DETERMINATION OF TRIBOLOGICAL AND MECHANICAL PROPERTIES OF SnPbCuSb (WHITE METAL) BEARINGS

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White metals (SnPbCuSb) are widely used as journal bearing materials for tin and lead based alloys. In this study, tribological and mechanical properties of these journal bearings manufactured from Sn based SnPbCuSb, pure Sn, pure Pb bearings and from alloy elements, pure Cu metals were determined. SAE 1050 steel shaft (journal) was used as a counter abrader. Wear experiments were carried out in every 30 min for the total of 150 min by using radial journal bearing wear test rig. It was shown that the lowest friction coefficient of bearing and journal wear loss occurred in SnPbCuSb alloyed bearing.

Key-words: *tribology, mechanical property, white metal bearings.*

In the past few years, wood, iron and skin have been used as journal bearing materials. Later, brass, bronze and white metal have also found some applications. Currently, in addition to these bearing materials, aluminum and zinc based materials are used as journal bearing materials. With technological improvements, self-lubricated sintered bearings are utilized where continuous lubricating is impossible and plastic materials are used in certain applications. Therefore, it is essential that the bearing material be chosen depending upon application area.

Wear resistance is one of the most important properties that journal bearings should posses. There are several studies and investigations dealing with wear resistance improvements of these materials [1–4].

The effect of tin on wear in copper based materials is important. Copper based tin bronzes that include tin are used as bearing material to have a high wear resistance [5]. Friction and wear properties of these materials can be improved by adding tin [6]. The tin bronze (90% Cu and 10% Sn) is the most suitable bearing material under corrosive conditions, at high temperatures and high loads [7]. The effect of copper on mechanical properties in tin-lead based materials is important. Copper increases the mechanical properties of tin-lead based materials [4]. In addition, antimony increases the hardness and mechanical properties of tin-lead based materials. It prevents shrinking during the solidification of tin-lead [8].

Tribo-materials used for crank shaft in automobiles have embedding ability and high wear resistance. These bearings contain lead, tin, aluminum and copper [2, 6, 7].

Lead and tin based white metal alloys are used due to their antifriction property as bearing materials. These alloys are produced by casting and spray deposition method. These casting alloys contain intermetallic phase. The process variables during spray forming of babbit bearing metal alloy strongly influence the microstructure and porosity of the spray deposits. The wear rate of the spray-formed alloy is lower than that of the as-cast alloy. Wear properties of the spray-formed alloy are attributed to the decreased intermetallic phases and modification in the microstructure of the eutectic phases [7]. SnPbCuSb (white metal) alloys are important due to non-seizure and good wear resistance like journal bearing material. These alloys are especially used in automotive and machine element applications as journal bearing materials [4].

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Tin based white metal (babbit) materials have been widely used as journal bearings due to their superior wear properties [8, 9]. In this study, friction coefficient, temperature values and wear losses of bearing-journal samples were determined by wearing [10, 11] on radial journal bearing wear test rig designed specially for this purpose and mechanical properties of SnPbCuSb white metal for Sn based alloys were determined.

Experimental studies. ***Preparation of experimental materials.*** In this study, pure Sn, pure Pb, pure Cu, SnPbCuSb white metal specimens were used as journal bearing and SAE 1050 was used as a shaft. The chemical composition of the used journal materials are given in Table 1 and their chemical composition – in Table 2. Dimensions of bearing specimens were as follows: inner diameter – $10^{+0.05}$ mm, width – 10 mm, and outer diameter – 15 mm.

Table 1. Chemical composition of journal material, wt.%

Material	C	Si	Mn	P	S	Fe
SAE 1050	0.51	0.3	0.7	0.04	0.05	Balance

Table 2. Chemical composition of bearing material, wt.%

Material	Sn	Pb	Cu	Sb
SnPbCuSb	80	3	6	11

The specimens were worn by radial journal bearing wear test rig under lubrication condition. The wear losses were measured under lubrication conditions of 20 N loads 1500 rpm (v = 0.785 m/s velocity) and every 30 min for 2.5 h (7065 m sliding distance). The lubricating was accomplished by using SAE 90 gear oil. The microstructures of wear surfaces were photographed using optical and scanning electron microscope.

Tensile, compressive, notch impact, three point bending, radial fracture and hardness tests were performed using ALŞA type tensile test rig depending on TS-138, and TS-269 (Turkish Standard) to obtain mechanical properties. Moreover, the hardness was measured using a SADT HARTIP-3000 type test rig.

***Radial journal bearing wear test rig*.** Journal bearings materials are generally selected from materials which have lower wear strength than the shaft material, thereby lowering the wearing of the shaft significantly. Therefore, journal bearing wear test rigs are designed to examine the wearing of bearing materials. In this study, a special bearing wear test rig has been designed to examine the wearing behavior of bearing material and the shaft together. Therefore, it is possible to investigate different bearing and shaft materials and the effects of heat treatment on these materials. Such a mechanism provides wear of bearings rather than using standard methods as this is a more appropriate direction [10].

The system is formed by a weight applied by a rigid bar, a steel bar connected to the bearing from a distance and a comparator. Friction coefficient is determined from the friction force formed along the rotating direction of the bearing and the movement of the steel bar connected to the bearing [11]. Radial wear test rig is illustrated in Fig. 1.

In the experiments under lubricated conditions, very little movement took place for high comparator coefficient of a spring and low friction. Therefore, a tensile spring of k = 0.004 N/mm has been connected on the opposite side of the comparator. The movements formed by the effect of the friction force have been measured by this method.

Surface roughness tests were performed on Mitutoyo-CE surface roughness test rig. The wear surfaces in the specimens were examined using the optical (Hund Wetzlar CCD-290) and scanning electron microscope (Jeol JSM-6060).

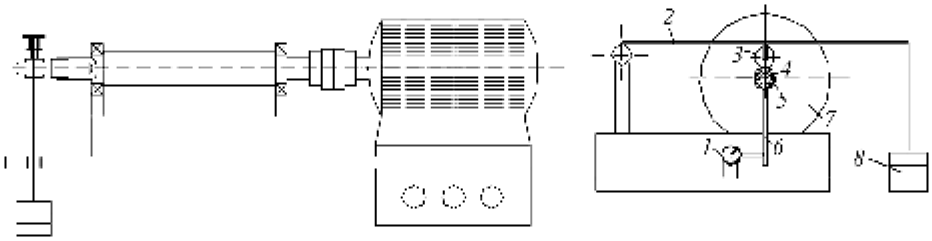


Fig. 1. Radial journal bearing wear test rig: *1* – comparator; *2* – rigid bar; *3* – load contact point (rolling bearing); *4* – journal sample; *5* – journal bearing samples; *6* – plate bar; *7* – motor; *8* – loads.

Results and discussion. ***Surface roughness and mechanical properties.*** Values of surface roughness before and after wearing process are shown in Table 3. These values of surface roughness of pure Sn and pure Pb decreased and of the other bearings increased after wear tests. Results of mechanical tests are given in Table 4. Hardness of this white metal bearing material was found to be around 30 HB. Tensile strength was found to be around 100 MPa.

Table 3. Surface roughness of bearing materials

Roughness (μm)	Pure Sn	Pure Pb	Pure Cu	SnPbCuSb
Before wear	1.35	2.92	0.45	1.33
After wear	0.96	2.33	0.68	2.62

Table 4. Mechanical properties of SnPbCuSb bearing materials

Materials	Yield strength $R_{p0.2}$, MPa	Tensile strength R_m, MPa	Elongation ε, %	Compressive strength σ_c, MPa	Notch impact strength, *J*	Bending angle, α°	Hardness, HB	Radial fracture strength σ_{rf}, MPa
SnPbCuSb	70	100	3.5	224	3	180	30	3

Wear properties. Friction coefficient, bearing temperature, bearing and journal weight loss values are given in Figs. 2–6. The friction coefficient-time variation of bearings is shown in Fig. 2, the temperature-time variation of bearings is given in Fig. 3. The wear losses of bearing-time variation of bearings are shown in Fig. 4 and the wear losses of journal-time variation of bearings are shown in Fig. 5.

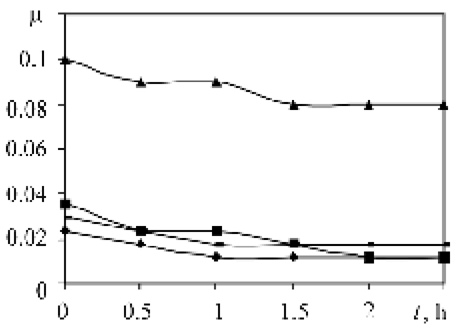


Fig. 2.

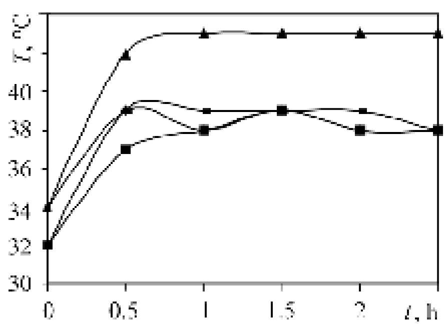
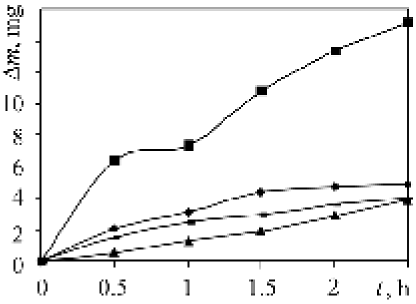


Fig. 3.

Fig. 2. The friction coefficient – time variation of bearings: ¿ – Sn; ¾ – Pb; ▲ – Cu; ¬ – SnPbCuSb.

Fig. 3. The temperature – time variation of bearings: ¿ – Sn; ¾ – Pb; ▲ – Cu; ¬ – SnPbCuSb.



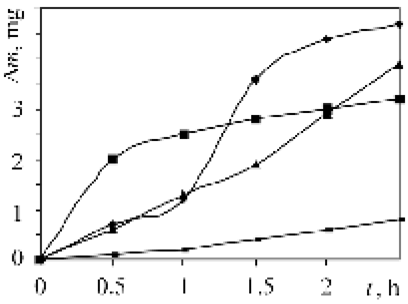


Fig. 4. Fig. 5.

Fig. 4. The wear losses, Δm, of bearing-time variation of bearings:

¿ – Sn; ¾ – Pb; ▲ – Cu; ¬ – SnPbCuSb.

Fig. 5. The wear losses, Δm, of journal-time variation of bearings:

¿ – Sn; ¾ – Pb; ▲ – Cu; ¬ – SnPbCuSb.

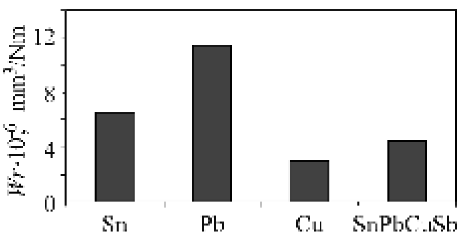
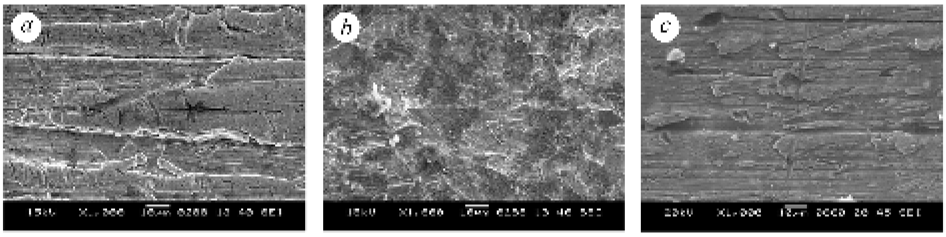


Fig. 6. The compare of wear rates, *Wr*, of bearing materials.

The wear rate values of bearings depending on materials are shown in Fig. 6. Friction coefficient was determined as a function of normal and friction force. The highest friction coefficient and bearing temperature occurred in pure Cu bearing. Pure Sn, Pb, Cu metal bearings get worn to journal more than that of the SnPbCuSb white metal bearing. The lowest friction coefficient, bearing and journal wear loss occurred in alloyed SnPbCuSb bearing. The highest bearing wear loss look place for pure Pb and journal wear occurred for pure Sn bearings. From these bearings, pure Sn wear lost was 15 mg, pure Pb wear lost was 5 mg, pure Cu and SnPbCuSb – 3 mg in 2.5 h. Journal wear loss for pure Sn was 5 mg, pure Pb – 3 mg, pure Cu – 4 mg, and that for alloyed SnPbCuSb bearing – was about 1 mg. Bearing wear rate of pure Sn was 6×10^{-6} mm^3/Nm, pure Pb – 11×10^{-6} mm^3/Nm, pure Cu – 3×10^{-6} mm^3/Nm, whereas that for alloyed SnPbCuSb bearing – about 4×10^{-6} mm^3/Nm. So, this bearing wear resistance increased in 4–5 times and journal wear resistance increased in 2–3 times because of alloy elements.

Some studies were done with tribological properties of Sn based and Sn, Pb containing Cu based journal bearings. Rivas et al. [12] determined the friction coefficient of about 0.073, wear loss of 1.76 mg in SAE 67 bronze (15% Pb, 7% Sn) bearings at 0.13 m/s sliding speed and 814 N loads. Elleuch [13], Zeren [14] and Feyzullahoğlu [15] determined the friction coefficient of about 0.05, wear rate of 10 mg in SAE 619 brass (2.4% Pb, 0.2% Sn, 39.5% Zn) and friction coefficient of about 0.06, wear rate of 20 mg in WM-2 (89% Sn, 7.2% Sb, 3% Cu) bearings at 1500 rpm sliding speed and 115 N loads, in dry and lubricated conditions. They reported that Sn element increased embedding ability of Cu based bronze, brass, and Sn based white metal bearings that had better tribological properties than those of bronze bearings. In addition, they reported that these alloys could be used in industry applications by adding different alloy elements. This situation is important for less bearing and journal wear. The differences in our results and those of other previous studies may be attributed to the fact that their materials were different from our materials. In addition, our results show that radial journal bearing test rig gives more accurate measurements.

Microstructure properties. SEM microstructures of wear surfaces of metal bearings are shown in Fig. 7. Homogeneous and wear tracks were present in bearings. Microfractures occurred in pure Sn and alloyed SnPbCuSb bearing. Huge and different wear tracks occurred in alloyed SnPbCuSb bearing due to different element phases. Wear tracks occurred but no local moving and friction direction were apparent in white metal bearing (Fig. 7).



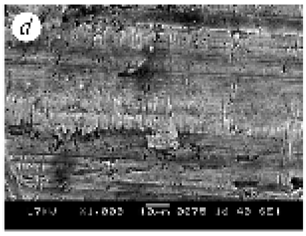


Fig. 7. SEM microstructure of wear surface of bearings: *a* – Sn; *b* – Pb; *c* – Cu; *d* – SnPbCuSb. ×1000.

SEM microstructure of tensile fracture surfaces of bearing material is shown in Fig. 8. Tensile fracture surfaces are visible, fractures occurred in SnPbCuSb alloyed white metal bearing materials as thick and brittle grained.

Rivas et al. [12] observed adhesive junctions in interface of bronze bearings. They reported that good wear performance of bearing was obtained because lead acts as an additional lubricant. Feyzullahoğlu [15] found embedding ability of Sn element. He also noticed two phases (zinc and copper) in brass bearings. In this study, similar wear tracks were obtained in lubricated conditions.

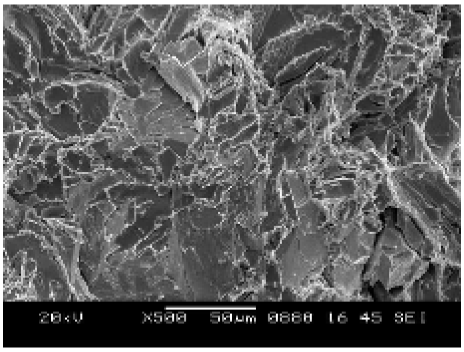


Fig. 8. SEM microstructure of tensile fracture surface of SnPbCuSb bearing material. ×500.

CONCLUSIONS

Based on the findings of our study, the following conclusions can be drawn:

Post wear values of surface roughness decreased in pure Sn, pure Pb and increased in the other SnPbCuSb, pure Cu bearings.

The highest friction coefficient and bearing temperature occurred in pure Cu bearing. The lowest friction coefficient, bearing and journal wear loss occurred in alloyed SnPbCuSb bearing.

The wear resistance increased about 4–5 times and journal wear resistance increased about 2–3 times because of alloy elements.

Adhesive wear tracks decreased in these alloyed SnPbCuSb bearing, due to alloy adding and better wear resistance property.

РЕЗЮМЕ. Досліджено трибологічні та механічні властивості матеріалу SnPbCuSb, який використовують для виробництва підшипників ковзання. Стрижень підшипників виготовлено зі сталі SAE 1050 і використано як показник (давач) зносу. Випробовували

кожні 30 min впродовж 150 min, застосовуючи радіальну машину з підшипником. Найнижчий коефіцієнт тертя опорного підшипника та найбільші втрати від тертя у підшипника з легованого сплаву SnPbCuSb.

РЕЗЮМЕ. Исследовано трибологические и механические свойства материала SnPbCuSb, который используют для производства подшипников скольжения. Стержень подшипников изготовлен из стали SAE 1050 и использован как показатель (датчик) износа. Испытывали на износ каждые 30 min в течение 150 min, используя радиальную машину с подшипником. Наиболее низкий коэффициент трения и наибольшие потери от трения в подшипника из легированного сплава SnPbCuSb.

1. *Schatt W. and Wieters K. P.* Powder metallurgy // Proc Mater, EPMA. – Shrewsbury, U. K., 1997. – P. 492.
2. *Enomoto Y. and Yamamoto T.* New materials in automotive tribology // Tribol. Lett. – 1998. – **5**. – P. 13–24.
3. *Eyre T. S.* Friction and Wear Control in Industry // Surf. Eng. – 1991. – **7**. – P. 143–148.
4. *Ünlü B. S.* Determination of Usability of Boronized Ferrous Based Materials as Bearing and Tribological Properties in Journal Bearings // PhD thesis. – Manisa: Celal Bayar University, 2004. (In Turkish).
5. *Investigation* of natural ageing in high antimonied lead alloys / H. Durmuş, C. Meriç, S. S. Yilmaz, and E. Akoral // Mater. Symp. – 2004. – **10**. – P. 194–199. (In Turkish).
6. *Dowson D.* History of tribology // Professional Engineering Publishing. – 1998. – P. 768.
7. *Upadhyaya A., Mishra N. S., and Ojha S. N.* Micro structural control by spray forming and wear characteristics of a babbit alloy // J. Mater. Sci. – 1997. – **32**. – P. 3227–3235.
8. *Barhust R. J.* Guidelines for designing zinc alloy bearings-a technical manual // Society of Automotive Engineers. – 1989. – P. 880289.
9. *Gronostajski J. and Chmura W.* Gronostajski Bearing materials obtained by recycling of aluminum and aluminum bronze chips // J. Mater. Proc. Technol. – 2002. – **125–126**. – P. 483–490.
10. *Atik E., Ünlü B. S., and Meriç C.* Design of radial journal bearing wear test rig // Conf. of Machine Mater. Technol. – Manisa, 2001. – **2**. – P. 98–103. (In Turkish).
11. *Ünlü B. S. and Atik E.* Determination of friction coefficient in journal bearings // Mater. Design. – 2007. – **28**. – P. 973–977.
12. *Rivas J. S., Coronado J. J., and G´omez A. L.* Tribological aspects for the shafts and bearings of sugar cane mills // Wear. – 2006. – **261**. – P. 779–784.
13. *Sliding* wear transition for the CW614 brass alloy / K. Elleuch, R. Elleuch, R. Mnif, V. Fridrici, P. Kapsa // Tribol. Int. – 2006. – **39**. – P. 290–296.
14. *Zeren A.* Embeddability behavior of tin-based bearing material in dry sliding // Mater. Design. – 2007. – **28**. – P. 2344–2350.
15. *Feyzullahoğlu E., Zeren A., and Zeren M.* Tribological behavior of tin-based materials and brass in oil lubricated conditions // Mater. Design. – 2007. – **29**. – P. 714–720.

Received 07.08.2009