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THE PROPERTIES OF BABBITT BUSHES IN STEAM TURBINE SLIDING BEARINGS

WŁASNOŚCI BABBITU STOSOWANEGO NA PANWIE ŁOŻYSKA ŚLIZGOWEGO W TURBINIE GAZOWEJ

The analysis of the properties of babbitt bushes is presented in this article. Materials intended for examinations were charged from the TK-120 steam turbine of TG-8 turbosystem from the Power Station Stalowa Wola. The specimens were subsequently tested for Brinell hardness, microhardness, bending strength and wear resistance. The wear tests were carried out using the block-on-ring tester. The samples were also investigated by means of both light microscopy (LM) and scanning electron microscopy (SEM).

Keywords: Babbitt bushes, properties, ingot, Babbitt bearing, microstructure

Do najpowszechniej stosowanych stopów łożyskowych należą stopy cyny i ołowiu. Stopy te posiadają plastyczną osnowę z cząstkami nośnymi twardych faz zapewniających dużą odporność na ścieranie. Najkorzystniejsze własności wykazują stopy na osnowie cyny zawierające: 7÷13% Sb, 3÷7% Cu i do 1,2% Cd, zwane babbitami cynowymi. Łożyska nośne wykonane z babbitów cynowych pracują w turbinie w warunkach tarcia płynnego. W wyniku tarcia w łożysku powstaje ciepło, co powoduje pracę łożyska w temperaturze zazwyczaj mieszczącej się w zakresie od 45 do 60°C. Zjawisko ścierania najintensywniej pojawia się podczas zatrzymywania lub rozruchu, kiedy łożysko pracuje w warunkach tarcia półpłynnego. W tych dwóch etapach pracy łożysk uwidacznia się wpływ materiałów, z jakich wykonano zarówno panew jak i czop.

W pracy stosowano stop łożyskowego Ł83 pobrany z gąski oraz turbozespołu TG-8 turbiny parowej TK-120 z Elektrowni Stalowa Wola. Badanie twardości prowadzono metodą Brinella, natomiast mikrotwardość mierzono metodą Vickersa. Badanie wytrzymałości na zginanie przeprowadzono na próbkach o wymiarach 5×5×40 mm pobranych zarówno ze stopu, którym wylano panew, jak i z gąski; wartość siły zginającej była rejestrowana w trakcie badania metodą trójpunktowego zginania. Badanie odporności na zużycie cierne oraz wyznaczenie współczynnika tarcia przeprowadzono na próbkach o wymiarach 20×5×5 mm przy zastosowaniu testera T-05. Badania prowadzono w warunkach tarcia suchego i z użyciem oleju TU-32. Mikrostruktura próbek obserwowana była przy użyciu mikroskopu świetlnego Olympus GX51 wyposażonego w cyfrową rejestrację obrazu. Zdjęcia wykonano w różnych miejscach próbek zarówno w jasnym jak i ciemnym polu widzenia oraz w świetle spolaryzowanym. Dodatkowo przy użyciu mikroskopu skaningowego Tesla BS301 dokonano obserwacji przełomów próbek po zginaniu oraz miejsca pęknięcia stopu, którym wylano panew.

1. Introduction

The most popular bearing alloys are based on tin and lead. They are widely used in friction assemblies (for example in: turbines, compressors, transport, cars, various friction units). These alloys are made of plastic matrix and load bearing particles dispersed in the matrix, which guarantee great abrasion resistance [1-5]. The most advantageous properties point at alloys based on tin containing: 7÷13% Sb, 3÷7% Cu and up to the 1.2% Cd called babbitt's tin according to PN-ISO 4381:1997.

Data available in literature on the babbitt with high amount of tin show that they can contain three phases: α, β, η or α, β, ε. The basic α phase can be present in the form of solid solution of anthymony and copper in tin or in the form of three-component eutectic [6].

The main object of this study is to determine the influence of the long-standing exploration on the microstructure and properties, and possible reasons of the babbitt bush failure. The samples for investigations were received from a babbitt ingot and steam TK-120 steam turbine of TG-8 turbosystem from the Power Station Stalowa Wola.

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2. Experimental procedure

Materials intended for examinations (antifriction alloy, oil) were charged from the steam TK-120 turbine TG-8 and from the ingot (antifriction alloy) from the Power Station Stalowa Wola. The working time of a babbitt bearing to the damage was above 50 000 hours. The composition of the high-tin SnSb12Cu6Pb antifriction alloy is given in Table 1.

TABLE 1

Chemical composition of babbitt alloy

Sn	Sb	Cu	Cd	Pb	As	Bi	Fe	Zn
Bal.	11.1	5.97	0.001	0.009	0.002	0.002	0.001	0.003

The specimens were subsequently tested for Brinell hardness, microhardness, bending strength and wear resistance. They were also analyzed by means of both light microscopy (LM) and scanning electron microscopy (SEM). The wear tests were carried out using the block-on-ring tester (Fig. 1)

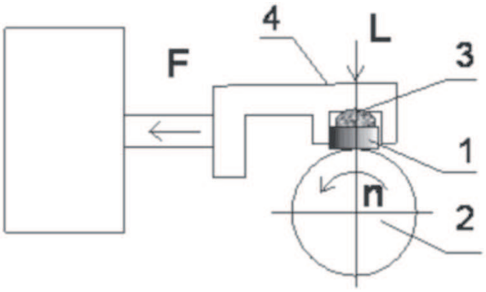


Fig. 1. Schematic view of block-on-ring tester

The sample (1) was mounted in a sample holder (4) equipped with a hemispherical insert (3) ensuring proper contact between the sample and a rotating ring (2). The wear surface of the sample was perpendicular to the pressing direction. Double lever system input the load **L**, pressing the sample to the ring with the accuracy of ±1%. The ring rotated with a constant rotating speed.

The wear tests conditions chosen for the current investigations were following:

- tested samples – rectangular specimens 20×4×4 mm,
- counterpart (rotating ring) – ϕ 49,5×8 mm, heat treated steel, 55 HRC,
- dry or wet sliding,
- rotational speed – 136 rev./min.,
- load – 67 N,
- sliding distance – dry 100, 1000 m; wet: 1000, 10000 m.

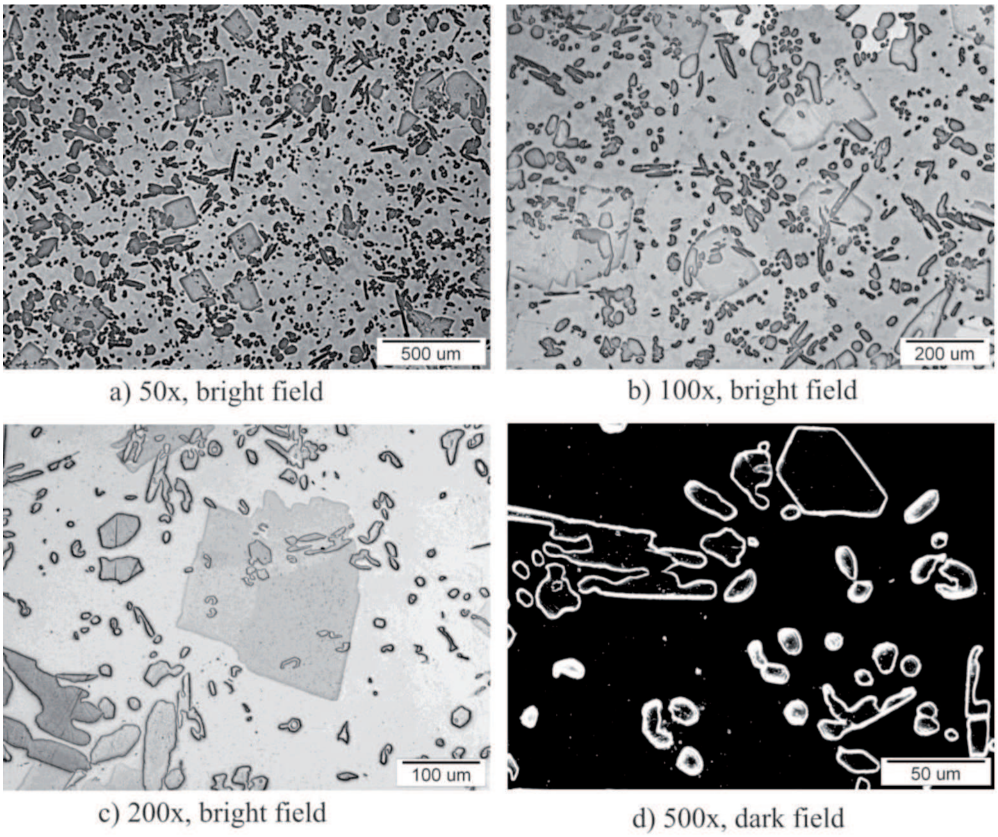
The measured parameters were:

- loss of sample mass,
- friction force F (used to calculate the coefficient of friction).

This tester enabled performing tests in accordance with the methods determined in ASTM D 2714, D 3704, D 2981 and G 77 Standards. The tests were performed under conditions of dry and fluid friction with using the following cooling-separating medium. The friction investigations with application of a lubricating medium started under a dry friction condition.

3. Results and the discussion

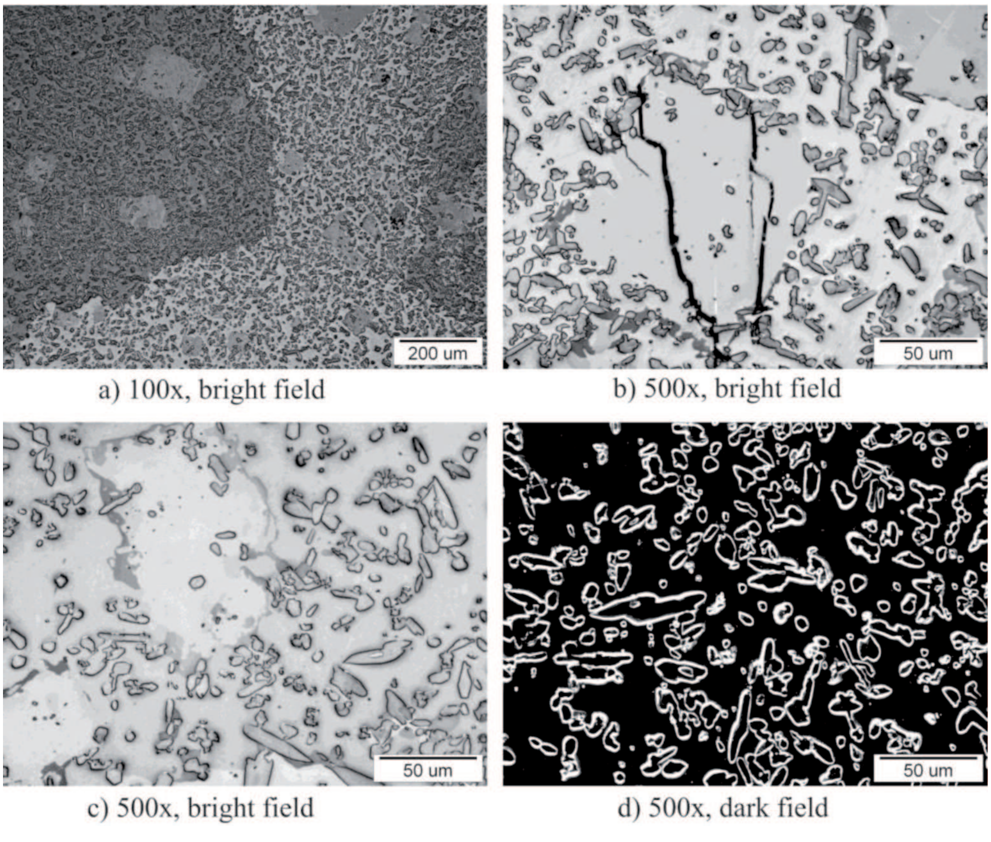
The microstructures of the babbitt ingot are presented in Fig. 2 whereas the microstructures of the bearing in Fig. 3. The characteristic hard phases of SnSb (square shape) and Cu_6Sn_5 (needle-like shape) in the background of soft matrix rich in the tin are observed. The X-ray diffraction presented in Fig. 4 confirms occurrence of these phases. The microstructures of the bearing sample show, that hard phase Cu_6Sn_5 predominate in comparison to the ingot sample. Also characteristic are cracking of the SnSb phase in the bearing sample what is presented at the Fig. 2. Also in the ingot babbitt we can see discontinuous in these phases.



a) 50x, bright field b) 100x, bright field

c) 200x, bright field d) 500x, dark field

Fig. 2. Microstructures of the babbitt ingot (B83)



a) 100x, bright field b) 500x, bright field

c) 500x, bright field d) 500x, dark field

Fig. 3. Microstructures of the bearing (B83)

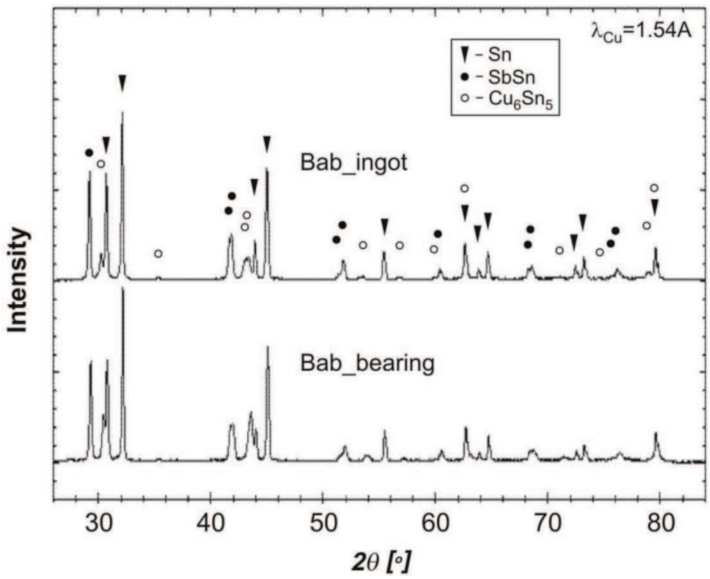


Fig. 4. X-ray diffraction analysis

The results obtained from the microhardness measurements are given in Fig. 5, whereas the data of the hardness measurements in Fig. 6 The highest average value of microhardness of the babbitt ingot was equal to 70μHv$_{100}$, what indicates presence of hard phase of SnSb in form of squares in the structure. On the other hand the (average) hardness of the matrix was found to be three times smaller and equal to 19 μHV$_{100}$. The average microhardness of the bearing babbitt was about – 41μHv$_{100}$.

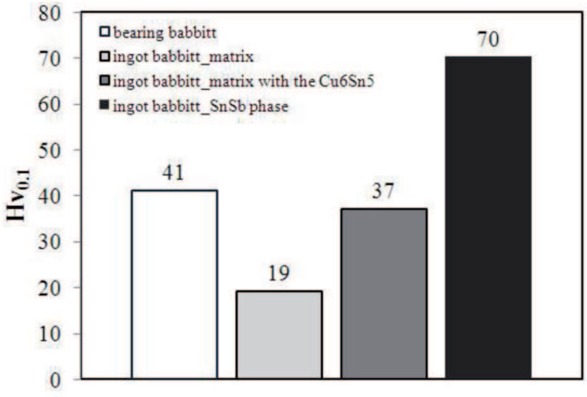


Fig. 5. Microhardness of the babbitt alloy

Results of the hardness measurements show higher level of the properties in the bearing samples with the comparison to the babbitt ingot. The average value is 29 HB and 23 HB for bearing and babbitt ingot, respectively (Fig. 6).

Occurrence of the fine precipitates uniformly distributed in the whole tin matrix cause higher level of microhardness/hardness of the bearing sample. This was confirmed by microstructure observations and shown in Figures 2 and 3.

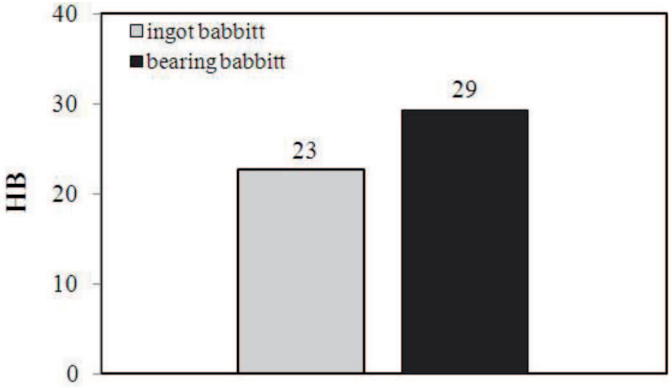


Fig. 6. Hardness of the babbitt alloy

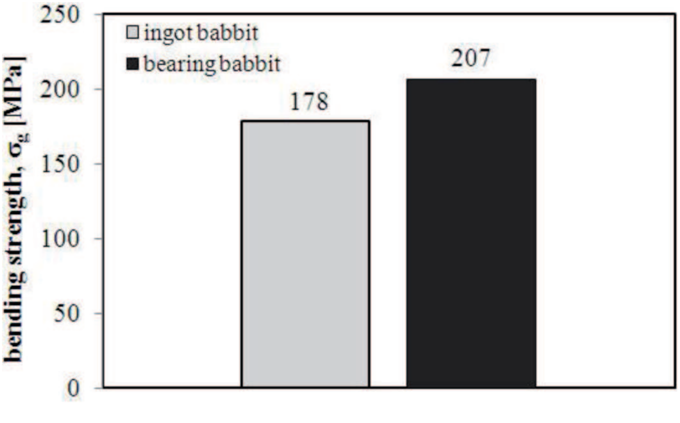


Fig. 7. The comparison of the bending strength of cast and bearing babbitt alloy

The results obtained in the bending test (Fig. 7) show higher bending strength in the bearing material in comparison to the ingot babbitt. The mean bending strength was 207 MPa for bearing and 178 MPa for ingot babbitt. This mark, that bearing material is more plastic than ingot babbitt. Large SnSb phases can acts as a notch and facility nucleation and propagation cracking of the material.

Fractures presented in figures 8 and 9 prove, that cracking nucleate and propagate mainly through the hard phases both in bearing and ingot babbitt alloy.

The analysis of the cracks indicates fragile fractures of the SnSb (β) and CuSn (η) hard phases (fig. 8, 9) and ductile fracture of the tin (α phase). The low ductility of babbitt alloy is caused by brittleness of the β phase, which because of the hexagonal lattice has a limited number of slip planes available for plastic deformation [6].

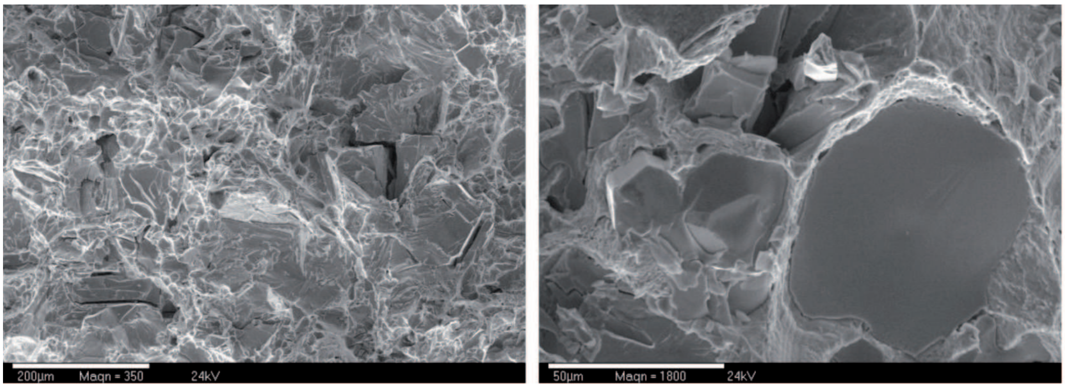


Fig. 8. Scanning electron micrographs of destroyed babbitt surface; ingot of babbitt alloy

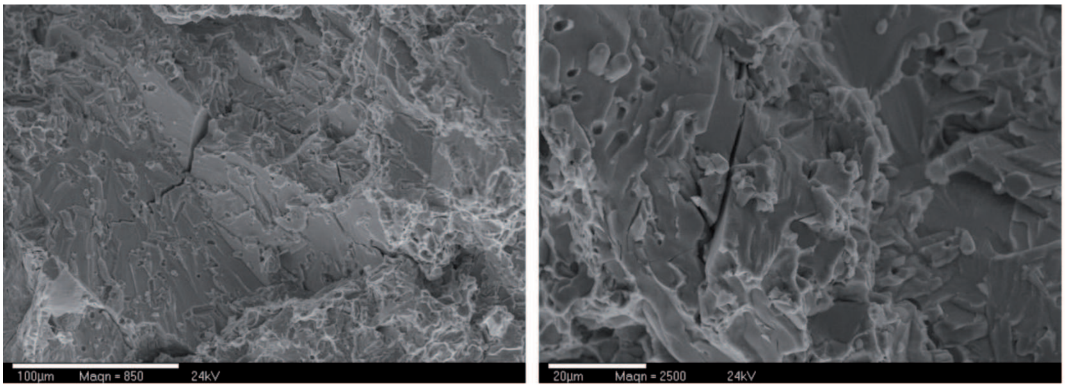


Fig. 9. Scanning electron micrographs of destroyed babbitt surface fracture; bearing

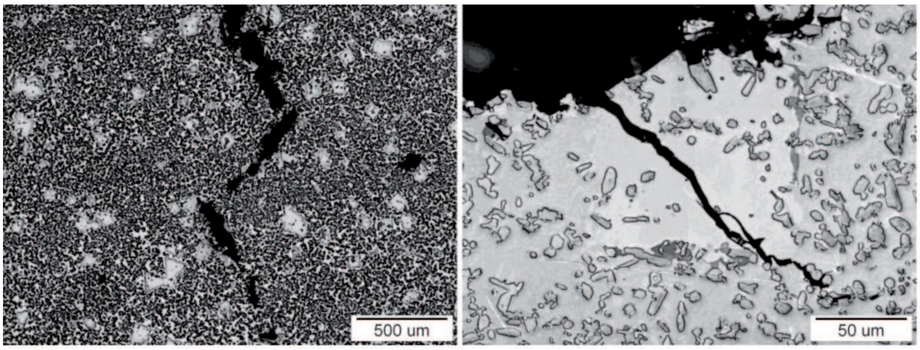


Fig. 10. Discontinuity propagate at the considerable distance in the bearing sample

Microstructures presented in Figures 2 and 3 indicate, that the precipitants existing in the investigated alloy occupy great fraction of the surface, what can directly influence brittleness of this material. These phases can be also seen at the fracture micrographs (Fig. 8). In the case of the bearing sample, characteristic are fine phases (Fig. 3) what is also visible at the fractures micrographs (Fig. 9). Cracking of the material can initiate also on the voids which form during founding process. Discontinuity of the material in the bearing sample propagates at the considerable distances what is presented in Figure 10.

The wear test results are given in Figures 11÷14.

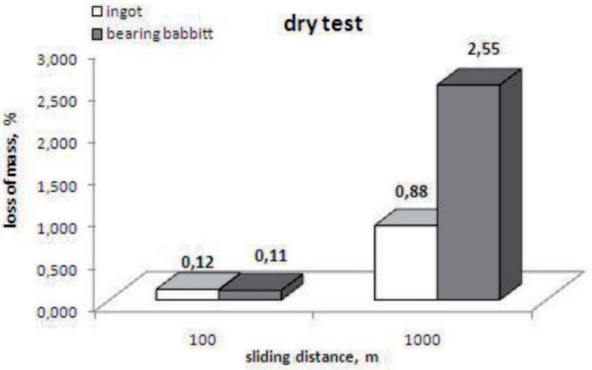


Fig. 11. Dependence of the sliding distance on the loss of mass of babbitt alloy in dry test

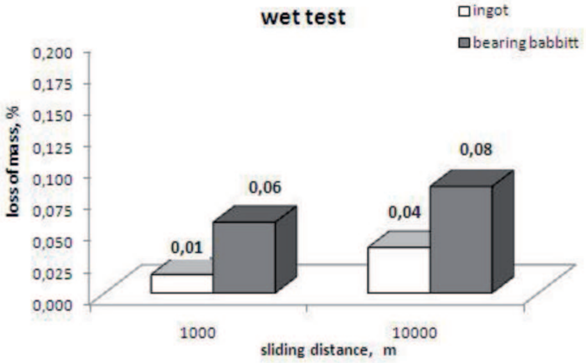


Fig. 12. Dependence of the sliding distance on the loss of mass of babbitt alloy in wet test

The loss of mass is a measure of the tribological properties of the babbitt samples [7÷9]. By comparing the wear resistance of samples received from ingot and babbitt bearing, it is evident that the babbitt bearing after sliding a distance of 1000m show 3 times higher loss of mass than the samples from the babbitt ingot. This can be explained by the microstructural changes during functioning of babbitt's bearing. The microstructures of the bearing sample show, that the hard phase Cu_6Sn_5 predominate in comparison to the ingot sample (Fig. 2 and 3). An application of TU 32 oil from the Power Plant Stalowa Wola as a lubricant and simultaneously as a cooling-separating medium causes a decrease of the mass loss during test on the sliding distance of 1000m from 2.55% to 0.06% and from 0.88 to 0.01 for the babbitt bearing and babbitt ingot, respectively. The performed tests indicated that an application of the oil was necessary since the mass losses were significantly smaller than the ones obtained for dry test. Using the oil causes the stabilization of the loss of mass during the wet test of the babbitt's bearing (Fig. 12).

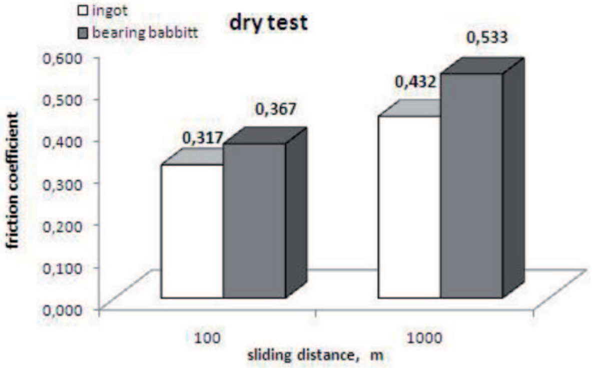


Fig. 13. Dependence of the sliding distance on the friction coefficient of babbitt alloy in dry test

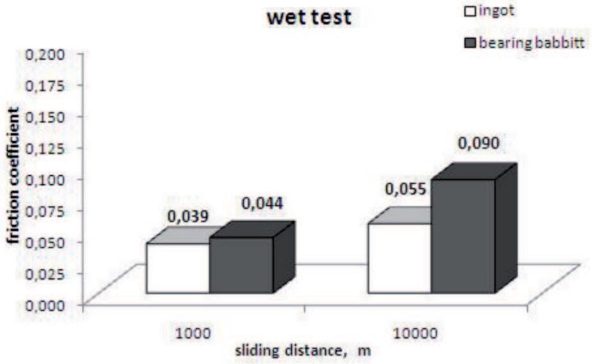


Fig. 14. Dependence of the sliding distance on friction coefficient of babbitt alloy in wet test

An application of oil TU 32 as a lubricant and simultaneously as a cooling-separating medium causes a decrease of the friction coefficient from 0.432 to 0.039 and from 0.533 to 0.044 for the babbitt ingot and babbitt bearing, respectively (on the sliding distance of 1000m). The samples made from the ingot are characterized by a lower friction coefficient than the samples made from the babbitt bearing. It is mainly affected by the predomination in the microstructure of the hard phase Cu_6Sn_5. Addition of oil causes a very significant (nearly ten times) reduction of the friction coefficient (Fig. 13, 14). Using of oil causes the stabilization of the friction coefficient during the wet test of babbitt's bearing (Fig. 14).

Characteristic surface topographies after the wear test are presented in Figures 15÷18.

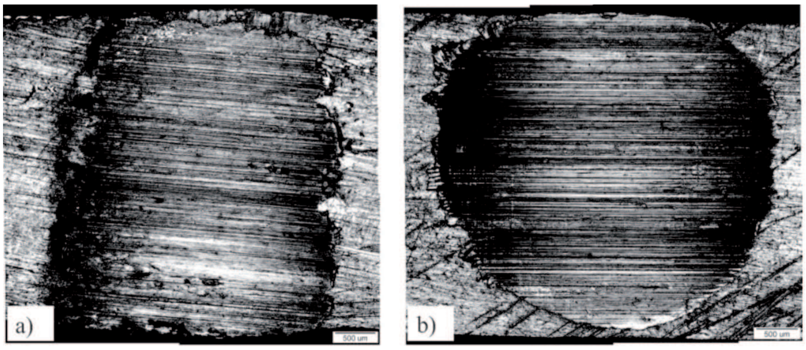


Fig. 15. The surface of the babbitt alloy after examining the wear resistance on sliding distance of 100 m in dry test, a) ingot, b) babbitt bearing

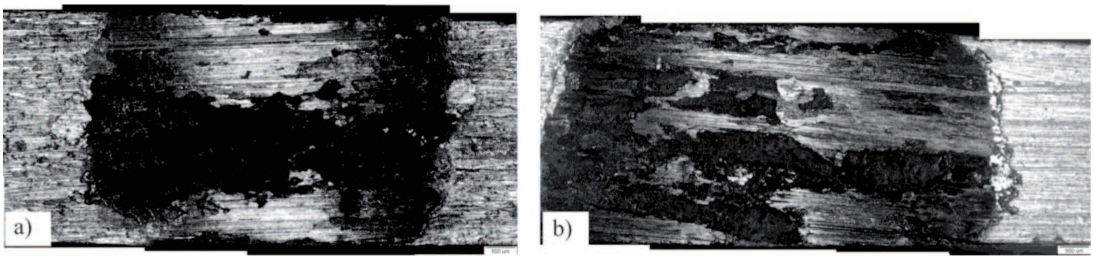


Fig. 16. The surface of the babbitt alloy after examining the wear resistance on sliding distance of 1000m in dry test, a) ingot, b) babbitt bearing

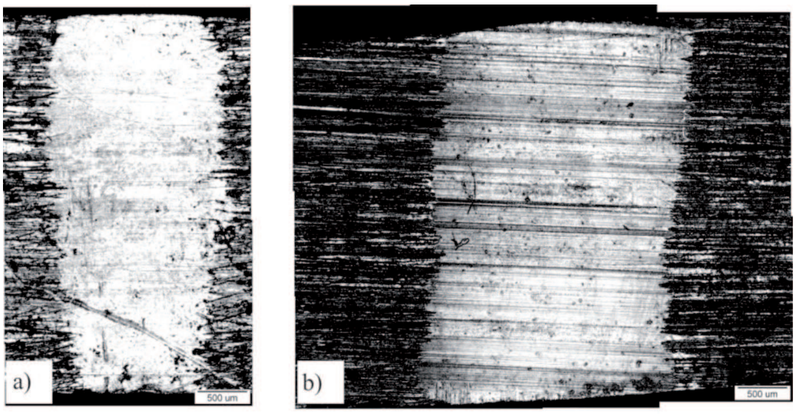


Fig. 17. The surface of the babbitt alloy after examining the wear resistance on sliding distance of 1000m in wet test, a) ingot, b) babbitt bearing

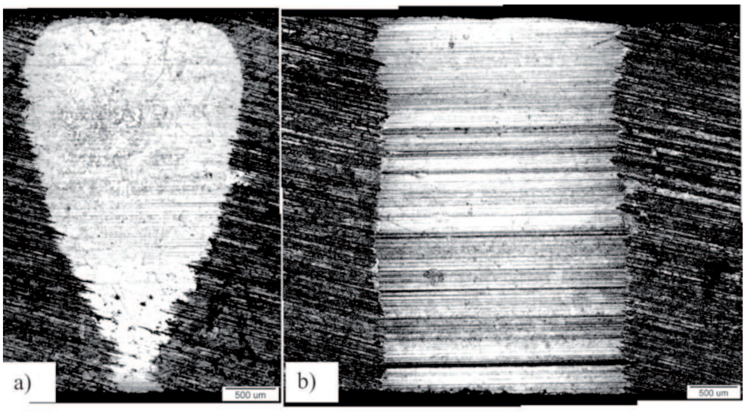


Fig. 18. The surface of the babbitt alloy after examining the wear resistance on sliding distance of 10000m in wet test, a) ingot, b) babbitt bearing

The friction surface obtained during the dry friction test presented in Figures 15 and 16 indicates that the dominating mechanisms of the friction wear were scratching, microcutting and adhesive wear. The hard phase Cu_6Sn_5 on the wear-surfaces were crushed and pulled out from the matrix and acts as abrasive particles which cause increase of the friction coefficient. An application of TU 32 oil (Fig. 17 and 18) completely eliminates the adhesive wear, which significantly decreases the friction coefficient and loss of the sample mass during the test.

4. Summary

The obtained results of the selected tribological properties and microstructural characterisation of the samples extracted from ingot and babbitt bearing and carried out under laboratory conditions are presented in this paper. Basing on the analysis of the test results the following conclusions can be drawn:

- Substantial difference exists in the microstructure and properties of the samples extracted from ingot and babbitt bearing.
- The microstructures of the bearing sample show, that the hard phase Cu_6Sn_5 predominate in comparison to the ingot sample.
- Higher hardness of the sample extracted from the babbitt bearing (29HB) in comparison with the hardness of the babbitt ingot (23HB) confirmed large amount of the hard phases Cu_6Sn_5 in the babbitt bearing.
- The long-time working of the babbitt bearing causes increase of their bending strength with comparison to the samples made from the ingot. In both cases cracking starts to propagate on the hard-phase precipitates.
- The ingot shows three times lower loss of mass during the dry test at a distance of 1000 m. The loss of mass is 0.9 and 2.5% for the ingot and babbitt bearing, respectively.
- The ingot shows also the lower loss of mass and friction coefficient during the wet test with comparison to the samples performed from babbitt bearing.
- Drawing and microcutting are the main wear mechanism observed during the tribological test. In the dry test also adhesive wear exists as a wear mechanism.

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