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Andrzej Posmyk[1]*, Jerzy Myalski[2]

[1] Silesian University of Technology, Faculty of Transport and Aviation Engineering, ul. Z. Krasińskiego 8, 40-019 Katowice, Poland
[2] Silesian University of Technology, Faculty of Material Engineering, ul. Z. Krasińskiego 8, 40-019 Katowice, Poland
**Corresponding author. E-mail: andrzej.posmyk@polsl.pl*

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INFLUENCE OF BASALT PARTICLES ON TRIBOLOGICAL PROPERTIES OF POLYMERIC COMPOSITES INTENDED FOR FRICTION CONTACTS IN MEANS OF TRANSPORT

The article presents the basics of the production and the results of tribological tests of a composite with an epoxy resin matrix with increased elasticity (Havel LGH 288) containing basalt particles (BP) in the amount of 20, 30 and 40 wt.% as the reinforcing phase, for friction elements of technical means of transport. Comparative tests were performed on a T-01 tribological tester at ambient temperature with pressure p = 5 MPa and relative speed v = 1 m/s, friction distance s = 1000 m. The tester reproduces the brake pad/disc contact. As a result of the tests, it was found that the developed composite material can rubbing against GJL-250 cast iron used for brake discs. The coefficient of friction in the contact stabilizes after running-in of the contact regardless of the particle content (μ = 0.5). The wear of the composite brake pad decreases, and the wear of the cast iron disc increases along with the content of basalt particles. The reason for such tribological properties is the high hardness of the basalt. The basalt particles cutting the cast iron intensify its wear. Their surface after running-in increases the actual contact area, which reduces the coefficient of friction. The matrix wear debris is deposited on the surfaces of the basalt particles. The heat generated by friction causes a local temperature increase on the basalt particles coated with wear debris, which results in a decrease in the coefficient of friction to 0.5, regardless of the BP content.

Keywords: transport, basalt particles, fiction in air, frictional brakes, vehicles

WPŁYW CZĄSTEK BAZALTOWYCH NA WŁAŚCIWOŚCI TRIBOLOGICZNE KOMPOZYTÓW POLIMEROWYCH PRZEZNACZONYCH DO SKOJARZEŃ CIERNYCH ŚRODKÓW TRANSPORTU

Przedstawiono podstawy wytwarzania i wyniki badań tribologicznych kompozytu przeznaczonego na elementy cierne technicznych środków transportu kompozytu z osnową z żywicy epoksydowej o podwyższonej elastyczności (Havel LGH 288) zawierającej jako fazę umacniającą cząstki bazaltowe (BP) w ilości 20, 30 i 40% wagowych. Wykonano badania porównawcze na testerze tribologicznym T-01 w temperaturze otoczenia przy nacisku p = 5 MPa i prędkości względnej v = 1.0 m/s, droga tarcia s = 1000 m. Tester odtwarza pracę skojarzenia klocek hamulcowy/tarcza. W wyniku przeprowadzonych badań stwierdzono, że opracowany materiał kompozytowy może współpracować z żeliwem GJL-250 stosowanym na tarcze hamulcowe. Współczynnik tarcia w skojarzeniu stabilizuje się po dotarciu skojarzenia niezależnie od zawartości cząstek (μ = 0.5). Zużycie kompozytowego klocka hamulcowego maleje, a tarczy żeliwnej rośnie wraz z zawartością cząstek bazaltowych. Przyczyną takich właściwości tribologicznych jest duża twardość bazaltu. Cząstki bazaltowe, skrawając żeliwo, intensyfikują jego zużycie. Ich powierzchnia po dotarciu zwiększa rzeczywistą powierzchnie styku, co zmniejsza współczynnik tarcia. Produkty zużycia osnowy są osadzane na powierzchniach cząstek bazaltu. Ciepło generowane tarciem powoduje lokalny wzrost temperatury na cząstkach bazaltu pokrytych produktami zużycia, co skutkuje spadkiem współczynnika tarcia do wartości 0,5 niezależnie od zawartości BP.

Słowa kluczowe: transport, cząstki bazaltowe, tarcie technicznie suche, hamulce cierne, pojazdy

INTRODUCTION

Basalt fibers and particles are increasingly used in the production of machine parts and devices due to their interesting properties such as [1-3]:
- low density (particles 1200 kg/m^3, fibers 2550÷÷2670 kg/m^3);
- wide application temperature range −260÷400°C;
- low thermal conductivity 0.031÷0.038 W/(mK);
- low thermal expansion ($3.5 \cdot 10^{-6}$);
- favorable price of particles (0.5 Euro/kg) compared to R glass fibers (15 Euro/kg);
- low impact on the environment due to their natural origin; the particles contain up to 60% SiO_2 and to 20% Al_2O_3.

These fibers and particles can be embedded in phenolic, polypropylene, polyamide, polyester epoxy and polycarbonate resins, which allows the production of composites with a wide range of properties and applications. Basalt fibers and particles can be coated with silanes, which facilitates binding to matrix materials during composite production.

Due to their content of hard components such as SiO, Al_2O_3, MgO, particles and fibers increase the wear resistance of many plastics. These components also increase the temperature range of composite application, which is of great importance in the production of friction elements of machine parts. The addition of basalt particles reduces the price of the composite as well.

The well-known applications of polymeric composites reinforced with basalt fiber in transport include a vehicle made in Russia (Yo microvan), whose body is made of such a composite, as well as components of Honda cars and motorcycles.

High-temperature resistant brake pads, clutch linings and wear-resistant exhaust pipes are also made of composites containing basalt fibers. The addition of basalt fibers (in the form of meshes) to asphalt surfaces increases their wear resistance, which extends durability.

The available literature provides information on the tribological applications of composites with basalt fibers [4-7], but there is little information on composites with particles, which are much cheaper than fibers [8]. Therefore, the authors decided to investigate the effect of basalt particles on the tribological properties of selected friction composites based on an epoxy resin matrix with the addition of 20, 30 and 40 wt.% basalt particles.

MATERIALS AND METHODS

Based on analysis of the literature [1, 6] and the authors' own research [7, 9], the matrix material was selected, i.e. an epoxy resin with increased elasticity Havel LH 288, crosslinked with an amine hardener H 133, and a border concentration of basalt particles, i.e. 20÷40 wt.% with a diameter of 60÷120 μm (Fig. 1).

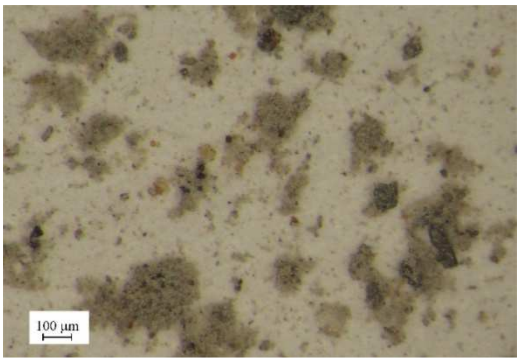

Fig. 1. Basalt particles used to produce composite

Rys. 1. Cząstki bazaltowe użyte do wytwarzania kompozytu

The basalt particles were introduced into the resin by mechanical stirring at the speed of 400 rpm, after mixing degassed in a vacuum dryer for 0.5 hours and then cast into molds with a diameter of 50 mm. The working surfaces of the cast iron samples were sanded with 120 sandpaper to obtain a brake disc roughness (Ra = = 1.5 μm). The surface of the composite was grinded with 500 sandpaper to obtain the topography and roughness of a brake pad. Macrophotographs of the samples are shown in Figure 2. Microphotographs of the surface of the composite with 30% particles before friction are shown in Figure 4a, after friction in Figure 4b and 4c.

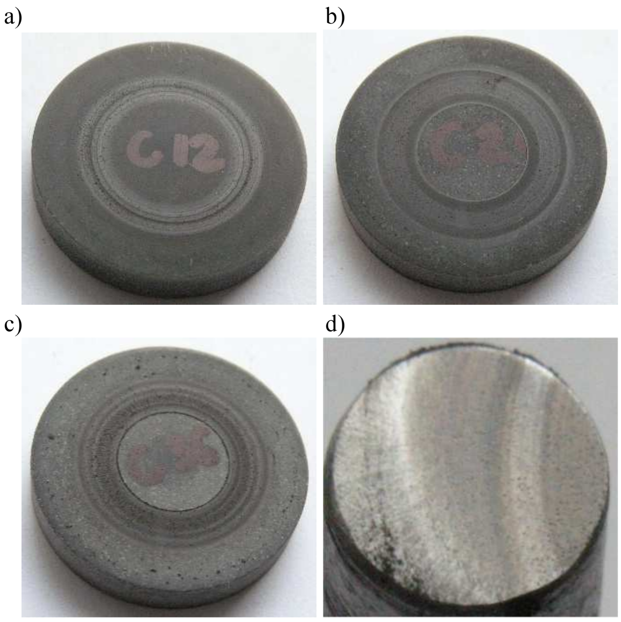

Fig. 2. Surface of composite counter-sample with 20% (a), 30% (b) and 40% (c) basalt particles content after rubbing against cast iron pin; (d) - contact surface after friction

Rys. 2. Powierzchnia kompozytowej przeciwpróbki o zawartości 20% (a), 30% (b) i 40% (c) cząstek bazaltowych po współpracy z żeliwnym trzpieniem; (d) - powierzchnia styku po tarciu

TRIBOLOGICAL EXAMINATION

Tribological studies of the developed composite with basalt particles were carried out on a pin-on-disc stand in friction in air conditions, taking into account its use on the friction elements of technical means of transport, e.g. clutches and brakes. The pin is made of cast iron with a GJL-250 ferritic-pearlitic matrix (φ = 6 mm, L-40 mm), and a composite disc (φ = 45 mm, g-5 mm). This contact reflects the contact of the composite brake pad with the cast iron brake disc.

The test parameters were selected to correspond to the braking conditions of a passenger car with a total weight of 2000 kg in city traffic. The average speed of the disc relative to the pin v = 1 m/s, unit pressure p = 5 MPa, and the friction distance s = 1000 m. During the tests, the friction forces were measured and recorded using a strain gauge force sensor with inaccuracy of the measuring path 1.5% and temperature near the friction zone (in the pin 2 mm from the friction surface). Examples of the coefficient of friction as a function of the friction distance are shown in Figure 3. The mass losses of the samples and counter-samples were determined using a laboratory balance with a resolution of 0.2 mg.

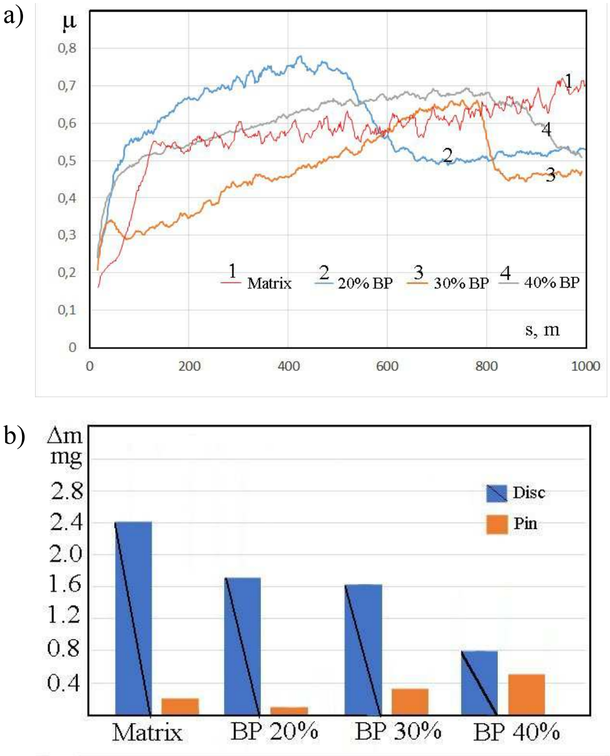

Fig. 3. Coefficient of friction vs. friction distance (a) and wear (b) in examined contacts

Rys. 3. Współczynnik tarcia w funkcji drogi tarcia (a) i zużycie (b) w badanych skojarzeniach

RESULTS AND DISCUSSION

Based on the results of the tests, it can be concluded that the addition of 20, 30 and 40% basalt particles to the epoxy resin allows a friction material rubbing against gray cast iron to be obtained. The presence of the basalt particles reduces matrix wear. Adhesive wear (tacking) and abrasive wear dominate in the contact. Under the influence of pressure and relative speed, local tacking (welding) of the surface roughness peaks and removal of the composite micro-volume as well as the cast iron matrix (ferritic-pearlitic) take place. Matrix wear debris deposits on the surface of the basalt particles (Figs. 2a, 4c). As a result, the surface roughness of the rubbing elements decreases.

The size of the tacking points affects the value of the friction force, which causes local separation of the particles from the resin, as shown in Figure 3b (gap marked 1) and 3c.

Hard precipitation of cementite in the cast iron causes abrasive wear of the composite matrix visible in the form of scratches along the direction of movement (Fig. 2a, b, c) and low wear of the basalt particles. The hard particles (8.5 Mohs) cause microcutting of the cast iron (Fig. 2d).

As the particle content increases, the wear of the composite decreases, but the wear of the cast iron pin increases. It is interesting that the wear of cast iron rubbing against a composite containing 20% BP is less than when rubbing against the matrix. The increased wear of cast iron rubbing against a composite containing 30 and 40% BP is due to the increased fraction of hard basalt particles in the friction surface of the composite.

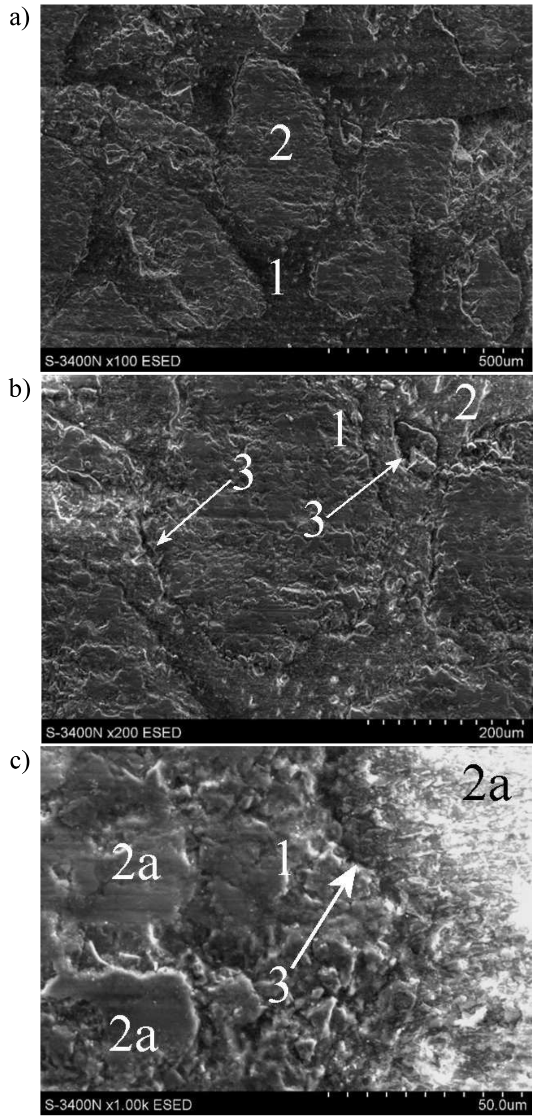

Fig. 4. Surface of composite with 30% BP before (a) and after (b, c) friction against cast iron, SEM: 1 - matrix, 2 - BP, 2a - BP coated with wear debris, 3 - delamination of BP from matrix

Rys. 4. Powierzchnia kompozytu o zawartości 30% BP przed (a) i po (b, c) współpracy ciernej z żeliwem, SEM: 1 - osnowa, 2 - BP, 2a - BP z produktami zużycia, 3 - odspojenie cząstki od osnowy

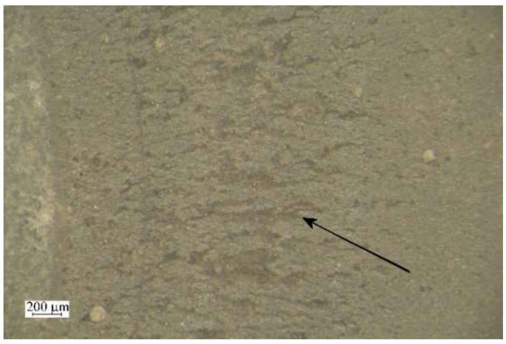

Fig. 5. Surface of composite with 20% BP after friction, LM: matrix deformations are marked with arrow

Rys. 5. Powierzchnia kompozytu o zawartości 20% BP po tarciu, LM: strzałką zaznaczono odkształcenia osnowy

The coefficient of friction at the beginning of sliding depends on the BP content, but after running-in, i.e. after about 900 m, the friction distance is similar (μ = 0.5). The decrease in the coefficient of friction during the run-in period is probably related to the deposition of wear debris on the BP surface. The presence of deteriorating heat dissipation from the matrix causes a local temperature increase and plasticization of the matrix wear debris deposited on the BP surface and a decrease in their shear strength, which is why the friction forces decreased by 500÷900 m on the friction distance. There is no local temperature increase in the matrix, therefore the coefficient of friction increased along the friction distance from 0.5 to 0.72, which causes intensive wear of cast iron pin (Fig. 6b).

a) b)

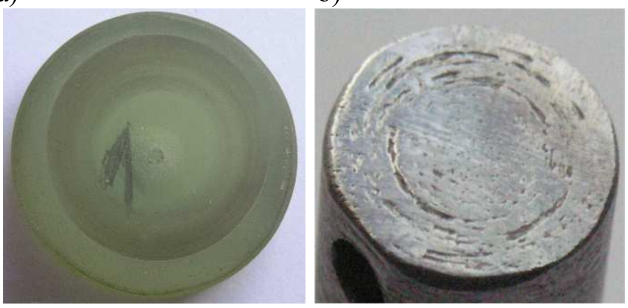

Fig. 6. Surface of matrix material (a) and pin (b) after rubbing

Rys. 6. Powierzchnia tarczy z materiału osnowy (a) i trzpienia (b) po tarciu

A higher temperature caused more intense adhesive bonding of the matrix with cast iron and its deformation (Fig. 5). Displacement of the pin relative to the disc caused plastic deformation of the matrix material (Fig. 2). Greater shear forces are needed to cut larger bonding points, which increase the friction forces.

A higher content of basalt particles reducing the friction forces causes a decrease in temperature in the friction zone, which protects the resin against deformation.

CONCLUSIONS

The results of the tests confirmed the possibility of producing a composite friction material with an epoxy resin matrix filled with basalt particles. The addition of basalt improves the heat resistance of the resin and reduces its wear. A content of hard basalt particles above 30% causes increased wear of the cast iron. The values of the coefficients of friction and their course in the function of the friction distance are typical for the friction materials used to date, which allows us to assume that the developed composite can be tested in real conditions, e.g. in disc brakes or clutches.

REFERENCES

[1] Basalt Products, Basic Information, Incotelogy GmbH, Pulheim 2019.

[2] Basalt chopped strand, Technical Data Sheet, Incotelogy, Pulheim 2015.

[3] Kozieł M., Charakterystyka krajowych bazaltów regionu dolnośląskiego z przeznaczeniem na włókna amorficzne, Prace Instytutu Szkła, Ceramiki, Materiałów Ogniotrwałych i Budowlanych, 2(4), Kraków 2009, 55-64.

[4] Todic A., Cikara D., Lazic V., Examination of wear resistance of polymer-basalt composites, Tribology in Industry 2013, 35(1), 36-41.

[5] Babu S.M., Rao M.V., Experimental studies on the effect of basalt powder inclusion on mechanical properties of hybrid epoxy and polyester reinforced with glass fibre, Lecture Notes in Mechanical Engineering, 2019, 25-31.

[6] Bazan P., Kuciel S., Kompozyty na osnowie poli(oksymetylenu) POM wzmacniane włóknami bazaltowymi, Przetwórstwo Tworzyw 2015, 3, 200-204.

[7] Posmyk A., Tribologia materiałów kompozytowych w pojazdach samochodowych, Wydawnictwo Politechniki Śląskiej, Gliwice 2020.

[8] Ary Subaia I.G.D., Atmika KT., Setiadi W.N., Parwata M.D., Wear behavior of basalt powder reinforced phenolic resin matrix composites brake lining, International Conference on Mechanical, Materials and Engineering 2016, 20-25.

[9] Myalski J., Kształtowanie właściwości tribologicznych kompozytów zawierających węgiel szklisty, Wydawnictwo Politechniki Śląskiej, Gliwice 2011.

