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ALUMINA/GRAPHENE COMPOSITE IN FRICTION AND WEAR TESTS - PART II

The presented work is a continuation of tribological research on alumina/graphene composites. In our previous publication the results of wear tests on the above mentioned composite at room temperature, but also at temperatures of 150, 300 and 500°C were presented. The studies showed that this composite is promising in relation to pure alumina at ambient temperature and 150°C. In order to determine more precisely the temperatures at which the tested material can work, abrasion tests were carried out at two additional temperatures, 80 and 200°C, and the results are presented in the following paper. Noticeable plastic deformation and wear greater than at room temperature was detected already at 80°C but it was still significantly lower than at 150°C when the composite wore significantly less than pure alumina. The test carried out in 200°C gave results similar to those for 300°C, which indicates significant degradation of the material at this temperature.

Keywords: **alumina, alumina/graphene composite, wear, friction, ball-on-disc**

KOMPOZYT TLENKU GLINU/GRAFENU W BADANIACH TARCIA I ZUŻYCIA - CZĘŚĆ II

Prezentowana praca jest kontynuacją badań tribologicznych nad kompozytem tlenek glinu/grafen. W naszej poprzedniej publikacji prezentowano wyniki badań ścieralności dla wspomnianego kompozytu w temperaturze pokojowej, ale również temperaturach 150, 300 oraz 500°C. Badania wykazały, że kompozyt ten jest obiecujący w odniesieniu do czystego korundu w temperaturze otoczenia oraz 150°C. W celu dokładniejszego wyznaczenia temperatur, w których może pracować badany materiał, przeprowadzono próby ścieralności w dwóch dodatkowych temperaturach, 80 oraz 200°C, i wyniki przedstawiono w niniejszej publikacji. Już temperatura 80°C prowadziła do wyraźnej deformacji plastycznej i zużycia większego niż w temperaturze pokojowej, ale wciąż było wyraźnie niższe niż to w 150°C, dla których kompozyt zużywał się mniej niż czysty tlenek glinu. Natomiast test przeprowadzony w temperaturze 200°C dał wyniki zbliżone do tych dla 300°C, co świadczy o wyraźnej degradacji materiału w tej temperaturze.

Słowa kluczowe: **tlenek glinu, kompozyt tlenek glinu/grafen, zużycie, tarcie, kula-tarcza**

INTRODUCTION

In recent years, graphene has been gaining popularity as an addition to ceramic materials, both in order to improve thermal and electrical conductivity, but also to improve tribological properties [1-3]. Aluminium oxide, despite its excellent strength properties when used in friction pairs with a specimen made of the same material, can lead to the extraction of grains and additional material wear by its own grains or debris.

In our previous work, tribological studies were carried out for both alumina and alumina samples with the addition of graphene [4]. Moreover, the tests were carried out at room temperature as well as at higher temperatures of 150, 300 and 500°C. As expected, at room temperature the graphene sample wore less than pure alumina and the coefficient of friction for the pair with the corundum counterpart was significantly lower for the sample containing graphene. This was due to the solid lubricant layer formation which was also observed in other publications [5, 6]. At elevated temperatures a sort of plastic deformation occurred for alumina at the friction surface and a combination of both deformation of alumina and graphene lubrication occurred at 150°C. At this temperature the use of the composite still seemed to be a favourable choice. Studies at temperatures of 300 and 500°C showed, however, that this type of composite is degraded by burning graphene. The aim of this publication is to supplement the knowledge about the wear and friction of the mentioned materials at temperatures slightly exceeding room temperature. The tests on the composite were performed at 80 and 200°C in order to determine more precisely the limit of applicability of the proposed material.

EXPERIMENTAL PROCEDURE

Tests were carried out on an alumina composite with 0.25 wt.% graphene platelets. The method of preparation and the initial materials were described in detail in the previous publication [4]. The graphs show the results of the wear rate and friction coefficient for room temperature, slightly elevated temperatures, i.e. 80 and 150°C, and for contrast at 200 and 300°C. Pure alumina was also tested at 200°C. The friction and wear experiment was conducted using the ball-on-disc test according to the procedure described in standard [7]. Pure alumina balls were used as the counterparts. The wear traces were observed with a Nova Nano SEM 200 scanning electron microscope and interferometric Pro-Film3D profilometer. The use of the profilometer also allowed the authors to determine the amount of material worn.

RESULTS AND DISCUSSION

The results of sliding friction tests are presented in Figures 1 and 2. The wear values presented in the graph (Fig. 1) were obtained by measuring the worn surfaces with the profilometer and calculated using the equation:

$$W_v = \frac{V}{F_n \cdot s}\left[\frac{\mathrm{mm}^3}{\mathrm{N}\cdot\mathrm{m}}\right] \tag{1}$$

where: V - volume of material worn in the friction process [mm^3], F_n - contact force between the ball and sample surface [N], s - friction path [m].

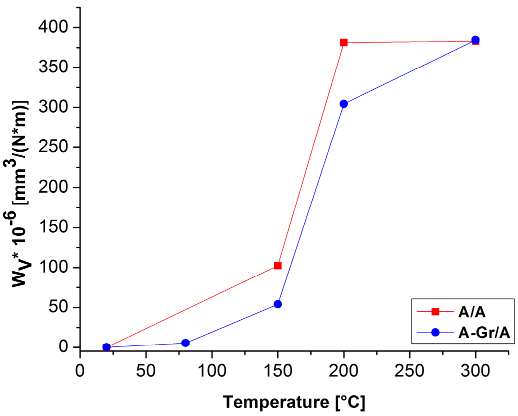

Fig. 1. Wear of tested materials at various temperatures

Rys. 1. Zużycie badanych materiałów w różnych temperaturach

The graph clearly shows that despite the general increase in wear with temperature, the composite wears less than pure alumina at temperatures of up to 300°C. These data, however, are not in close correlation with the of the coefficient of friction values. Additional measurements confirmed the tendency of the coefficient of friction to increase with the temperature to 150°C, where the values stabilize around 0.9. However, particular attention is paid to the fact that the value for pure alumina at 150°C is lower than for the composite. As mentioned in a previous publication [4], this indicates that a comparison of the coefficient of friction is not sufficient and should not always be regarded as a decisive factor when selecting the material to work under given conditions.

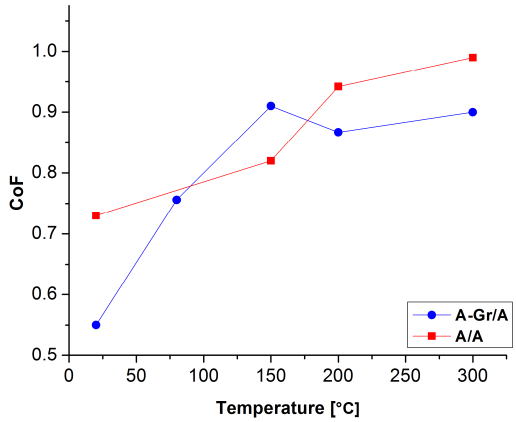

Fig. 2. Relation of coefficient of friction of tribosystems with temperatures in friction zone

Rys. 2. Zależność współczynnika tarcia badanych skojarzeń od temperatury w strefie tarcia

The SEM images illustrate how the surface of the samples was worn. The changes in the nature of the wear can be clearly noticed as the temperatures increase. Figure 3 shows that at ambient temperature, the wear and tear consists of brittle cracking of the surface layer and slight plastic deformation.

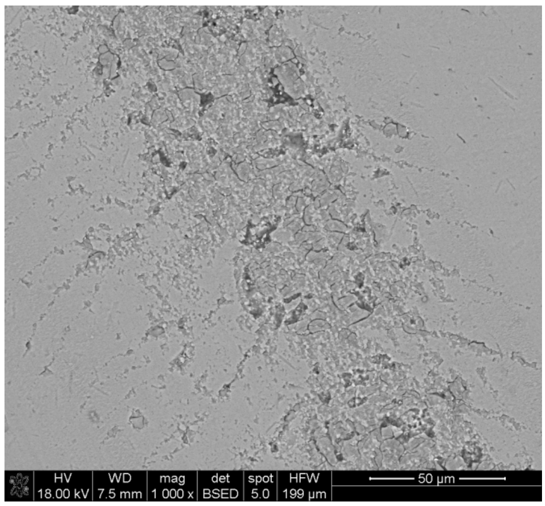

Fig. 3. SEM micrograph of alumina/graphene composite wear trace at room temperature

Rys. 3. Obraz SEM śladu wytarcia w kompozycie tlenek glinu/grafen w temperaturze pokojowej

By increasing the temperature to 80°C, the plastically deformed areas are significantly increased, and at 150°C these processes are already very intensive (Fig. 4). A further temperature rise increases the plastic deformation and it can be seen that the deformation layer is thicker (Fig. 5).

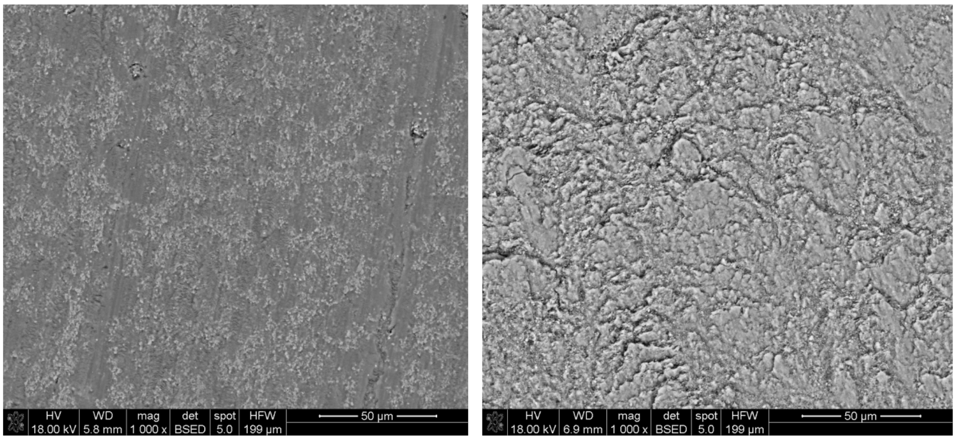

Fig. 4. SEM micrograph of alumina/graphene composite wear trace at slightly elevated temperatures (in order from left: at 80 and 150°C)

Rys. 4. Obraz SEM śladu wytarcia w kompozycie tlenek glinu/grafen w lekko podwyższonych temperaturach (w kolejności od lewej: w 80 oraz 150°C)

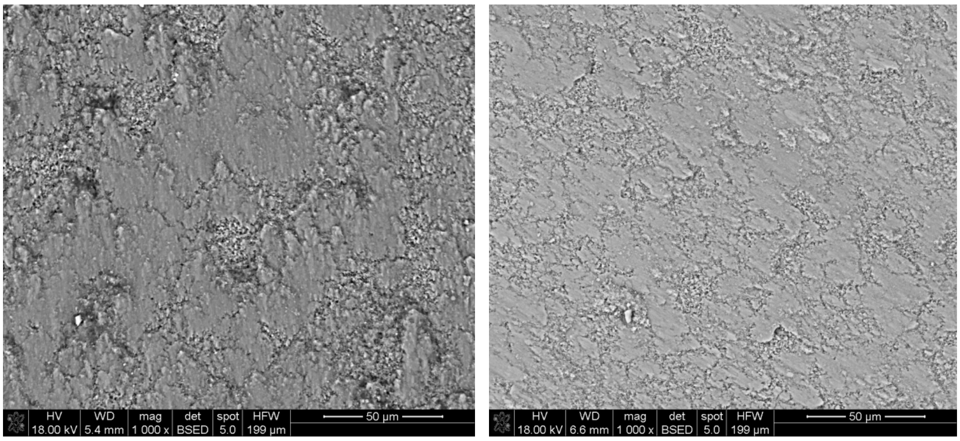

Fig. 5. SEM micrograph of alumina/graphene composite wear trace at significantly elevated temperatures (in order from left: at 200 and 300°C)

Rys. 5. Obraz SEM śladu wytarcia w kompozycie tlenek glinu/grafen w istotnie podwyższonych temperaturach (w kolejności od lewej: w 200 oraz 300°C)

The changes, associated with the described deformations, are also clearly illustrated on the wear profiles shown below. At 20°C (Fig. 6) the wear trace is relatively shallow compared to the other profiles. However, a relatively small increase in temperature results in significantly deeper abrasion of the material (Fig. 7). For 200 and 300°C the wear progressed to a three- or fourfold greater depth than in the case of 150°C.

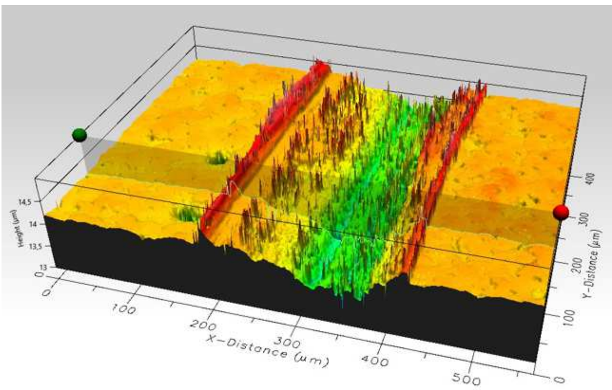

Fig. 6. Wear profile of composite samples at room temperature

Rys. 6. Profil zużycia próbek kompozytowych w temperaturze pokojowej

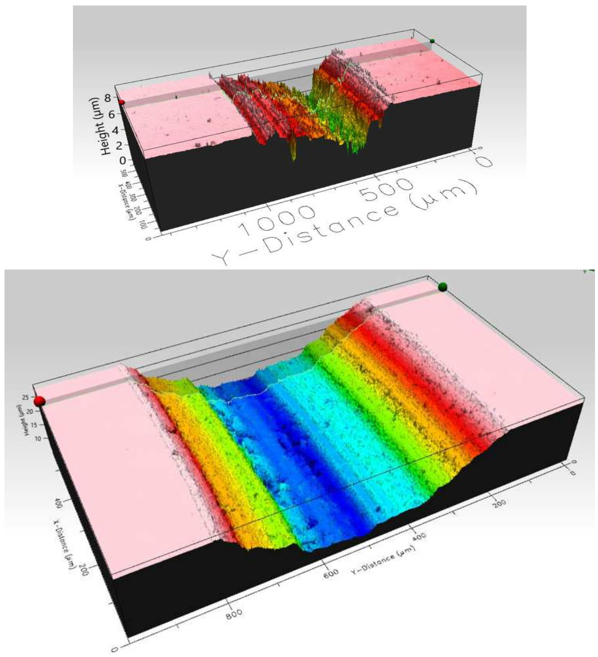

Fig. 7. Wear profiles of composite samples at slightly elevated temperatures (in order from left: at 80 and 150°C)

Rys. 7. Profile zużycia próbek kompozytowych w lekko podwyższonych temperaturach (w kolejności od lewej: w 80 oraz 150°C)

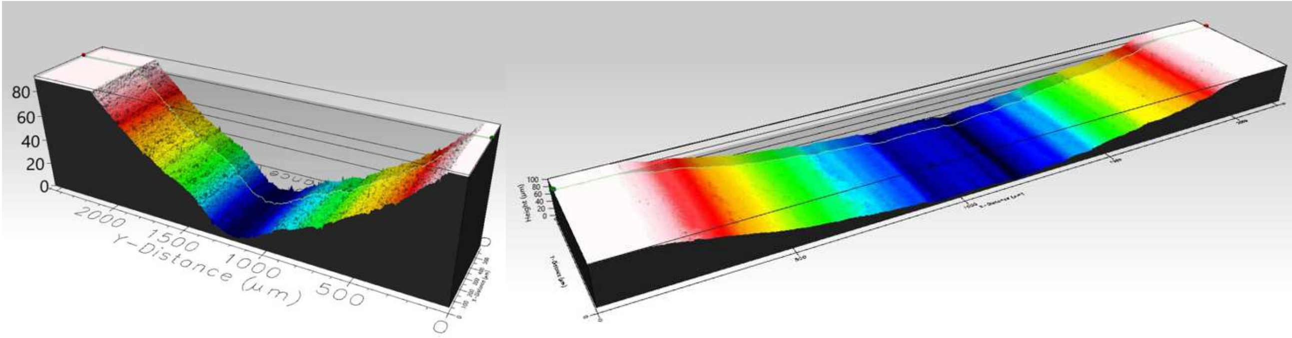

Fig. 8. Wear profiles of composite samples at significantly elevated temperatures (in order from left: at 200 and 300°C)

Rys. 8. Profile zużycia próbek kompozytowych w istotnie podwyższonych temperaturach (w kolejności od lewej: w 200 oraz 300°C)

CONCLUSIONS

The use of a corundum graphene composite at room temperature gives satisfactory results. Measurements performed at 80°C confirmed that even at a slightly elevated temperature, the material is subject to significant wear. Above room temperature, the depth of the plastic deformation zone at the surface notably increased with the temperature. At 200°C the observed wear rate reached a value similar to that measured at 300°C. However, in the temperature range of 20÷200°C, the wear was lower than that registered for pure alumina, hence it can be concluded that the addition of graphene led to an improvement in wear resistance. Nonetheless, this material cannot be considered to be used apart from room temperature as its degradation increased significantly with even a slight increase in the test environment temperature.

Acknowledgements

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