M. BABIĆ, R. NINKOVIĆ

RESEARCH

Zn-Al Alloys as Tribomaterials

In the paper are presented results of tribological investigations of possibilities for application of the Zn-Al alloys of Yugoslav production for manufacturing the elements of tribo-mechanical systems aimed for motion guiding, within the technical systems of various purposes. In order to clearly establish the tribological potential of these alloys, the tribological parameters (parameters of friction and wear) of the Zn-Al alloy are compared to parameters of the lead-tin bronze, as a widely applied conventional bearing material.

The established level of tribological characteristics, both from aspect of wear and aspect of friction, show that Yugoslav Zn-Al alloys represent respectable tribological materials. Considering the simulated conditions of tribological interactions, results nominated these alloys as candidates for bearing's materials for conditions of limiting lubrication, that are characteristic for high loads and low sliding speeds. With respect to bronze they have better anti-frictional characteristics, higher resistance to wear and lower price costs

Keywords: *Zn-Al aloys, Tribology, Friction, Wear, Bearing's Materials*

1. INTRODUCTION

Though conventional bearing materials (especially bronzes) are still dominating in industrial practice, in the past two decades a there is a growing number of published information about results of investigation on their substitution by zinc-aluminum alloys [1, 2, 3, 4]. The basic motive of such investigations is of course of economic nature. Namely, the Zn-Al alloys are characterized by significantly lower price, even to 50 %, with respect to bronze. Besides that, these alloys can successfully be machined by standard casting procedures, like sand casting, centrifugal, permanent and continual casting. Total savings of substitution bronzes with these alloys are estimated up to the level of 35-90 % [3].

The concept of application of Zn-Al journal bearings as substitution for the bronze ones is not new [2]. The first experiences are related to the period of the Second World War, when different Zn-Al alloys (before all with only 30 % of Al) were used instead of bronze, primarily due to lack of copper. Besides for bearings, the Zn-Al alloys were applied also for other machine elements, like the worm gears, components of hydraulic installations, etc.

Special importance in development of Zn-Al alloys during the seventies and eighties has the International Lead and Zinc Research Organization. Based on their investigations and investigations of other research centers and manufacturers in this area the Zn-Al alloys for casting were developed, marked as ZA-8, ZA-12 and ZA-27. Such coding (in which the numerical code denotes the eventual content of aluminum) is accepted also by the ASTM standards B 669-89, while according to European norm EN 1774-98 the following codes are used: ZL8, ZL12 and ZL27.

Summing up the world experience, based on laboratory research and investigations in exploitation conditions (primarily on manufacturing machines in mining), the conclusion can be drawn that the Zn-Al alloys, compared to bronzes, have better anti-frictional characteristics, better characteristics from the standpoint of running in, better ability for pressing in the abrasive particles, lower friction coefficient, longer working life and lower price costs. Based on such world experiences from Europe and America in the area of the ZnAlCuMn alloys, and also based on own investigation, about a decade

Dr Miroslav BABIĆ
Faculty of mechanical engineering
Kragujevac,University of Kragujevac
S.Janjic 6. 34 000 Kragujevac, Serbia
babic@knez.uis.kg.ac.yu
Mr Rato NINKOVIĆ
RAR d.o.o
11273 Batajnica, Serbia
rato@eunet.yu

ago the company RAR from Belgrade, using exclusively domestic raw materials, starts casting these alloys, primarily those with aluminum content over 10 % like are RAR-12 and RAR-27. Realized good carrying capacity and wear resistance enabled application of these alloys, especially for mining equipment and mechanization for tribo-elements, like the sliding radial and journal bearings, various bushings, nut for the screwed spindles, guides, etc.

Systematic investigations of the RAR alloys characteristics, with aim to evaluate them as the tribological material for manufacturing the sliding elements were supported by the Ministry for Science and Technology of Republic of Serbia, as well as a series of customers, within the innovation project coded as MHT. 2.02.0012.B. In this paper are just presented some of the obtained results by which is shown the possibility of substitution of bronzes, what, besides other, is very significant from the aspect of reducing the needs for importing the deficient tin.

2. EXPERIMENT

Tribometric investigations are of the model type and they were performed on the computer-supported tribometer. Based on requirements to realize the contact and relative motion type similarity on model and real system, for tribological modeling of sliding bearing was chosen (in tribometric practice the most present) pin-on-disc contact scheme with continuous sliding (Figure 1). As in real tribological system bearing / journal, the tribologically critical contact element is bearing, on the model, the stationary pin corresponds to it, which is, due to small degree of covering, tribologically more critical contact element of the contact pair on the model.

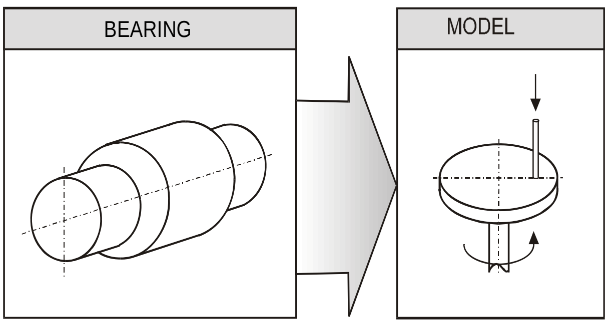

Figure 1. Tribotesting model system

In conducted tests were used pins of cylindrical form, with diameter of 2.5 mm, with flat, ground front (contact) surface (nominal contact area 5 mm^2), made of tested bearings materials. Rotational discs of diameter 100 mm were made of construction steel C 4732, which was thermally treated, of hardness 38 HRC. Contact surfaces were machined by grinding, under the same conditions. The machined contact surfaces quality of pins and discs is characterized by roughness at the level of approximately R_a = 0.3 µm.

In this paper is presented a part of results which provide a possibility for tribological comparison of the RAR Zn-Al alloy, with commercial mark RAR-27, casted in ingot mold, and the lead-tin bronze CuPb15Sn8. Chemical compositions and physical-mechanical properties of these materials are given in tables 1 to 3.

Table 1. Chemical composition of CuPb15Sn8

Chemical element	**Percentage content**
Cu	76.0
Sn	7.63
Pb	12.31
Others	Remaining

Table 2. Chemical composition of RAR-27

Chemical element	**Percentage content**
Al	26.20
Cu	2.30
Mg	0.029
Zn	Remaining

Table 3. Physical-mechanical properties of samples

Physical-mechanical property	**Tested materials**	
	RAR-27	**CuPb15 Sn8**
Hardness (HB)	124	90
Tensile strength R_m (MPa)	451	188.9
Extension (%)	5.2	7.85
Yield strength $R_{p0.2}$ (MPa)	353	131.7
Elasticity modulus (Mpa)	137.6	110
Density ρ (kg/dm^3)	4.94	8.28

Investigations of selected samples of materials' pairs were done in the following conditions:

- Sliding rate: 0.15 m/s
- Contact pressure: 3.5 and 7 Mpa
- Type of lubrication: Limiting
- Lubricant's temperature: 50 °C
- Environmental conditions: Room temperature (20 to 25 °C) and normal atmosphere

3. INVESTIGATIONS RESULTS

Individual tribometric tests for each of combinations of the contact conditions were conducted for 4.5 hours, what corresponds to the friction path of 3000 m. By periodical measurement of wear by the weight method and continuous measurement of the friction parameters, the series of data were generated, by whose processing the results were obtained which can serve for comparison of the tribological behavior of the RAR-27 alloy and lead-tin bronze, in condition of limiting lubrication.

The obtained wear curves, as functions of the weight lost by wear versus the friction path (or time), have the classical form with the expressed running-in period and the uniform wear period, Figure 2. Based on the wear curves, the corresponding rates of wear were calculated, in two ways, as the mass rate in mg/h and as the volume rate in mm^3/h (Tables 4 and 5). In the given tables is presented the total wear rate, as well as the wear rate for the area of stationary wear. The volume wear arte is used due to different density of the tested materials.

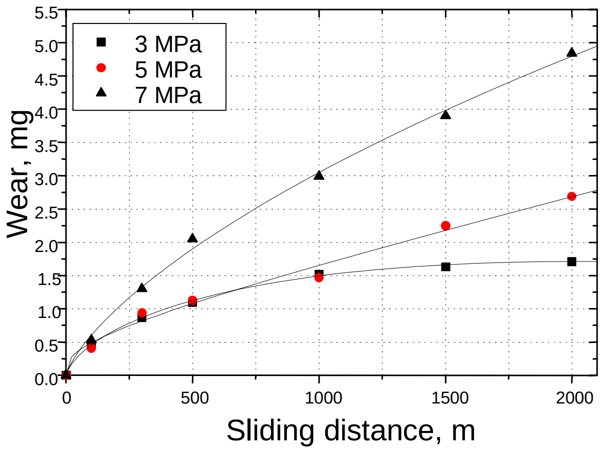

Figure 2. Wear curves

Table 4. The wear rate for material RAR-27

Pressure Mpa	Wear rate			
	Total		For stationary area	
	mg/h	mm^3/h	mg/h	mm^3/h
3	0.46	0.09	0.22	0.044
5	0.72	0.144	0.56	0.11
7	1.31	0.26	1.00	0.20

Table 5. The wear rate for material CuPb15Sn8

Pressure Mpa	Wear rate			
	Total		For stationary area	
	mg/h	mm^3/h	mg/h	mm^3/h
3	1.73	0.19	1.40	0.154
5	2.20	0.24	1.98	0.216
7	-	-	-	-

The wear rate of tested materials increases with increase of load, what was expected in conditions of the limiting wear. At pressure of 7 Mpa for the RAR-27 alloy the significant increase of the wear rate occurs (Figure 3). That points to the fact that material is closing to limiting load, from the viewpoint of wear, what is confirmed also by appearance of the more prominent plastic deformation of the sample material (Figure 4), during the tests with pressures of 7 Mpa and higher. Simultaneous load of 7 Mpa has, for samples made of CuPb15Sn8, caused a great dissipation of results, due to present inclusions and material's inhomogeneity, so these results were not accepted as significant.

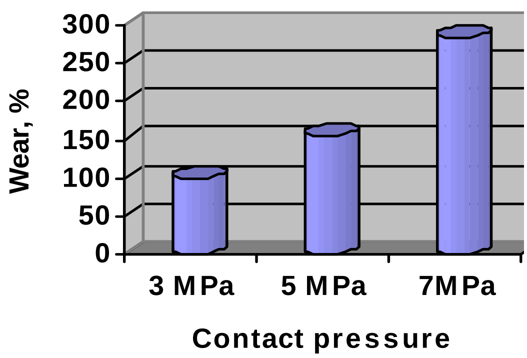

Figure 3. Wear vs contact pressure

Figure 4. Deformation of the sample material

For comparison of alloys in Figure 5 the volume wear rate was chosen, since it is directly related to linear wear, which is, in the system of journal bearing, responsible for increase of clearance and loss of the bearing's working ability. Obtained results point that, at the same testing conditions, for all applied loads, lower wear rate, for the given friction path, corresponds to material RAR-27 with respect to material CuPb15Sn8. It can be seen that the larger differences in the wear rates correspond to lower contact loads.

It is usual today, due to possibility of direct comparison of tribological properties of materials, which are obtained in different contact conditions, to use the parameter which represents the wear amount per the unit of the normal contact load and the friction path.

This parameter, in literature present as the specific wear rate, according to Yugoslav standard represents the wear intensity. Values of this parameter for the compared alloys are given in Table 6, where is for comparison, also for this case, used the volume wear. The corresponding graphic representation is shown in Figure 6.

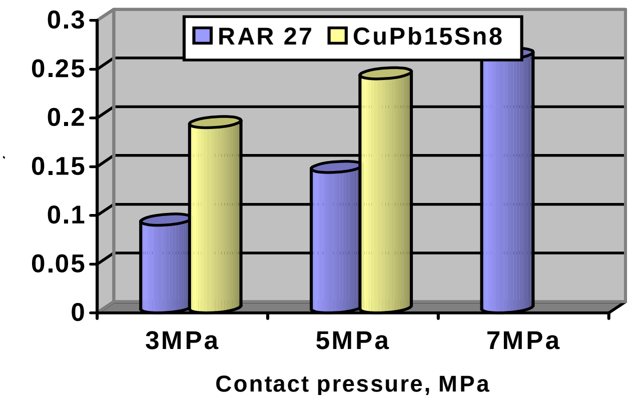

Figure 5. Wear rates of tested materials

Table 6. Wear rate of alloys RAR-27 and CuPb15Sn8

Contact pressure (Mpa)	RAR-27		CuPb15Sn8	
	Specific wear rate X 10^{-6} (mm^3/Nm)	Friction coefficient	Specific wear rate X 10^{-6} (mm^3/Nm)	Friction coefficient
3	11.00	0.105	20.90	0.120
5	10.60	0.100	17.7	0.100
7	13.74	0.086	-	-
Average	**11.78**	**0.097**	**19.3**	**0.11**

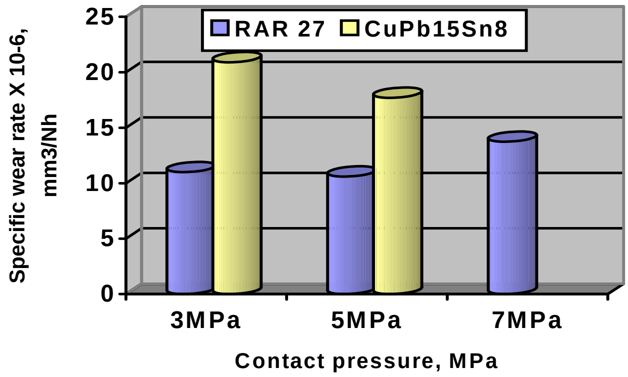

Figure 6. Specific wear rates of tested materials

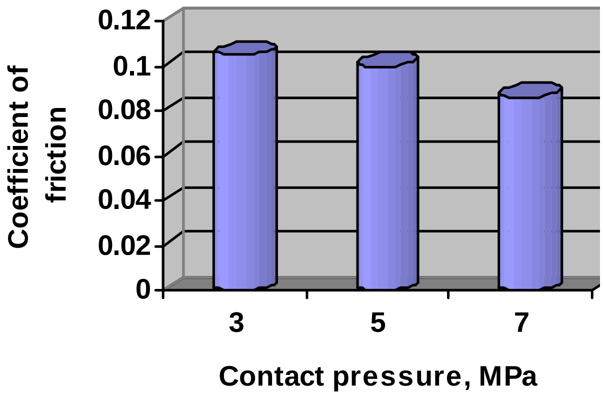

Figure 7. Coefficient of friction vs contact presure

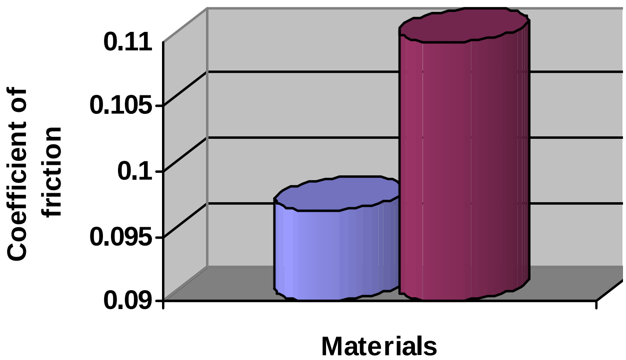

Figure 8. Friction coefficient of tested materials

Though, in principle, the increase of wear rate corresponds to in crease of contact load, as it was shown in Tables 4 and 5, it is obvious that the gradient of that increase lags behind the gradient of the contact load increase. Due to that, such expressed wear rate does not have the increase tendency, but even shows decrease with increase of the contact load, from 3 to 5 Mpa. It can be seen that the wear rtae is almost twice lower for the RAR-27 alloy.

During the course of test operations, according to previously described procedure, data was gathered about force, namely the friction coefficient, that are memorized as time series. After the known characteristic fall at the very beginning of the process, the friction force maintains relatively balanced level, without prominent trends, either increase or decrease. Such a development of the wear process is characteristic for all the varied contact conditions, from the standpoint of material, sliding speed and contact pressure.

Considering that, it is the most convenient, in analysis of the obtained results, to keep in mind only the average values of the friction force, namely the friction coefficients, which are results of the averaging process over the time series in all the repetitions for the certain contact conditions (Table 6).

The established decrease of the friction coefficient with increase of the contact pressure, in both tested bearings materials, is in compliance with known principles of the frictional behavior of the metallic materials in the limiting friction conditions. There, the tendency of the friction coefficient decrease with increase of pressure is significantly more prominent for the RAR-27 alloy (Figure 7). For all the three levels of contact pressure RAR-27 has somewhat lower friction coefficients. Based on obtained results, besides prominent advantage with respect to the wear characteristics, another advantage can be noticed also, that one being related to the anti-frictional characteristics of the RAR-27 alloy, with respect to the lead-tin bronze, what was illustrated by Figure 8.

4. CONCLUSION

The established level of tribological characteristics, both from aspect of wear and aspect of friction, show that Yugoslav Zn-Al alloys represent respectable tribological materials. Considering the simulated conditions of tribological interactions, results nominated these alloys as candidates for bearing's materials for conditions of limiting lubrication, that are characteristic for high loads and low sliding speeds. With respect to bronze they have better anti-frictional characteristics, higher resistance to wear and lower price costs.

5. REFERENCES

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