjected to a small load (10N), which, along with the increase in slip speed, may have had an influence on the decrease in wear intensity due to pulled out sand grains (from silicate counter sample) being thrown out of the contact area. This may be the cause of a significant drop in the friction coefficient for the slip speed of v_p = 0.45 m/s.

Based on the results obtained, it can be concluded that the increase in slip speed in sliding contact does not result in an increase of wear intensity, and in some cases (Hardox 500 steel), it even leads to its decrease. In the future, it is recommended to expose the steels in question to a higher load in relation to slip speed.

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