# THE PHYSICAL MODEL OF CHANGES SETTING IN MULTILAYER BEARINGS

**Stanisław Kowalczyk**

*Military University of Technology, Faculty of Mechanical Engineering*
*Institute of Motor Vehicles and Transportation*
*Gen. Sylwestra Kaliskiego2, 00 – 908 Warsaw, Poland*
*tel.: +48 22 6839449, fax: +48 22 6839449*
*e-mail: skowalczyk@wat.edu.pl*

***Abstract***

*This work presents the physical model of changes setting in multilayer bearing of combustion engines. It is known, that the slide bearing of high-load combustion engines independently from manufacturing technology, must have a material stability with regard on diffusion process of the alloy components. The present state of materials used on slide multilayer bearings of combustion engines has not changed during the last 30-year. Only small changes and modifications of material multilayer bearings, with the use of the same groups of materials, independently from specific manufacturing technology of bearing and their use were observed. The change of bearings materials, growth of operating requirements of combustion engines, ecological limitation and the price of materials may force changes in present constructional and technological conception of multilayer, in range of materials selection and building the bearings. This work presents the physical model of changes setting in multilayer bearing on different building. It was found that the slide bearing of high-load combustion engines is not physically and thermally stable up to 180°C. Different models show that after heating, all phases and structural components present on graph of equilibrium in given temperature are not created.*

***Keywords:*** *combustion engines, multilayer bearing, research, material stability, physical model*

## 1. Introduction

In the eighties of XX century the attention was paid to the role of changes in chemical composition and structure materials of sliding layers bearings [1-4]. The situation presented above was caused by unexplained cases of effacing the slide bearing in high-load combustion engines, where a clean nickel with satisfactory sliding proprieties was electrolyticly applied on a barrier layer. Other researches, in which different barrier layers were used, did not give positive results. It was observed that there is a decrease of tin in overlay in multilayer bearings on a lead matrix. As a result of growth of total service load bearing and its temperature of work, the tin from an overlay was diffusing in a direction of indirect layer, the bronze. It caused the fall of a tin content in an overlay, which led to a lower corrosion resistance and endurance of alloy. All experiments, which have been made so far, did not bring unambiguous settlement on physical model of changes setting in a structure of multilayer bearings material.

## 2. Results of investigations of thermal stability bearings layers

The environmental conditions, in particular the temperature of engine, influence the thermal stability of multilayer bearings materials. The researches show that stability of usable properties of multilayer bearings can be increased. This would counteract the diffusion of component alloys between layers of bearing. The growth of temperature of working bearings accelerates diffusive processes in bearings layers. It causes the reduction of their properties, in particular fatigue resistance and seizure resistance. It concerns particularly the area of the barrier layer, which should be taken as a weakness of multilayer bearing.

The analysis of equilibrium system [5] shows that solution and chemical compounds like: Cu-Sn, Ni-Cr; Al-Ni, Al-Cr, Sn-Ni, Sn-Cr, Ni-Cu, Cu–Cr, can by created during the work of bearing. The possibility of creating the threefold system compound Sn-Ni-Cr, or a fourfold system compound Sn-Ni-Cr-Cu cannot be excluded. As results of reactive diffusion the structural reconstruction of layers in multilayer bearings can be expected.

In the research different bearings were examined: bearings with galvanized overlay PbSn10Cu6 and a barrier layer - Ni, vacuum-deposited film AlSn20Cu1 and an interlayer - Ni-Cr. The samples of trade bearings were used in the examination. They were heated in controlled conditions in the temperature up to 180°C for 300 hours.

As it is shown in Fig. 1 (adequately: the bearing without heating - Fig. 1a and the bearing after heating - Fig. 1b) there is a change of value of elements' intensity concentration as well as common, with solid character, occurrence of tin and copper in overlay bearing in microarea of bearings with overlay PbSn10Cu6. The tin and copper grouping in the barrier layer can be the treated as a proof of creating chemical compounds (Cu-Sn or Cu-Sn-Ni) in examined bearing layer.

a) b)

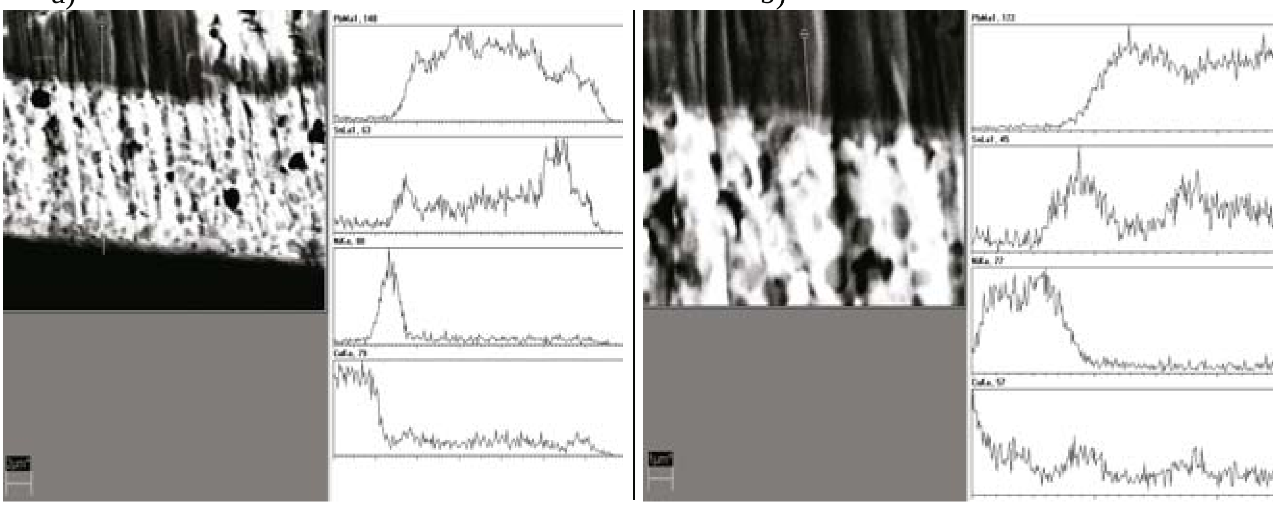

*Fig. 1. The example of structure and lining of concentration elements in the layer zone of bearing: a) - the bearing without heating, b) - the bearing after heating*

a) b)

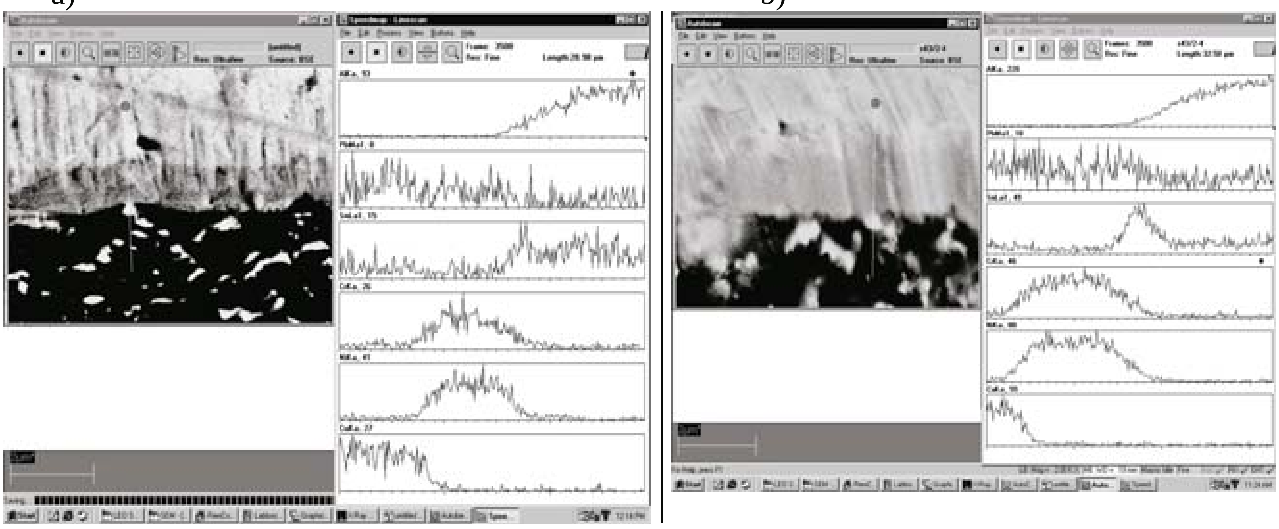

*Fig. 2. The example of structure and lining of concentration elements change in the layer zone of bearing: a) - the bearing without heating, b) - the bearing after heating*

The Fig. 2 presents the material structure of examined bearing layer, in particular the barrier layer (adequately: the bearing without heating - Fig. 2a and the bearing after heating - Fig. 2b). In both considered variants a thin, 2 μm thick, rather homogeneous interlayer of Ni – Cr, is visible which separates alloy AlSn20Cu1 vacuumed-deposited film on basis of bronze CuPb23Sn2. To reveal expected intermetallic phases in the zone of barrier layer, after heating the bearing, the chemical composition was analysed in the mikroareas, along chosen scanning lines. The visible distribution of concentration of analysed chemical elements (Ni-Cr) shows that its character is similar.

## 3. The physical model of changes setting w multilayer bearings

The model construction of changes proceeded in multilayer bearings was based on the results obtained during realization of work as well as on own researches, which present the determination concerning diffusive processes and identification of components structure formed in this process. Researches, which have been done, include five different material and technological solutions of multilayer bearings. These results were confirmed by other authors engaged in this matter [6-13]. The general form of physical sliding layer model is presented in Fig 3. The model of diffusion in materials of bearing layer with overlay (PbSnCu and AlSnCu), which takes into account the penetration of grains borders in unbalanced structure, was presented in Fig 4, 6 and 8. The physical model of changes proceeded in materials of bearings layers with overlay mentioned above was shown in Fig. 5, 7 and 9.

The structure of tribological model WŁ can be written in form presented below:

$$WŁ = \{ E, W, R \},$$

where:
E - elements (1), (2), (3), (4), (5), (6) of tribological system,
W - proprieties of the tribological system elements,
R - interrelation between elements of tribological system.

Proprieties of tribological system elements (1) and (3), (4) are dependent on: geometry of surface, chemical constitution of superficial layer, phase structure and tension in superficial zone, resilience module and schedule of hardness in section of superficial layer.

The tribological system element (2) is characterized by viscosity of grease oil, which changes dependently on temperature and pressure. The surrounding also called an environment of tribological system, it characterised by chemical constitution as well as by water steam in it.

The interrelations between tribological system elements (1), (2), (3), (4), (5), (6) proceeded in:

- the process of contact,
- the process of friction,
- the process of wear,
- the process of changing the conditions of exploitation,
- the process of changing the conditions of lubrication.

Technological, material and structural factors considered together decide about the intensity of interrelation. Among them, technological factors have the biggest impact on properties of tribological system elements (1) and (2), because during the realization of technological process a surface layer with defined resistance on technological wear created. However, the essence of wear is dependent not only on individual characteristics of material and its surface layer, but also the whole tribological system presented in Fig.3.

The entry parameters in this model save the material and technological features, as well as factors of extortion, which are the results of an exploitation process.

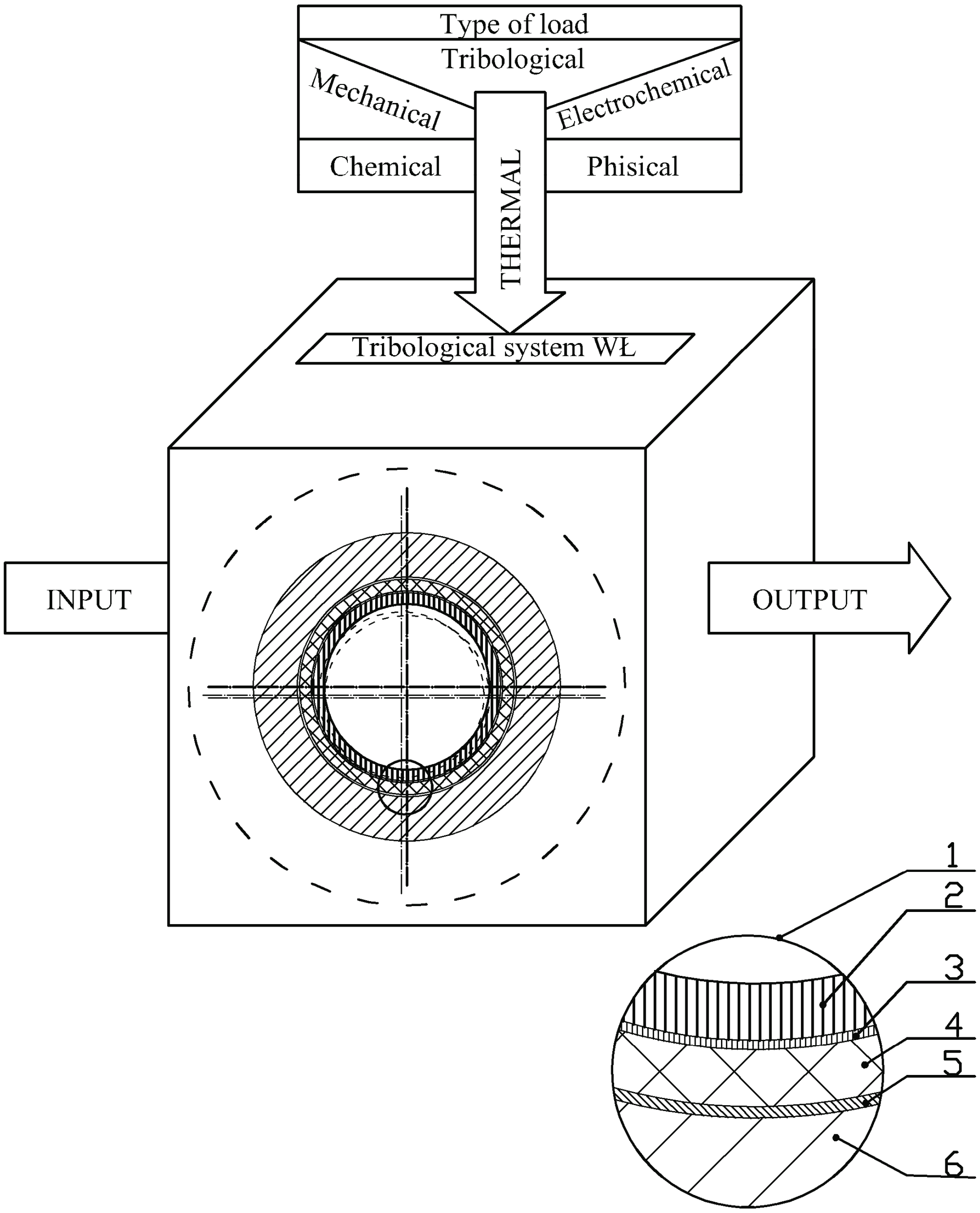


*Fig. 3. A general form of studied sliding bearing model*
*1 - crankshaft main bearing journal, 2 - grease oil, 3 - protective layer, 4 - overlay, 5 - interlayer (barrier layer), 6 - bearing material layer*

The process of wear in the plain bearing unit of tribological system, treated as a plain bearing unit of frictions can be disturbed by external factors like: thermal load (the thermal energy), chemical load (aggressive atmospheric environment), mechanical load (energy of mechanical trembling), electrochemical load (chemical activity of surrounding correlated with electric activity), physical load (energy of radiation), and tribological load (energy of friction).

Exit parameters in this model present the results of researches as a resistance to tribological wear. This is the answer to entry parameters, which cause changes leading to a reduction of usable properties in materials of sliding layers bearings.

Presented models show that in materials of examined bearings all phases and structural components shown on graphs of equilibrium are not created in materials of examined bearings after soaking. Bearings where changes in the structure of materials were observed, can potentially work shorter and their use in combustion engines can by limited.

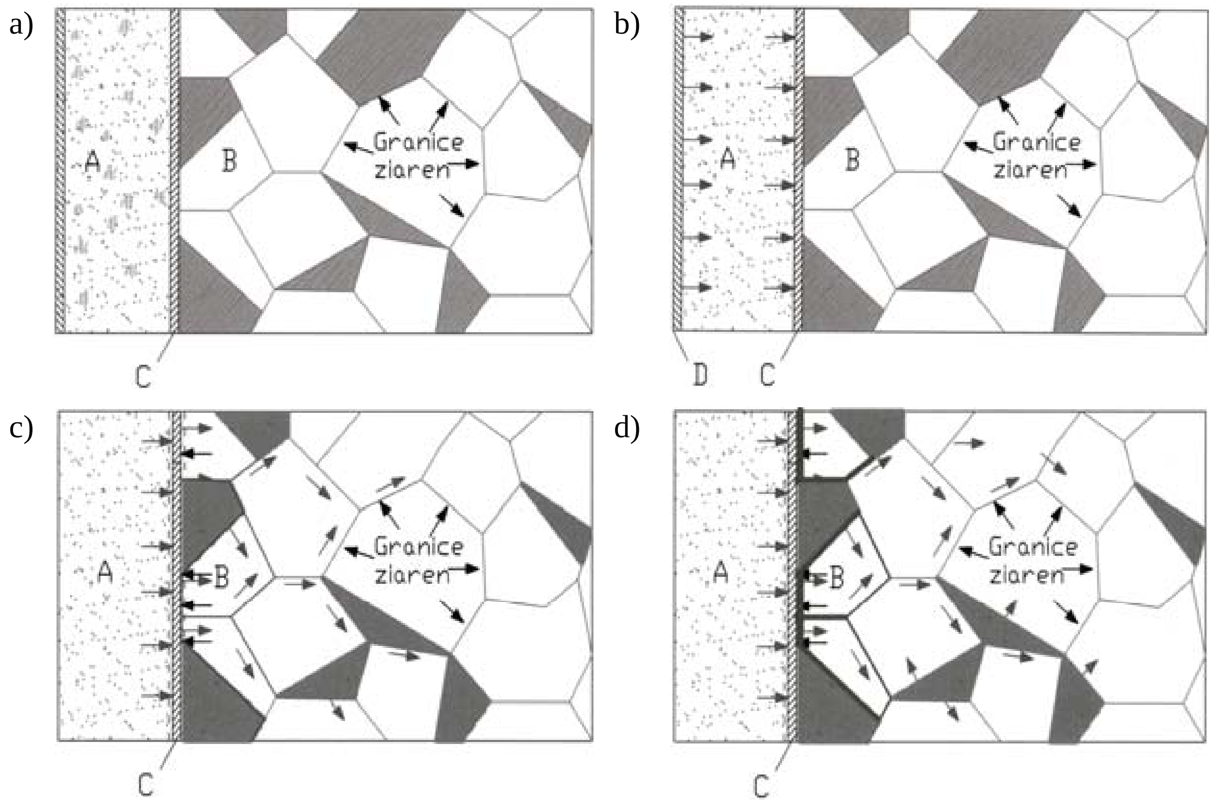


*Fig. 4. The model of diffusion in material of bearing layers with (Pb - Sn – Cu) overlay, which takes into account the penetration after grain boundary in conditions the metastable state of structure: a) - the bearing without heating; the bearing after heating, suitably: b) - 120 °C, c) - 150 °C, d) - 180 °C; A-overlay, B-bearing material layer, C-interlayer (barrier layer), D- protective layer*

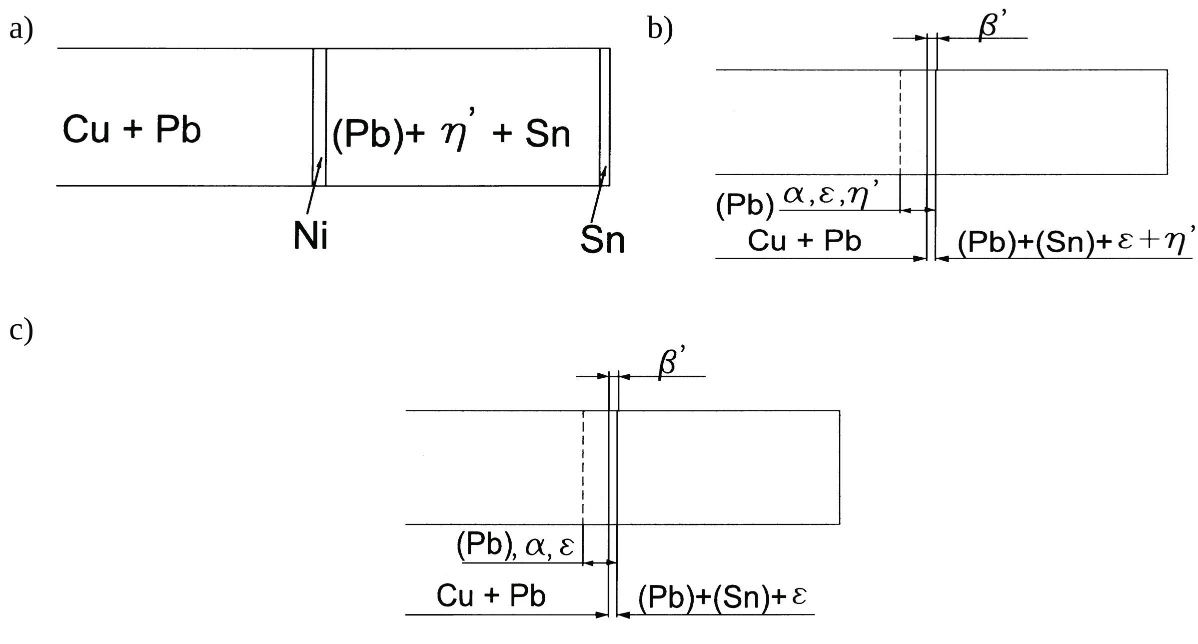


*Fig. 5. The physical model of changes setting in materials of bearing layers of the Pb-Sn-Cu sliding layer, where: (Pb) – solid solution Sn w Pb, (Sn) – solid solution Pb w Sn, η' - intermetallic phase $Cu_6Sn_5$, ε - intermetallic phase $Cu_3Sn$, β' - intermetallic phase $Ni_3Sn_2$: a) - the bearing without heating; the bearing after heating, suitably: b) - 150 °C, c) - 180 °C*

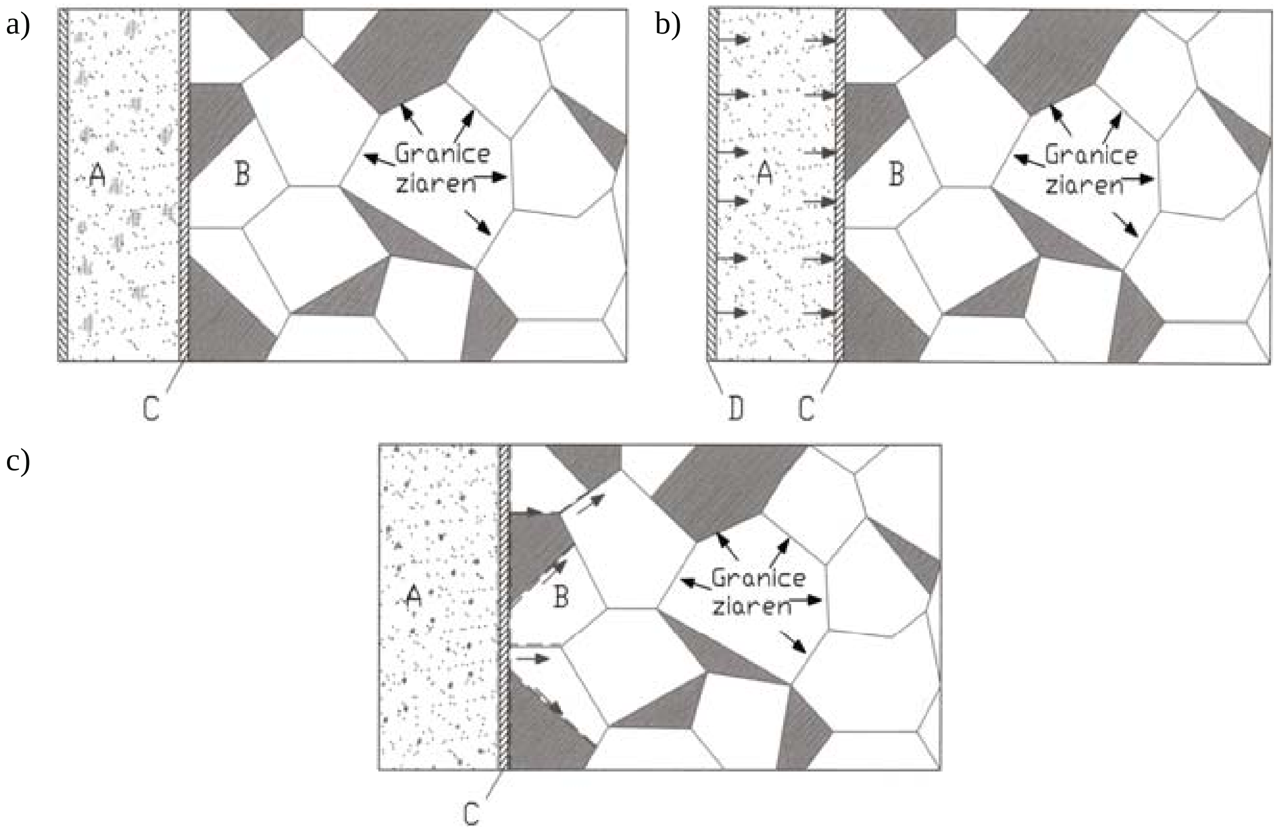


*Fig.6. The model of diffusion in material of bearing layers with (Pb - Sn – Cu) overlay, which takes into account the penetration after grain boundary in conditions the metastable state of structure (of 6%Cu concentration in sliding layers) : a) - the bearing without heating; the bearing after heating, suitably: b) - 150 ℃, c) - 180 ℃; A-overlay, B- bearing material layer, C-interlayer (barrier layer), D- protective layer*

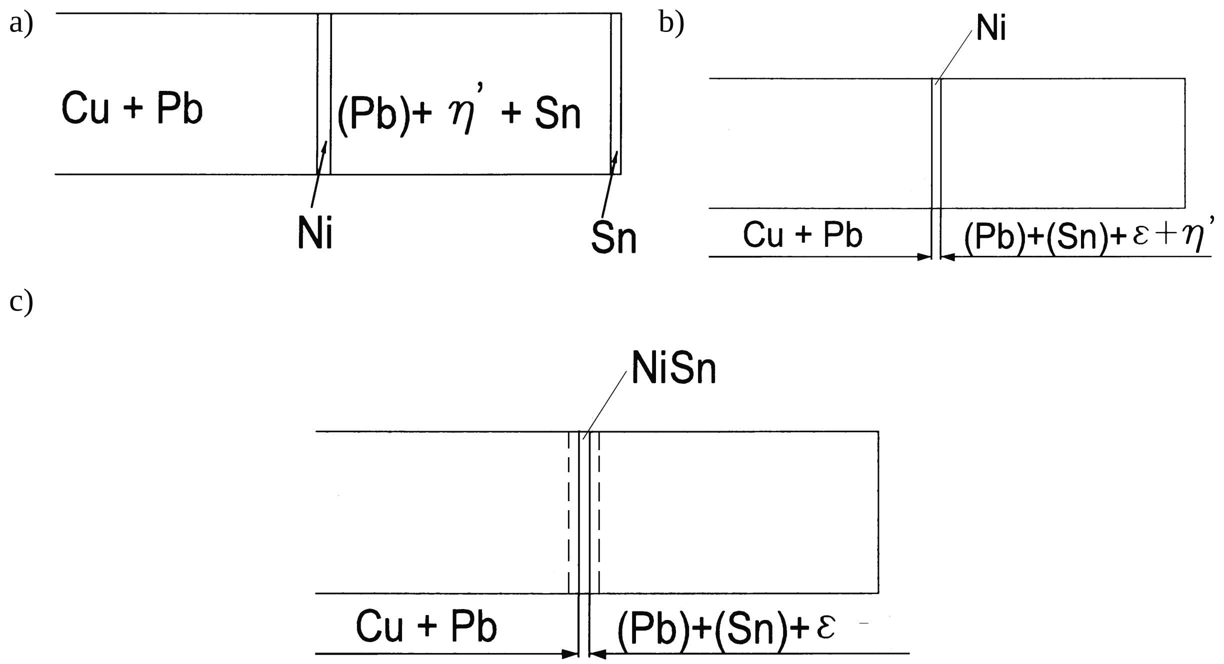


*Fig. 7. The physical model of changes setting in materials of bearing layers of the Pb-Sn-Cu overlay, where: (Pb) – solid solution Sn in Pb, (Sn) – solid solution Pb in Sn, $\eta'$ - intermetallic phase $Cu_6Sn_5$, $\varepsilon$ - intermetallic phase $Cu_3Sn$, a) - the bearing without heating; the bearing after heating, suitably: b) - 150℃, c) - 180℃*

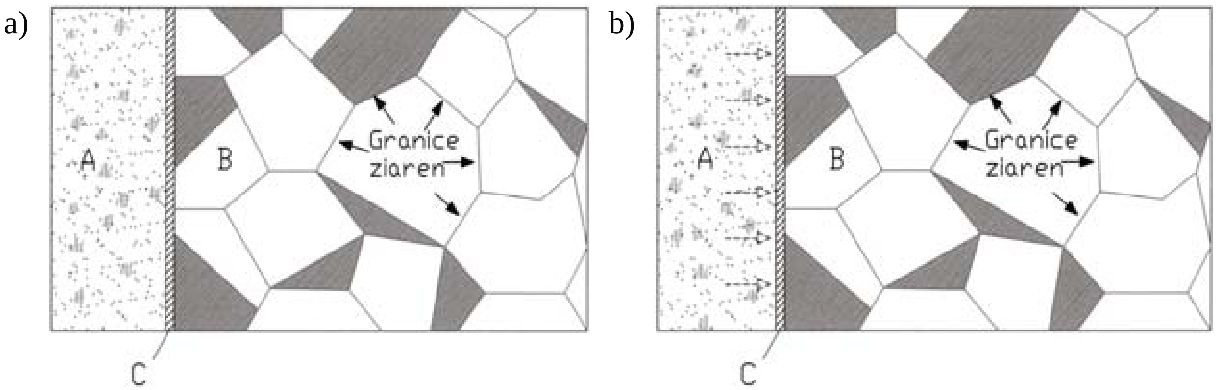


*Fig. 8. The model of diffusion in materials of bearing layers with ( Al - Sn – Cu) overlay, which takes the taking into account the penetration the grain boundary in conditions the metastable state of structure; a) - the bearing without heating; b) - the bearing after heating in temperature - 180 °C;*
*A- vacuum-deposited film, B- bearing material layer, C-interlayer (barrier layer)*

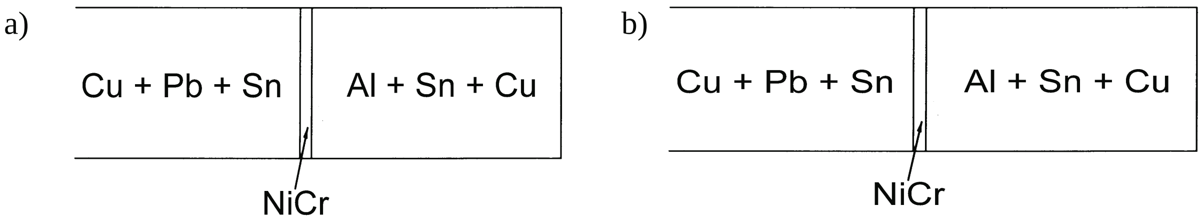


*Fig. 9.The physical model of changes setting in material of bearings layers from layer the sliding Al - Sn - Cu, where: NiCr - solid solution Cr in Ni; a) - the bearing without heating; b) - the bearing after heating in temperature 180 °C*

## 4. Conclusion

Different models show that after heating, all phases and structural components present on graph of equilibrium in given temperature, are not created. The bearings, in which changes in structure of layer materials were observed can probably work shorter. Thier use in combustion engines can be also limited.

Further researches should focus on qualification of mechanism and possibility of moderating the process of mutual diffusion in metallic multilayer arrangements of sliding bearing as well as the use of generalized Darken's model to describe these phenomena in the aspect of forming the multilayer proprieties in sliding bearings.

## References

[1] Davies, G. J., et al., *The development of new bearing materials.* Industrial Lubrication and Tribology, November/December 1986.

[2] Sakamoto, M., et al., *Diffusion Behavior of Overlay for Three Layers Engine Bearings.* Techn. Pap. Series, No. 890555, 1989.

[3] Sasaki, S., et al., *Damage to Cu-Pb Bearing for Diesel Engines and Causes Thereof.* Techn. Pap. Series, No. 870582, 1987.

[4] Bierlein, J. C., De Hart, A. D., *Score resistance, hardness and performance of diffused copper-nickel-tin bearings.* Techn. Pap. Series, No. 830064, 1983.

[5] Ganina, N. I., et al., *Diagramy sostojania mietaliczieskich sistiem: Ni-Cr; Al.-Ni, Al.-Cr, Sn-Ni, Sn-Cr, Ni-Cu, Cu-Cr.* XXXII, Moskwa 1989.

[6] Kowalczyk, S., *Dyfuzyjne procesy a odporność korozyjna stopów warstw ślizgowych łożysk wielowarstwowych*. Problemy eksploatacji, Nr 1, s.73-86, 2001.

[7] Kowalczyk, S., *Wpływ temperatury pracy łożysk wielowarstwowych na ich właściwości użytkowe.* V Międzynarodowe Sympozjum IPM, WAT, Warszawa,1993.

[8] Kowalczyk, S., *Wpływ temperatury pracy łożysk wielowarstwowych silnika typu AA i pochodnych na ich właściwości użytkowe.* Materiały konferencyjne XX Jesienna Szkoła Tribologiczna, Spała, 1995.

[9] Gola, W., Kowalczyk, S., *Wpływ ochronnej powłoki cyny na własności wielowarstwowego łożyska z warstwą ślizgową ołów - ind.* Materiały konferencyjne „Inżynieria Łożyskowania '96", Gdańsk-Sopot, 1996.

[10] Cypko, E., Kowalczyk, S., Radzimierski, M., *Badania struktury materiałów łożysk ślizgowych wielowarstwowych z warstwami napylanymi*. V Sympozjum Naukowo-Techniczne „Silniki Spalinowe w zastosowaniach wojskowych" Jurata, 2001.

[11] Cypko, E., Kowalczyk, S., Tyeskyer, Ye. I., Kosov, O. D., Tyeskyer, S. Ye., *Isslyedovaniye strooktoori i svoystv pokritiy na osnovye alyoominiya dlya mnogosloynih podshipnikov skol'zhyeniya.* Ooprochnyayooshshiye Tyehnologii i Pokritiya Nr 10/2005.

[11] Kowalczyk, S., *Barrier layers in multilayer slide bearings of the combustion engines.* Journal of KONES Powertrain and Transport, No 4, vol. 14, 2007.

[12] Kostrzewa, S., Kowalczyk, S., Rożniatowski, W., *Materiały stosowane w łożyskach ślizgowych – stan obecny i tendencje rozwojowe*. Inżynieria Materiałowa nr 5 (137)/2007.