The tribological properties of Al-brasses in various environments

Tribologické vlastnosti hliníkových mosazi v různých protředích

Lovíšek M.[1], Liptáková T.[1], Bronček J.[2], Dundeková S.[3]
[1] University of Žilina, Department of Material Engineering
[2] University of Žilina, Department of Design and Mechanical Elements
[3] Research Centre of the University of Žilina
E-mail: lovisekmartin@gmail.com

Tribological properties of Al-brass pipes of various producers were studied in different environments. The tested brasses have very similar chemical composition, but they differ in microstructure due to mainly by heat treatment after cold drawing. Microstructure as well as roughness of surface influence chemical and mechanical properties which are important in operating conditions. The experiments of tribological behavior were made in various environments, dry air, cooling treated water and 3.5 % solution of NaCl at room temperature 21 ± 2°C. The tribological tests were carried out on the Linear Tribometer at normal loading 5 N by the method ball on plate for the duration of 5500 s. The measured friction coefficients were evaluated by the program DIAdem and the diagrams were created from signal generated by software NSignal Express.

Tribologické vlastnosti trubek z hliníkových mosazí od různých výrobců byly studovány v odlišných prostředích. Testované mosazi měly velmi podobné složení, ale lišily se v mikrostruktuře hlavě díky rozdílnému tepelnému zpracování po tváření za studena. Mikrostruktura i hrubost povrchu ovlivňují chemické a mechanické vlastnosti, které jsou významné pro provozní podmínky. Tribologické vlastnosti byly sledovány v různých prostředích: suchý vzduch, chladicí voda a roztok umělé mořské vody (3,5 % NaCl) při laboratorní teplotě. Tribologické testy byly provedeny s pomocí Lineárního Tribometru za běžného zatížení 5 N metodou kuličky na ploše po dobu 5500 s. Naměřené frikční koeficienty byly vyhodnoceny pomocí programu DIAdem a diagramy byly vytvořeny pomocí softwaru NSignal Express.

INTRODUCTION

Copper and its alloys are very frequently used construction material regarding their corrosion stability, good heat conductivity, mechanability and mechanical properties. The object of our research there are Al-brasses pipes from various producers applied in industry for liquid media transport. In these conditions the pipes are chemically loaded by various environments and mechanically by flow. In operating condition the transported liquids can contain small solid particles with abrasive effect. So in real service the pipes can degrade by corrosion, erosion-corrosion and abrasion [1-3]. This work is focused on tribological properties of Al-brasses in three environments (dry air, 3.5% solution of NaCl, and treated cooling water). Tribological properties of Cu–Al alloys were studied by many authors and can be said that friction and wear properties of them are determined mainly by plastic deformation and fracture in surface layers. The results confirm also a great effect of microstructure especially grain size as well as surface roughness. The experiments were performed mostly in dry air when adhesion, ploughing and abrasion are dominant mechanism of wear [4-6].

EXPERIMENTS

The experimental materials the Al-brasses of various producers (M1, M2, M3, M4) were tested and their chemical composition is in Table 1. According to authors [5] friction coefficient increases with Al concentration

Tab. 1. Chemical composition of the tested Al brasses / *Chemické složení Al-mosazí*

Element	Zn	Al	As	Sn	Mn	Pb	Fe	Ni	Cu
M1 [wt.%]	22,49	2,11	0,018	0,0038	<0,001	0,0097	0,0177	<0,001	75,2139
M2 [wt.%]	23,43	2,06	0,0205	0,0225	0,0052	0,0165	0,0530	0,0492	74,0759
M3 [wt.%]	22,65	2,10	0,0183	0,0017	<0,001	0,0052	0,0078	<0,001	75,0718
M4 [wt.%]	22,07	2,06	0,0247	0,0143	0,0088	0,0098	0,0237	0,135	75,4696

and in the tested brasses the content of Al is the same. The other important parameters are microstructure and surface state [4] Microstructures of the Al-brasses are formed by α solid solution of Zn, Al and other elements in Cu. They differ in grain size and homogeneity caused by temperature and time of annealing. It can be compared in Fig. 1. The effect of microstructure occurs also evident on results of corrosion and erosion-corrosion tests [6].

Characterization of the surfaces was carried out by SEM (Fig. 2). The measurement of roughness and microhardness were made also and results are in and Table 2. The surfaces differ in character of amount oxidizing products on the surface, topography. Lower roughness was measured for the M4 specimens. The M2 and M4 samples had also determined the lower microhardness.

Tribological properties of the Al-brasses were carried out on the linear tribometer used for the evaluation of the surface properties of various materials.

Tab. 2. Microhardness and roughness of the Al-brasses / *Mikrotvrdost a hrubost povrchu Al-mosazí*

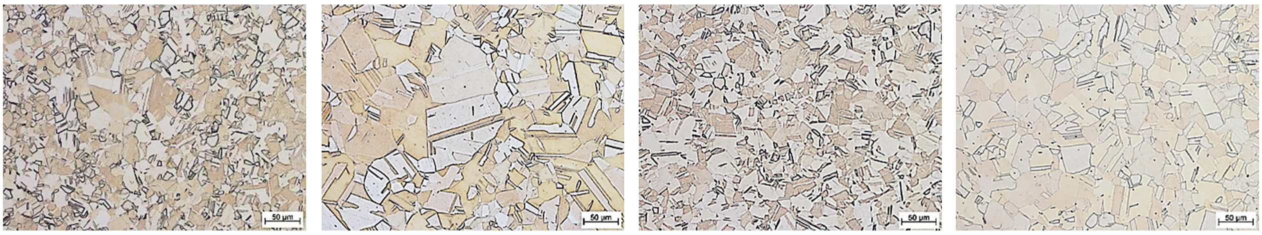
Microhardness	M1	M2	M3	M4
Average grain size (µm)	26	42	24	38
Average value HV2	88,6	75	90,6	78,4
Average value HV02	88	81.6	93.8	86.6
Roughness, Ra (µm)	0.59	0.571	0.767	1.29

This tribometer works on Ball–on–Plate Method and can reproduce loads similar to those expected in real life conditions. [7-9]. A tribological couple is composed of two members. The main part of a microtribometer is a tribological knot which consists of a ball (fixed on the end of a roller) and a flat sample in a shape of a plate. The motion of a ball is not uniform, linear reversible. The moving ball is pressed to the sample, fixed in a bowl, by its head weight and a plumb [10]. The value of the frictional force F_T is determined by tensometric measurement of the plate position. The values of a friction coefficient are calculated from known values F_T and F_N. The testing method has been chosen to find out the dependency of a friction coefficient for different values of loading at the chosen speed v. The speed of a moving pin on the sample had a sinusoidal curve within the values $v = 0$ to 20 mm s^{-1} (one cycle lasted 5.5 s). The test was realized in three environments under the atmospheric conditions, in the cooling water (pH = 8) and in the 3.5% NaCl solution. The friction coefficient μ is expressed by share of tangential frictional force F_T and load normal force F_N:

$$\mu = \frac{F_T}{F_N} \tag{1}$$

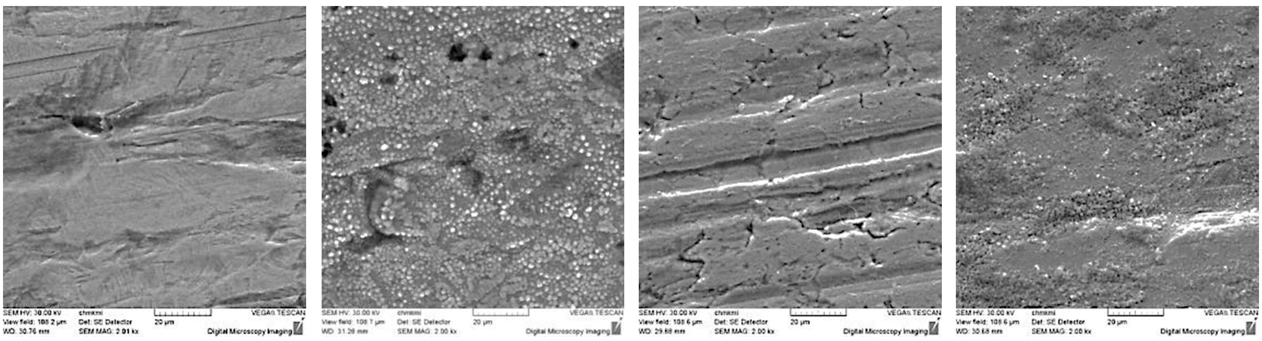
The loading was constant with the value of $F_N = 5$ N. The length of the test was limited by time ($t = 5500$ s) or by the length of the ball path $s = 100$ mm (Fig. 3).

By the described tribological test the friction coefficients in three environments were measured and the



M1 M2 M3 M4

Fig. 1. Microstructure of the Al-brasses
Obr. 1. Mikrostruktura Al-mosazí



M1 M2 M3 M4

Fig. 2. Surface state of the tested Al-brasses
Obr. 2. Stav povrchu testovaných Al-mosazí

results are graphically expressed in Fig. 4, 5 and 6. In air conditions can be seen effect of grain size on friction coefficient (specimens M1, M3 about 25 µm and M2, M4 about 40 µm). This factor however was not effective in liquid environments and (Fig. 5 and 6) but the course of friction coefficients was similar in specimens with alike grain size. It seems that liquid change controlling steps of wear and performs like lubricant. Corrosion products created in more aggressive conditions decrease friction coefficients of all studied brasses. But the real effect on wear has to be determined by weight analysis of samples, search character of surface (SEM, EDX) after loading and this way will the research continue.

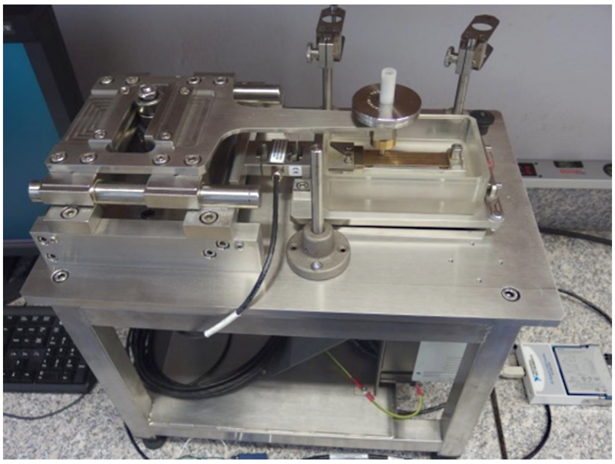


Fig. 3. The scheme of a building structure of the linear microtribometer
Obr. 3. Obrázek lineárního mikrotribometru

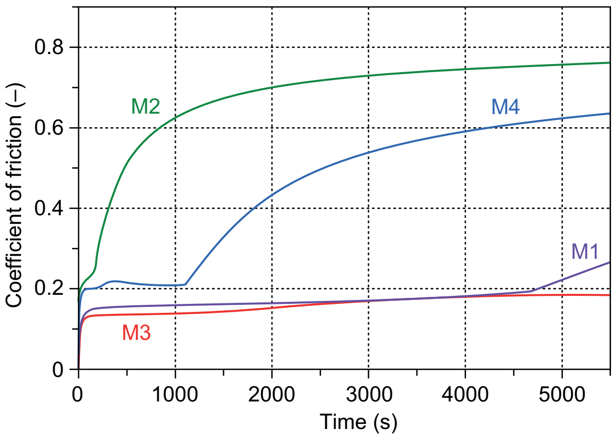


Fig. 4. Friction coefficient of the Al-brasses measured in air
Obr. 4. Frikční koeficient Al-mosazí na vzduchu

CONCLUSIONS

Friction coefficient of the Al-brasses of various producers with very similar chemical composition is in air conditions essentially affected by grain size. In liquid

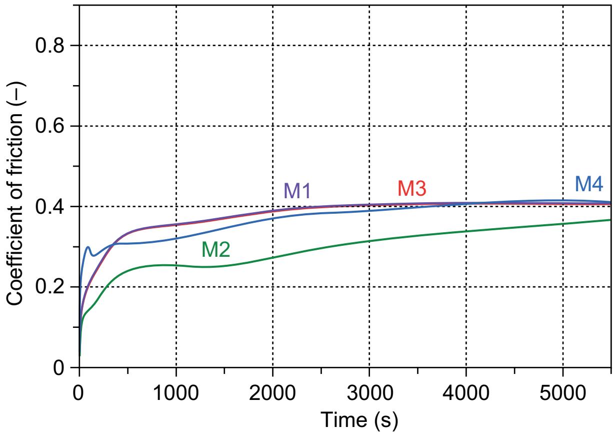


Fig. 5. Friction coefficient of the Al-brasses measured in cooling water
Obr. 5. Frikční koeficient Al-mosazí v chladicí vodě

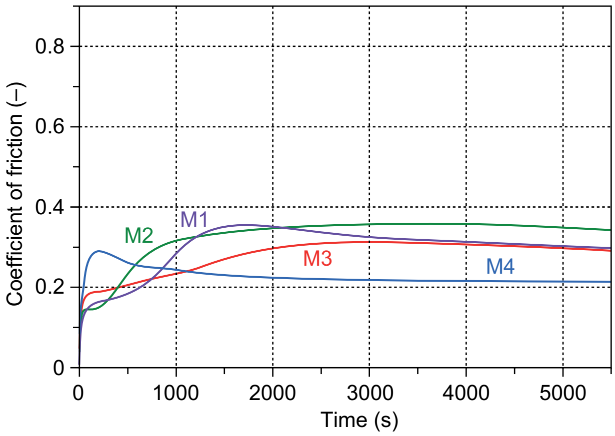


Fig. 6. Friction coefficient of the Al-brasses measured in NaCl solution
Obr. 6. Frikční koeficient Al-mosazí v roztoku NaCl

environments friction coefficients of all tested brasses dropped and it is proven that grain size is not then a dominant factor. Corrosion properties, surface state of the brasses and corrosive effect of environment influence values of friction coefficient. Corrosion products decrease friction of the brasses.

Acknowledgment

The research is supported by European regional development fund and Slovak state budget by the project "Research center of University of Žilina", ITMS 26220220183 , the project VEGA No. 1/0720/14.

REFERENCES

1. Callcut, V. The brasses: properties & applications. 2nd edit. Hemel Hepstead : CDA Publication, 2005.
2. Heitz, E. Chemo-mechanical effects of flow on corrosion, *Corrosion* **1991**, 47, 135-145.

3. Chen, J.L. – Li, Z. – Zhao, Y.Y. Corrosion characteristic of Ce Al brass in comparison with As Al brass, *Materials and Design* **2009**, 30, 743–1747.
4. Moshkovitch A., Porfilyev V., Lapsker I., Rapoport L. Friction, wear and plastic deformation of Cu and α/β bras under lubricatin conditions, *Wear* **2014**, 320, 34-40.
5. Senhadji S., Belafiri F., Robbe-Valoire F. Experimental investigation off riction coefficient and wear rate of brass and bronze under lubrication conditions, *Tribology in Industry* **2016**, 38 (1), 102-106.
6. Liptáková, T., Lovíšek M., Hadzima B., Dundeková S. Material parameters affecting degradation processes of Al-brasses in pipe systems, *Archives of Materials Science and Engineering* **2015**, 76 (1), 27-34.
7. Blaaškovič, P. et al. *Tribológia*. Bratislava: Alfa, 1990. 360s. ISBN80-05-00633-0.
8. Bronček J., Fabian P., Radek N. Tribological Research of Properties of Heat – Treated Cast Irons with Globular Graphite, *Materials Science Forum* **2015**, 818, 209-212.
9. Brezinová J., Draganovská D., Guzanová A., Balog P., Vňaš J. Influence of the hardfacing welds structure on their wear resistance, *Metals* **2016**, 6 (2), 1-12.