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THE INFLUENCE OF RADIATION MODIFICATION ON TRIBOLOGICAL PROPERTIES OF T5W, T7W PLASTICS USED IN KINEMATICS SYSTEMS

WPŁYW MODYFIKACJI RADIACYJNEJ NA WŁAŚCIWOŚCI TRIBOLOGICZNE TWORZYW T5W, T7W STOSOWANYCH W UKŁADACH KINEMATYCZNYCH

Key words:

composite materials, radiation modification, oxide layers, friction coefficient, wear intensity

Słowa kluczowe:

tworzywa kompozytowe, modyfikacja radiacyjna, warstwy tlenkowe, współczynnik tarcia, intensywność zużywania

Summary

T5W and T7W plastics are a composite with a PTFE matrix and a prepared carbon powder as a dispersive phase. Due to the low friction coefficient value, these plastics are often used as a guide ring in the pneumatic and hydraulic piston–cylinder systems and the shock absorbers. This work attempts to increase wear resistant of plastics through the application of radiation

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modification. The plastics were associated with oxide layers obtained on the EN AW-5251 aluminium alloy via an electrochemical method route. Tribological tests were conducted on the T-17 tester in technically dry conditions.

INTRODUCTION

Composites based on PTFE are one of the most frequently used materials, as far as the production of guide rings and seals are concerned, since they have applications in actuators, compressors, and dampers. Fillers of graphite, coal, coke, and oxides of some metals, in form of plates and fibres, are used in order to produce composites with PTFE matrices. Composites often interact in a sliding manner with oxide layers on aluminium elements of piston-cylinder devices under conditions of dry friction. The idea of an association of material with a hard, wear-resistant oxide layer is to create a slide film causing a decrease of resistance to motion. However, it results in an increase of wear in the initial phase of association. In a number of publications, there are some papers devoted to a decrease of the friction coefficient of materials coming into tribological contact through the modification of the surface layer by means of a material in the form of carbon, graphite, or molybdenum disulphide **[L. 1, 2]**. Modification of the anodic oxide layer has been carried out using various technologies of surface layer production, beginning from a simple and inexpensive electrolytic method **[L. 3, 4]**, to more expensive methods, such as of ion implantation or vacuum arc **[L. 5, 6]**. Many works paid attention to the modification of the polymer in order to reduce the friction effects in the sliding couple. The usage of radiation modification against some materials has a significant influence on structure changes of the materials, which causes a decrease of micromechanical properties and wear resistance **[L. 7, 8]**. The author of the research attempted to increase the wear resistance of T5W and T7W used in piston-cylinder devices by radiation modification.

RESEARCH MATERIAL

T5W and T7W are composites created on a PTFE matrix with dispersoid, in the form of prepared coal powder, used in the production of guide rings in pneumatic actuators. In the research, the T5W **(Fig. 1a)** and T7W samples were repeatedly subjected to electron beam of 26 kGy. The samples were irradiated from one to four times. Radiation was done in the Institute of Nuclear Chemistry and Technology in Warsaw, using a laser electron accelerator Elektronica LEA (with electron energy 10MeV and power of 10 kW). The materials were associated with oxide layers, used for the coverage of internal cylinder bearing surfaces of non-lubricated pneumatic actuators. The oxide layers **(Fig. 1b)** were produced on EN AW-5251 aluminium alloy by electrochemical oxidation at constant current, in electrolytes with organic

acid additives. The oxidation was carried out in 303 K for 180 A·min/dm^2 electric charge density.

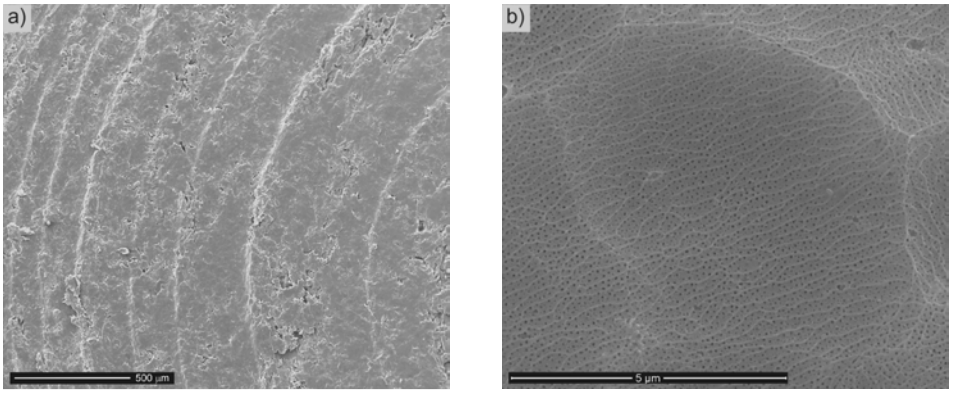

Fig. 1. Surface morphology before tribological test: a) T5W material b) oxide layer
Rys. 1. Morfologia powierzchni przed testem tribologicznym: a) materiał T5W b) warstwa tlenkowa

RESEARCH METHODOLOGY

Tribological tests were conducted on a T-17 test stand. The stand is assigned for materials interacting in a sliding manner in reciprocal motion. The tribological tests were carried out in dry friction with a constant temperature of 296 K ± 1 K and a constant air humidity of 50% ± 5%. The tests were conveyed on a 50--kilometre path of friction with an initial phase of 15-kilometre grinding, with surface thrust of 1 MPa and an average rubbing speed of 0.2 m/s. The friction force was recorded with an analogue-to-digital converter Spider 8. Weight wear of the material was determined by a WA-35 analytical balance with 0.1 mg precision. In order to assess the influence of the geometry of interacting surfaces on the tribological tests, the roughness of the oxide layers was measured with a Form Talysurf profilograph (2D).

RESEARCH RESULTS

As the result of tribological test, the aluminium oxide layers with a slide film **(Fig. 2b)** from T5W **(Fig. 2a)**, T7W plastics were obtained.

The influence on the applied modification on the wear intensity of the materials analysed and the friction coefficient value of the slide pair were determined based on the obtained data from the tribological test. Based on the T5W wear intensity analysis **(Fig. 3)**, it can be concluded that irradiation caused a predicted improvement of the wear resistance of the material. An increase of radiation dose caused a decrease in the material's wear value, and with 78 kGy, it comprised 47% of an unmodified material, which was 0.034 mg/km precisely.

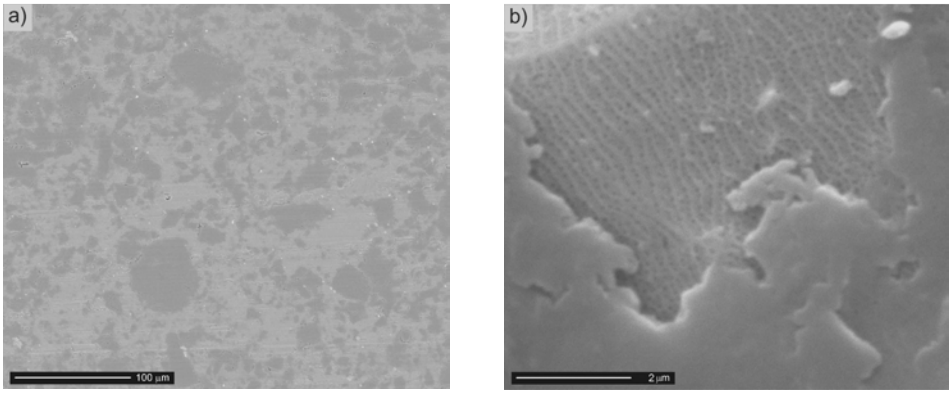

Fig. 2. Surface morphology after tribological test a) T5W material b) oxide layer
Rys. 2. Morfologia powierzchni po teście tribologicznym: a) materiał T5W b) warstwa tlenkowa

A consecutive dose increase up to 104 kGy, and it resulted in a 36% increase of the material's wear value, as compared to the unmodified material. A similar tendency was observed for T7W **(Fig. 3)**. In this case, an increase in the wear value comprised 27% of the unmodified material's wear value, which was 0.017 mg/km; however, the lowest wear value was observed for 52 kGy, after which an increase of wear appeared, up to 0.041 mg/km for a 104-kGy radiation dose. It might thus be observed that T7W had a higher wear resistance, both in unmodified and modified forms, for 26 and 52 kGy radiation doses. The usage of radiation above 78 kGy, in case of T5W, and above 52 kGy in case of T7W causes adverse changes in the structure of the material resulting in a decrease

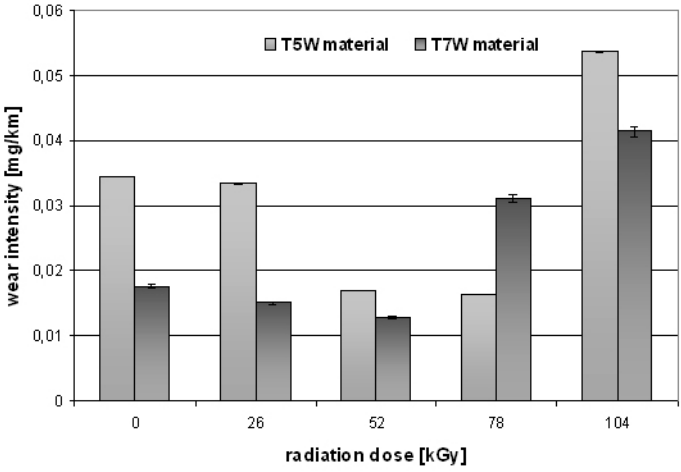

Fig. 3. The influence of radiation modification on wear intensity for connection oxide layer with material T5W, T7W
Rys. 3. Wpływ modyfikacji radiacyjnej na intensywność zużywania tworzywa T5W, T7W w skojarzeniu z warstwą tlenkową

of tribological wear. An analysis of the slide associations researched revealed a reverse tendency of the friction coefficient dependencies to radiation dose **(Fig. 4)**, in comparison to the tendency of wear intensity to radiation dose. For the lowest wear intensity values, the highest values of friction coefficient were observed.

The result of slide interaction between oxide layers and T5W and T7W materials is a decrease in roughness values of the tribological pair. Values of Rq **(Fig. 5)** and Rz indicate the low roughness of the oxide layer.

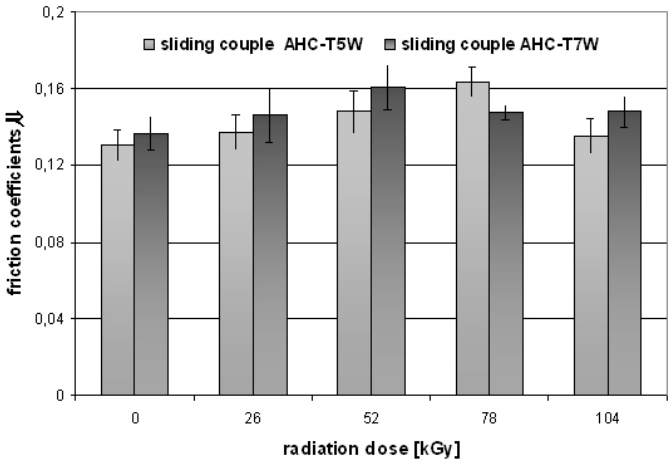

Fig. 4. The influence of radiation modification on the friction coefficient for connection oxide layer with material T5W, T7W

Rys. 4. Wpływ modyfikacji radiacyjnej na wartość współczynnika tarcia tworzywa T5W, T7W w skojarzeniu z warstwą tlenkową

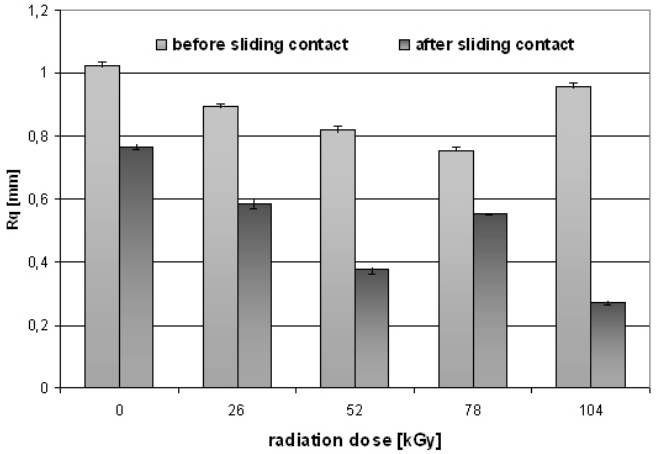

Fig. 5. Mean square deviation of the roughness profile Rq of the oxide layer in connection to T5W material that was subjected to radiation modification

Rys. 5. Średnie kwadratowe odchylenie chropowatości Rq warstwy tlenku przed i po współpracy z tworzywem T5W poddanym modyfikacji radiacyjnej

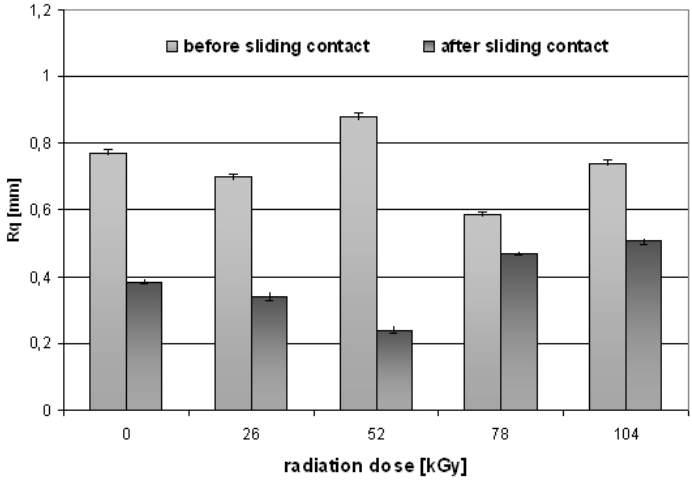

Fig. 6. Mean square deviation of the roughness profile Rq of the oxide layer in connection to T7W material that was subjected to radiation modification

Rys. 6. Średnie kwadratowe odchylenie chropowatości Rq warstwy tlenku przed i po współpracy z tworzywem T7W poddanym modyfikacji radiacyjnej

The Rsk assymetry coefficient for the majority of layers is negative, which gives evidence of a bearing-like surface character, which is desirable for slide associations. As a result of slide interaction, the coefficient value decreased in all cases, which indicates the usability of the layers for tribological interaction.

CONCLUSION

From the observed dependencies, it can be concluded that the radiation modification of 52 kGy for T5W and 78 kGy for T7W causes advantageous changes of the materials for tribological applications. An abrupt wear resistance of materials, as exposed to higher radiation doses, may indicate a degradation of structure.

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Streszczenie

Tworzywa T5W i T7W to kompozyty wytworzone na osnowie PTFE z fazą dyspersyjną w postaci proszku węgla preparowanego, używane do produkcji pierścieni prowadzących stosowanych w siłownikach pneumatycznych. Autor pracy podjął próbę zwiększenia odporności na zużycie tworzyw T5W, T7W stosowanych w układach tłok–cylinder, poprzez zastosowanie modyfikacji radiacyjnej. W pracy próbki z tworzywa zostały poddane kilkukrotnemu napromieniowaniu strumieniem elektronów, w dawce po 26 kGy. Tworzywa skojarzono z warstwami tlenkowymi stosowanymi na pokrycia wewnętrznych gładzi cylindrów niesmarowanych siłowników pneumatycznych. Warstwy tlenkowe wytworzono na podłożu stopu aluminium EN AW-5251 w procesie elektrochemicznego utleniania metodą stałoprądową. Badania tribologiczne przeprowadzono na testerze T-17. Tester przeznaczony jest do badań materiałów współpracujących ślizgowo w ruchu posuwisto-zwrotnym. Testy tribologiczne przeprowadzono w warunkach tarcia technicznie suchego, na drodze tarcia 50 km, ze wstępnym etapem 15 km docierania, stosując obciążenie 1 MPa oraz średnią prędkość ślizgania 0,2 m/s. Na podstawie danych otrzymanych w wyniku przeprowadzonego testu tribologicznego określono wpływ zastosowanej modyfikacji na intensywność zużywania badanych tworzyw oraz wartość współczynnika tarcia pary ślizgowej. Z analizy badań wynika, że przeprowadzenie modyfikacji radiacyjnej w dawce do 52 kGy dla tworzywa T5W oraz do 78 kGy dla tworzywa T7W wywołuje korzystne dla zastosowań tribologicznych zmiany w strukturze tych tworzyw. Nagłe obniżenie odporności zużyciowej tworzyw w wyniku zastosowania większych dawek promieniowania może być efektem degradacji struktury tworzywa.