DAMAGE OF THE CuPb20 SLIDING BEARING

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Abstract:
The analysis of hydrodynamic steel sliding bearing with leaded bronze lining, which had a reduced shortened lifetime due to its unequal wear, was carried out. The lining structure of this bearing was compared to those of the bearing with a high lifetime and of the unused bearing. It was shown that the short lifetime is caused by wrong lubricating oil. The use of unsuitable oil led to the formation of hard and brittle layer containing phosphide (Cu3P) at the lining surface. The scaling off particles of the layer influenced the friction conditions and accelerated the wear.

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1. INTRODUCTION

Sliding bearings are the machine parts making the transmission of the rotation motion from shafts and pins possible. Sliding bearings have good sliding properties, smooth running without seizing and low friction coefficient [1,2]. The present paper deals with the hydrodynamic steel bearings with the leaded bronze lining.

The lead contents in these bearings is usually 20 – 30 %; in special cases, however, it can be even higher than 30 %. Lead decreases the friction coefficient. In the liquid state, copper and lead are partially miscible. In the solid state, the both metals are almost not miscible, the solubility of copper in lead is approximately only 0.05 %. Different properties of copper and lead (temperature of solidification, density) and immiscibility in the solid state can cause a significant segregation. The structure of cast leaded bronzes consists of the copper matrix and lead in the interdendritic areas. In the sliding bearings, a uniform dispersion of lead in copper is quite significant. The leaded bronze linings are centrifugally cast in a thin layer into a steel base. The alloy is sufficiently rapidly cooled and has a suitable structure [1,3-6].

The article [6] deals with Cu-Pb alloy with the lead contents of 5, 10, 15, 20, 25, 30 and 40 weight percent. The mechanical properties such as tensile strength, 0.2% tensile and compressive stresses, hardness and percentage elongation, decreased with increasing amounts of lead in the alloy. The wear volume decreased with increasing amounts of lead in the alloy. After a short running-in period, there is steady state wear during which a linear relationship between wear volume and sliding distance is maintained. In all the cases, irrespective of lead content in the alloy, the wear rate decreases with increasing sliding velocity, attaining a minimum value, and then increases with increasing sliding velocity.

2. EXPERIMENTAL MATERIAL AND TESTS PROGRAM

Analyses are aimed at finding the cause of a very short lifetime of the ϕ90 mm sliding bearing. The lining of the sliding bearing was made from CuPb20 leaded bronze. The bearing was made in the frame of new production series; there was a spare part, which withstood in the machine only one year. Together with the bearing of the reduced lifetime, two another bearings were analyzed as well – the original bearing of ten years lifetime and

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a quite new bearing, which has not been used before. The designation of the sliding bearings is given in Tab. 1.

The experimental program was divided into two parts: analysis of the structure of the lining cross-section and analysis of their surfaces. Chemical composition of lining was determined with the help of energy-dispersive X-ray spectrometer (EDX) of scanning electron microscope (SEM).

Table 1. Analyzed bearings

Specimen	Bearing
A	Original bearing - lifetime 10 years
B	New bearing - lifetime 1 year
C	New unused bearing

3. RESULTS AND DISCUSSION

3.1. The lining cross section

Structures of cross sections were studied using the optical and scanning electron microscopy.

The dendritic structure of cast Cu grains, depicted in Figs. 1-6, is inhomogeneous in all the three bearing bushes what is caused by the casting technology of bushes. The unsatisfactory bush B has markedly smaller thickness of the CuPb20 lining than the bush A. No structural defect, which could be a potential cause of unsatisfactory lifetime, was detected in the lining of the bush B. It is apparent from Figs. 2 and 4 that the surface parts of lining of bearing A (Fig. 2) and bearing B (Fig. 4) are completely lead-free or they contain only small lead residues. Therefore, during the operation, lead is gradually removed from the interdendritic areas to oil and remains only between the secondary dendrite arms. The boundary between the subsurface layer and the rest of lining, characterized by the boundaries with and without lead in the interdendritic areas, what is well apparent from the elemental EDX analysis. The results of this analysis are given in Figs. 7-10. The thickness of the lead depleted layer changes in both bearings. In some places of bearing B, the depleted layer reaches the surface of the steel bush.

In the case of the unused bearing C, lead is distributed relatively uniformly along the whole thickness of the lining. There is a typical structure of rapidly cooled Cu-Pb type alloy that is influenced by the heat removal into the steel bush. While in the case of bush A the lining surface is smooth with undamaged dendrites (Fig. 2), the surface layer of the lining of bush B consists of a mixture of disintegrated Cu dendrites, Pb particles and oil residues (Fig. 4).

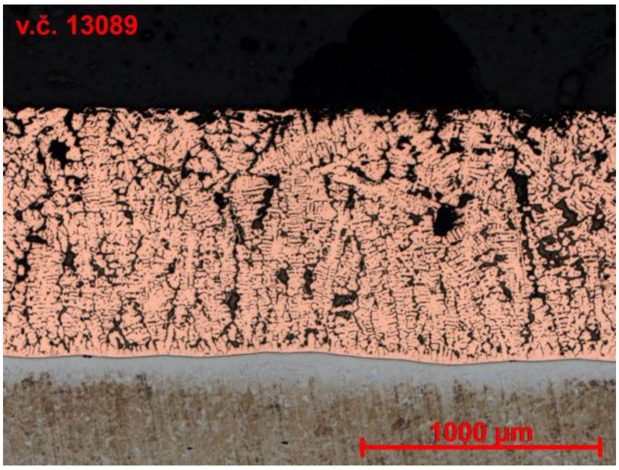

Fig. 1. Specimen A

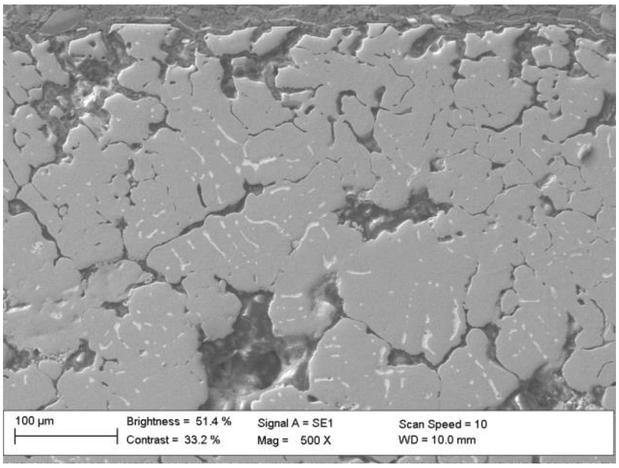

Fig. 2. Subsurface layer, specimen A, SEM

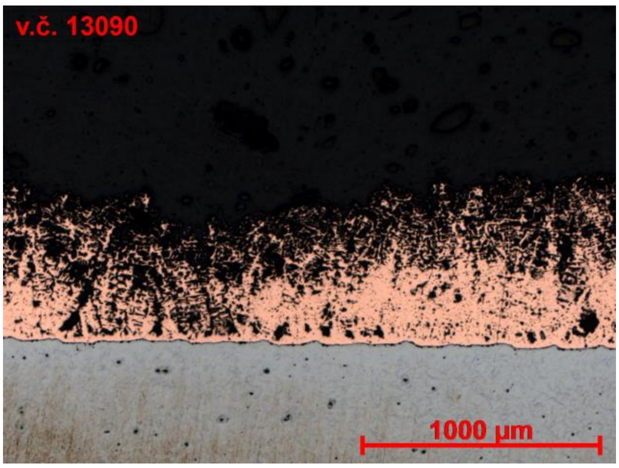

Fig. 3. Specimen B

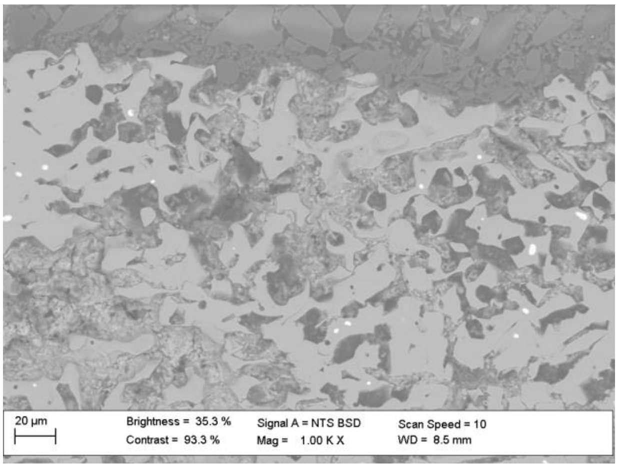

Fig. 4. Subsurface layer, specimen B, SEM

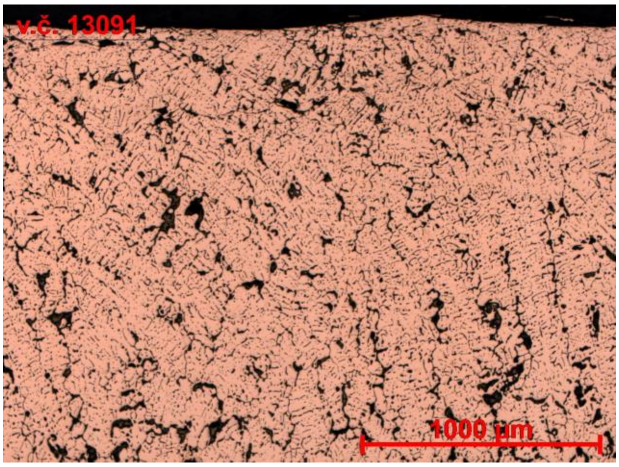

Fig. 5. Specimen C

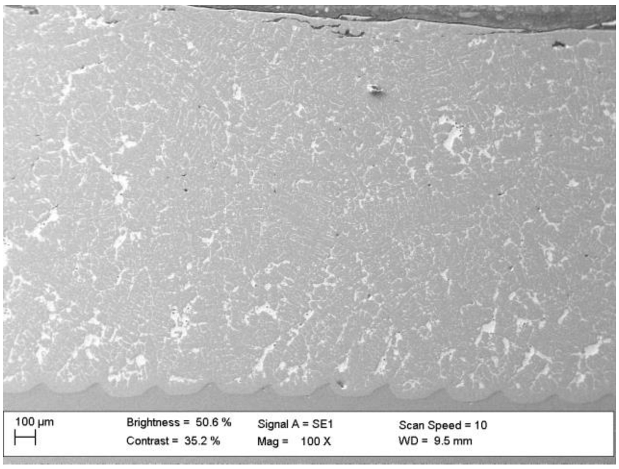

Fig. 6. Subsurface layer, specimen C, SEM

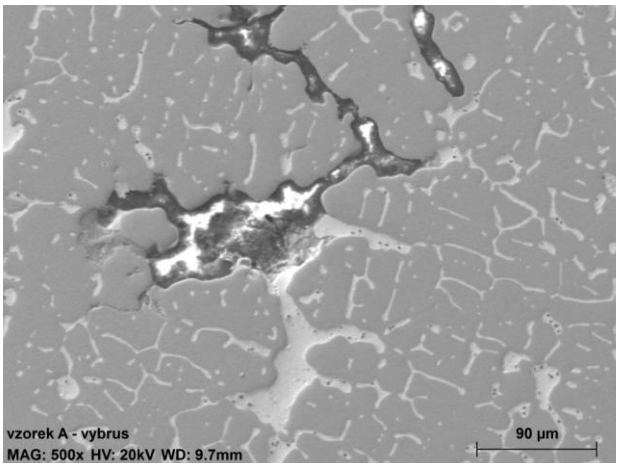

Fig. 7. Analyzed area by EDX analysis, cross section of the lining, specimen A

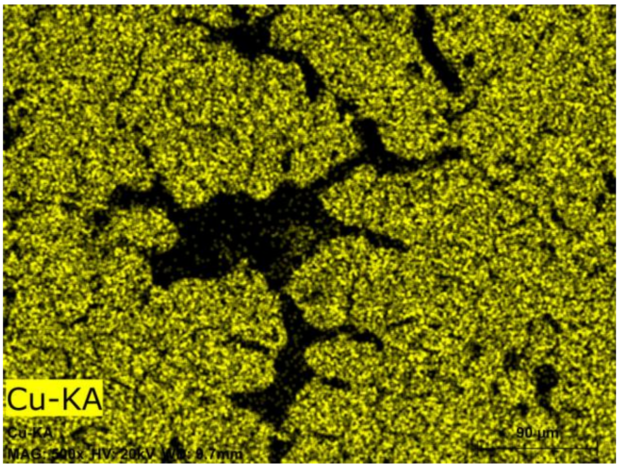

Fig. 8. Distribution of copper, EDX analysis, cross section of the lining, specimen A

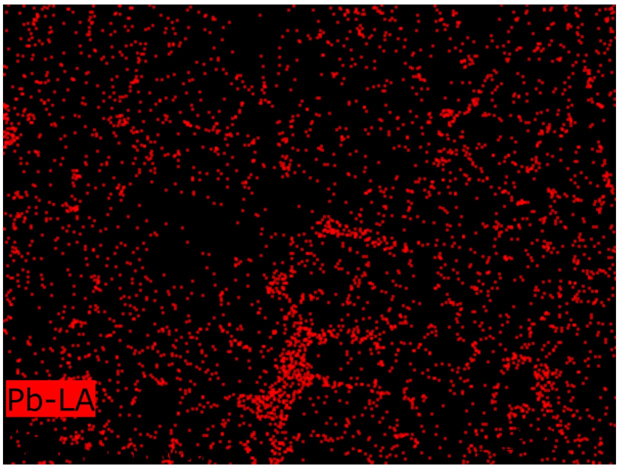

Fig. 9. Distribution of lead, EDX analysis, cross section of the lining, specimen A

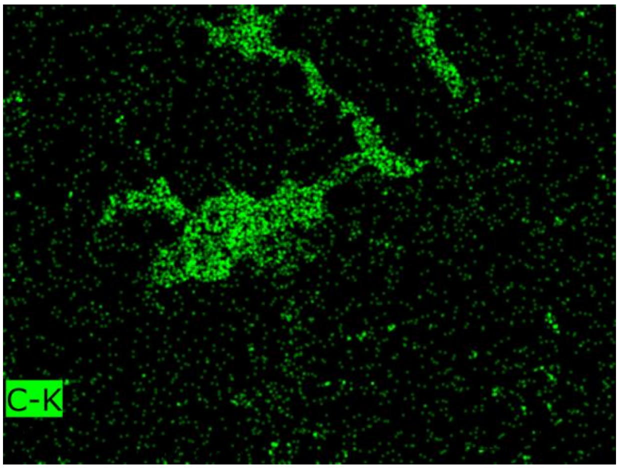

Fig. 10. Distribution of carbon (oil, friction products), EDX analysis, cross section of the lining, specimen A

3.2. The lining surface

The lining surfaces of three bushes differ substantially from each other. The surface structure of bush A (satisfactory, with the long lifetime) is of the cast type with very well-defined copper grains and interdendritic areas (Fig. 11). Light coloring of interdendritic areas arises from a filler, which is charged in the SEM. There are the lubricating oil and friction products, the electrical conductivity of which is very low. Lubricating oil together with the friction products, replaces lead in the interdendritic areas.

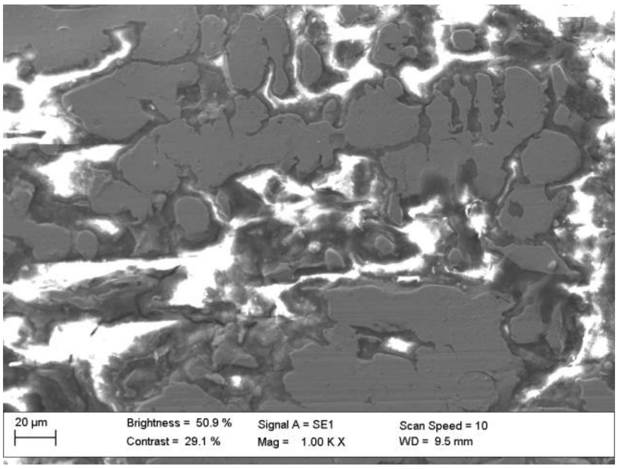

Fig. 11. Surface of the lining, specimen A

The surface of unsatisfactory bearing with the short lifetime (B) is covered with consistent layer of oil and friction products, which both overlap the cast grains and fill in the interdendritic areas (Fig. 12). The layer surface is cracked and of the brittle type. There are probably fatigue cracks that can be the cause of a gradual destruction of the layer during the operation of the bearing. The destruction is accompanied by scaling off particles of the layer. Brittle and hard particles can then influence the friction conditions and accelerate the wear of the lining. The surface of the unused bush C is coherent and smooth (Fig. 13). There are no features on the surface, which would give evidence that the structure is of the cast type. The state of the surface is influenced by operation. In its course, the soft copper and lead are easily deformed and then form the overlaps (Fig. 6).

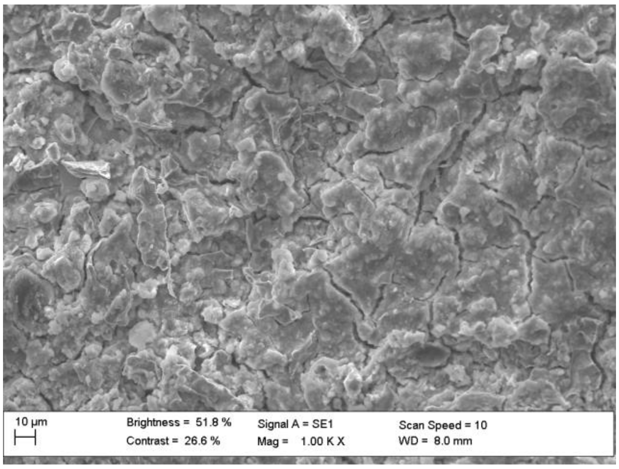

Fig. 12. Surface of the lining, specimen B

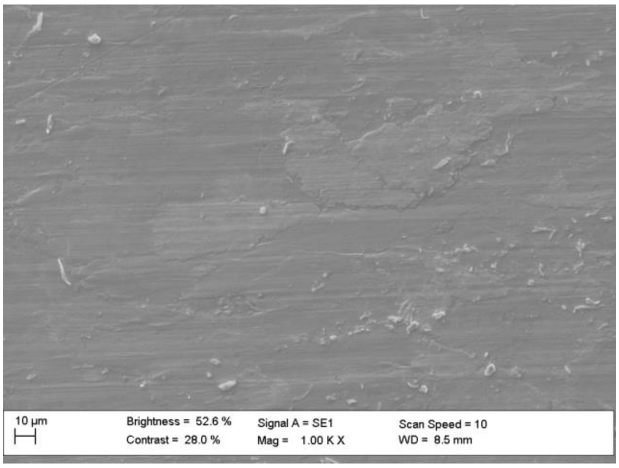

Fig. 13. Surface of the lining, specimen C

3.3. Chemical composition of the lining by EDX analyses

The results of chemical analyses of the lining surfaces are given in Tab. 2. Owing to presence of the surface layer in the bush B, the results of analyses of both bushes (A, B) differ significantly from each other. The differences are apparent both for metallic elements Pb and Cu and non-metallic elements contained in the lubricating oil or, in the case of bush C, in the surface contamination after operation.

The surface layer in the unsatisfactory bush contains more Pb, and, as for the non-metallic elements, mainly more P and less Ca than that one in bush A. The differences in P and Ca contents in surface layers of bushes A and B can suggest that a low lifetime of bush B can be in connection with the composition of lubricating oil. The presence of Ag and Zn, as well as the differences in their contents, cannot be accounted for, due to the lack of information on possible source of these elements. A lower Pb contents on the surface of bearing A in comparison to bearing B can be explained by the fact that there is almost no Pb in the interdendritic areas in its subsurface layer (Figs. 2 and 4). It follows, therefore, that a higher Pb concentration in the faulty bearing B can be attributed to accumulation of the part of lead in the surface layer during the operation. Due to the fact that phosphorus together with copper form a hard and brittle phosphide (Cu_3P), an increased P contents in the surface layer can be related to presence of this phosphide and can be one of the causes of the short lifetime of bush B. Therefore, to exclude the use of copper with a higher phosphorus contents, the SEM analysis of phosphorus contents in copper in the lining was carried out as well. The analysis was carried out in the lining near the steel bush, where the lining was not damaged and was not affected by the friction conditions at the lining surface. The results of the analysis are given in Tab. 3. It follows from the results obtained that copper contained only traces of P in all investigated bushes. Thus, the most probable source of a higher P contents in the surface layer seems to be the used oil for lubrication of the bush.

Table 2. Chemical composition of the lining surface by EDX [wt. %], * average of three measurements

Specimen	C	O	Al	P	S	Ca	Fe	Cu	Zn	Ag	Pb
A*	33.91	15.02	0.12	0.43	3.83	1.45	0.31	41.33	0.89	1.42	1.28
B*	26.25	11.81	0.20	1.57	3.73	0.32	2.01	45.55	1.82	0.76	5.99
C	13.05	3.44	-	-	0.90	-	-	70.55	-	-	12.05

Table 3. Analyzed bearings

Specimen	A	B	C
P [wt. %]	0.07	0.05	0.03

4. CONCLUSION

The results of the analyses of the bearings can be briefly summarized as follows:

- At the lining surface of bearings with the long and short lifetime, the lead is removed from the interdendritic areas in copper grains during the operation. However, lead remains between the secondary dendrite arms.
- The interdendritic areas in the bearing with the long lifetime is filled with the lubricating oil and friction products. On the surface of the bearing with the short lifetime, a coherent layer has been formed. This layer is brittle and, owing to loading, has also cracked. It contains disintegrated copper particles and a mixture of oil and friction products. Its formation and gradual spalling off seems to be the most probable cause of a rapid wear of the lining.
- The surface layer in the bush with the short lifetime has the composition different from those of oil and friction products in the interdendritic areas in the bush with the long lifetime. The surface layer of the bush with the short lifetime has an increased phosphorus contents and lower calcium contents. As phosphorus together with copper forms hard and brittle phosphide Cu_3P, the formation of the coherent brittle surface layer is caused by a higher phosphorus contents.
- The possibility that a higher phosphorus contents comes from copper used for the CuPb20 lining was excluded.
- The structure of the unused bearing does not contain any defects or anomalies which could be a potential cause of a decreased lifetime of the bearing.
- From all the above follows that the decrease of lifetime is caused by the change of the oil composition. This change was confirmed by the user´s information.

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