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Dry Sliding Wear behavior of some Cu and Al Alloys

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In this paper, a study concerning the dry sliding wear behavior of three Cu and Al alloys namely CuSn12, CuAl10Fe3 and AlSi12 was made. For this three alloys type, all tests have been performed with a tribometer using the pin-on-disk method (POD) according to the ASTM G99 standard, where the working conditions (applied load, linear speed, motor speed and distance) were the same. As an important parameter, the coefficient of friction (COF) versus time / distance was monitored respective the wear rate coefficient was calculated. The obtained results were compared between them, and the specific images were acquired through a digital microscope and specialized software. In addition, to these tests, the hardness of these alloys was carried out using a Vickers microhardness tester.

Keywords: *dry sliding wear, coefficient of friction, wear rate*

1. Introduction.

Wear and corrosion occurs in all of the engineering industries. Also, as a wear mechanism, the sliding wear is present in many applications this due to the dynamic interaction of mechanical components surfaces [1-5].

The intensity of the abrasive wear, which is more common, depends on the operating conditions and the behavior of used materials that can have a poor or a good wear resistance. For example, gray cast irons and also some coatings can have a good sliding wear resistance and alloys like Al and Sn alloys or alloys, which don’t are characteristic to dynamic contact processes, can have a poor sliding wear resistance [6-8].

As usually materials used in industry, they are bronzes, which are Cu alloys with different alloying elements. The most used bronzes are the Cu-Sn alloys. The hard bronzes are more resistant and are used for the mechanical components casting. As an important feature is the friction resistance [9-11].

On the other hand, the Cu-Al alloys have o good corrosion resistance against the Cu-Sn alloys [12].

As a tin bronze alloy CuSn12, which has resistance to wear and tear, corrosion and sea water, can be used for sliding bearings, moderate bearing pressures (with adequate lubrication), spindle nuts, worm gears or cylinder liners. The CuAl10Fe3 aluminium bronze, which is very hard, is not suitable for use in sea water, but as applications this alloy is suitable for machine parts submitted to stresses between -200 and +200 ^{o}C. As aluminum alloys, those can be used for casting, molding and welding, AlSi12 used for casting machines parts. In order to achieve good wear resistance, alloys like tin bronze, aluminium bronze and aluminium alloys, were studied [13-15].

The present work aims to study the dry sliding wear behavior of the alloys mentioned above and also to make reproducibility regarding similar results, all this with the authors knowledge in the field of wear using professional apparatus. In addition, to dry sliding wear tests, the hardness of the CuSn12, CuAl10Fe3 and AlSi12 alloys was carried out using a Vickers microhardness tester, because the hardness play an important role. Compered to other preview studies, with an increasing of the hardness values, the wear resistance can also increase [16].

2. Experimental procedure.

The used equipment for the dry sliding wear and for the microhardness measurement it is shown in Figure 1.

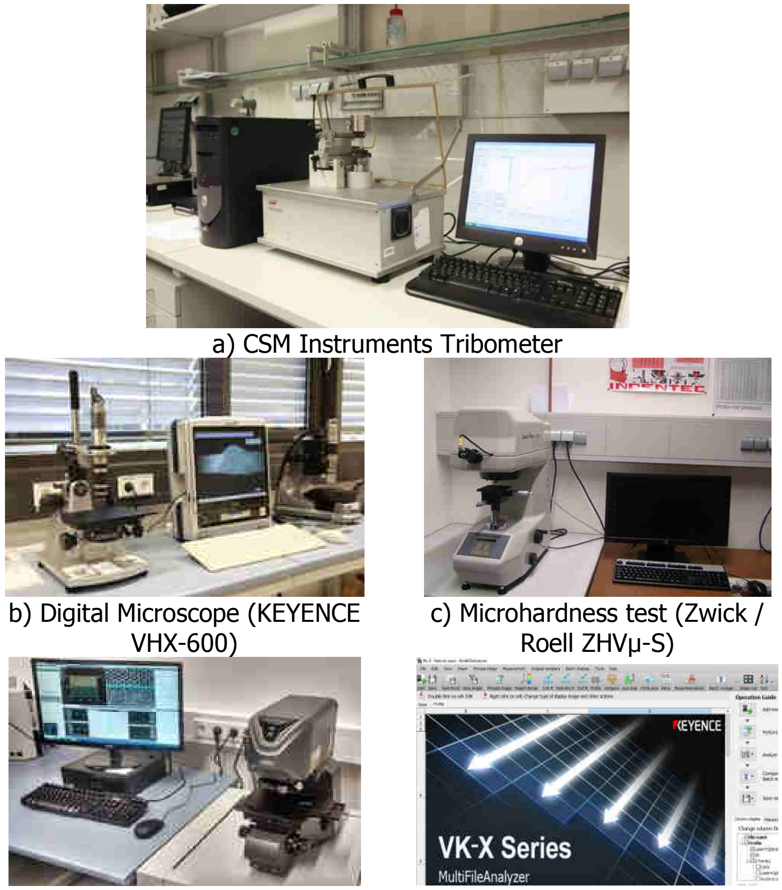
For the tribometer arrangement a 100Cr6 steel ball was used (6 mm in diameter) as static partner, respectively the Cu and Al alloys as rotating samples.

According to the ASTM G99 Standard, the pin-on-disk method (POD) was used respective the temperature was set at 20 ^{o}C and the air (as atmosphere environment) at 50% humidity. The samples with a cubic shape of 8 mm respective the 100Cr6 steel ball, were cleaned with acetone. The main parameters are shown in Table 1.

Table 1. Main parameters for the dry sliding wear tests

Samples	Applied load [N]	Radius [mm]	Linear speed [mm s^{-1}]	Motor speed [rpm]	Distance [m]	Distance [laps]	Time [s]
CuSn12	7	4.06	170	400	150	5890	883
CuAl10Fe3							
AlSi12							

The microhardness measurements were carried out according to ASTM E 384. These measurements were performed in 5 different spots. The load used for determining the Vickers microhardness was 2.942 N applied on each indentation for 15 seconds.



a) CSM Instruments Tribometer

b) Digital Microscope (KEYENCE VHX-600)

c) Microhardness test (Zwick / Roell ZHVμ-S)

d) Confocal 3D Laser Scanning Microscope (KEYENCE VKX-260K)

f) Keyence VK-X – MultiFileAnalyzer Software

Figure 1. The equipment for experimental measurement.

The chemical composition of the samples is reported in Table 2, where common elements are Al, Cu, Zn and Fe.

Table 2. Chemical composition of the samples

Samples	Si	Mn	Ni	Al	Cu	Ti	Pb	Sb	Sn	Zn	Fe
CuSn12	11.03	0.44	-	88	0.01	0.01	-	-	-	0.03	0.47
CuAl10Fe3	-	0.1	0.19	9.6	80.1	-	-	6.9	0.02	0.4	2.66
AlSi12	-	-	0.02	0.06	87.3	-	0.17	-	12.3	0.03	0.1

3. Results and discussions.

The COF values of the samples are shown in Table 3, respective the wear rate values (where h is the wear track depth, s - wear track width, A - cross section area, V - volume loss and k is the wear rate) and coefficients are shown in Table 4 and in Figure 2.

Table 3. COF values of the samples

Samples	Start	Min	Max	Mean	Std. Dev.
CuSn12	0.292	0.228	0.469	0.448	0.033
CuAl10Fe3	0.322	0.215	0.381	0.266	0.018
AlSi12	1.581	0.291	1.581	0.355	0.104

Table 4. Wear rate values

Samples	h [µm]	s [µm]	A [µm^2]	W_v [mm^3]	k [mm^3 N^{-1} m^{-1}]
CuSn12	14.20	855.97	8104.27	0.2067	$1{,}97 \cdot 10^{-4}$
CuAl10Fe3	9.45	733.36	4619.24	0.1178	$1{,}12 \cdot 10^{-4}$
AlSi12	31.04	1027.24	21268.75	0.5426	$5{,}17 \cdot 10^{-4}$

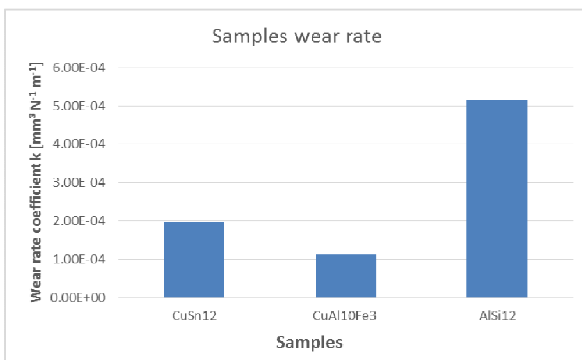


Figure 2. Wear rate coefficients of the samples.

Other images of the samples under the dry sliding wear conditions, images regarding the COF evolution, ball wear track, sliding wear track and the measurement details of the wear track profile are presented in Figures 3 ÷ 14.

Also, the microhardness values of the sample are presented in Figures 15÷17, where the mean values of these measurements are as following: 148 HV0.3 for CuSn12, 239 HV0.3 for CuAl10Fe3 and 73 HV0.3 for AlSi12.

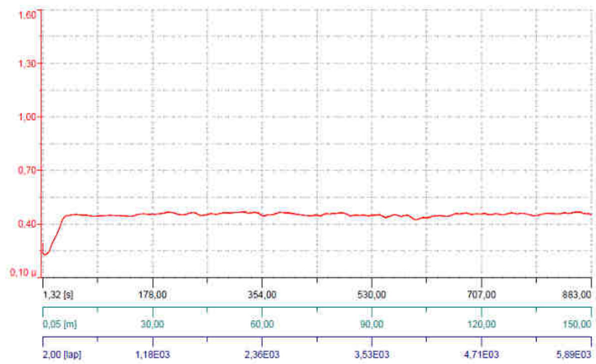


Figure 3. COF evolution versus time / distance for CuSn12.

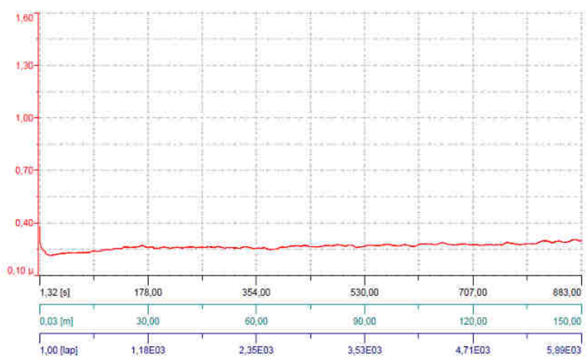


Figure 4. COF evolution versus time / distance for CuAl10Fe3.

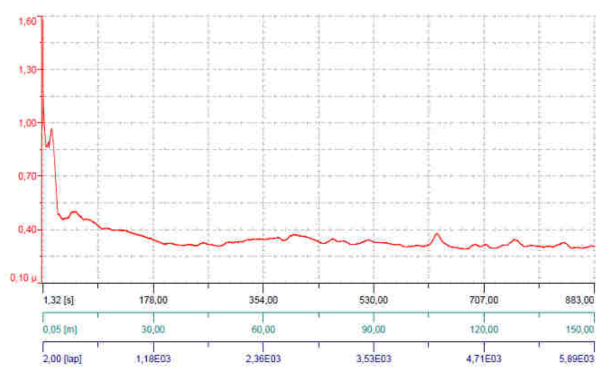


Figure 5. COF evolution versus time / distance for AlSi12.

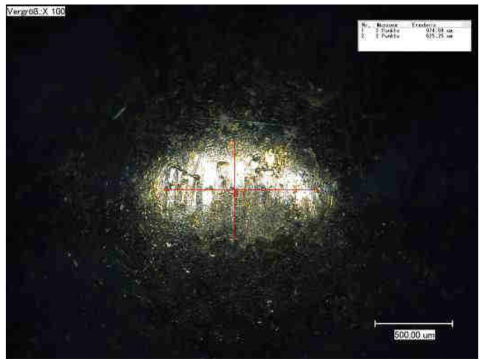


Figure 6. Micrograph of the 100Cr6 ball wear track against CuSn12.

Figure 7. Micrograph of the 100Cr6 ball wear track against CuAl10Fe3.

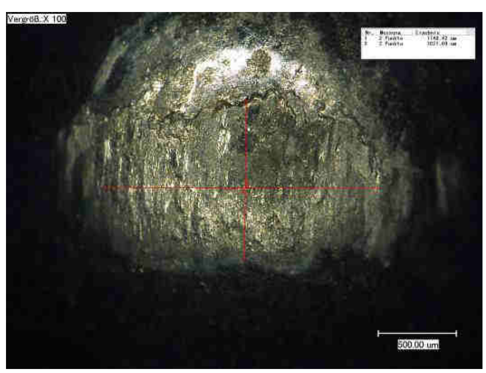


Figure 8. Micrograph of the 100Cr6 ball wear track against AlSi12.

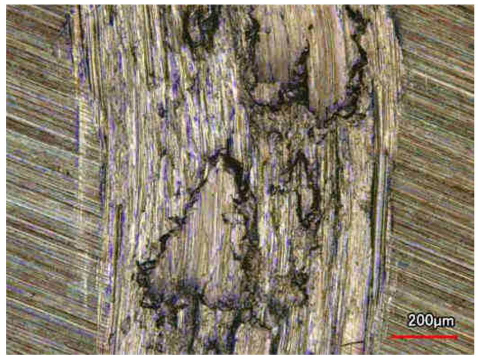


Figure 9. Micrograph of the sliding wear track for CuSn12 sample.

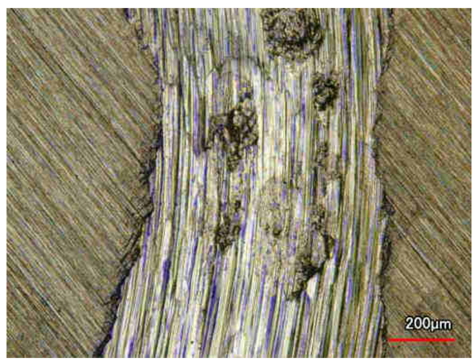


Figure 10. Micrograph of the sliding wear track for CuAl10Fe3 sample.

Figure 11. Micrograph of the sliding wear track for AlSi12 sample.

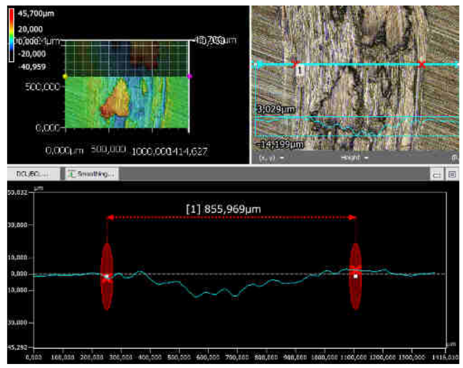


Figure 12. Measurement details of the wear track profile for CuSn12.

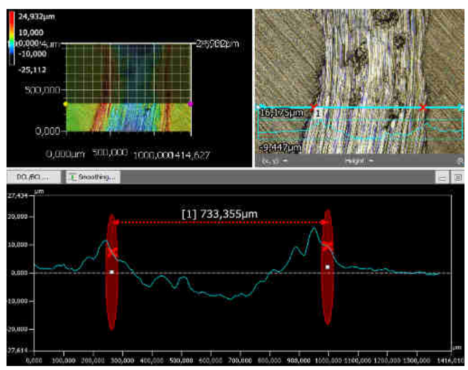


Figure 13. Measurement details of the wear track profile for CuAl10Fe3.

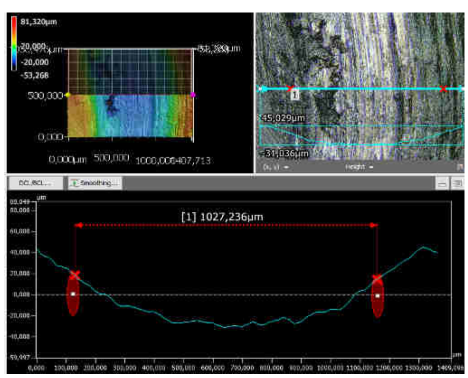


Figure 14. Measurement details of the wear track profile for AlSi12.

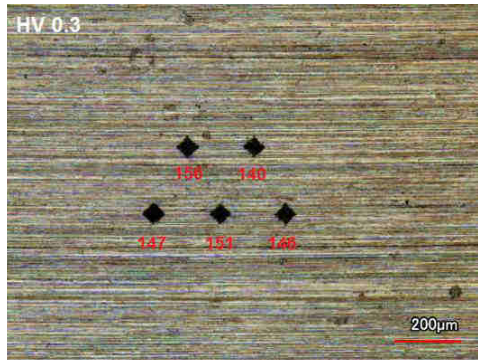


Figure 15. Microhardness values obtained for CuSn12 sample.

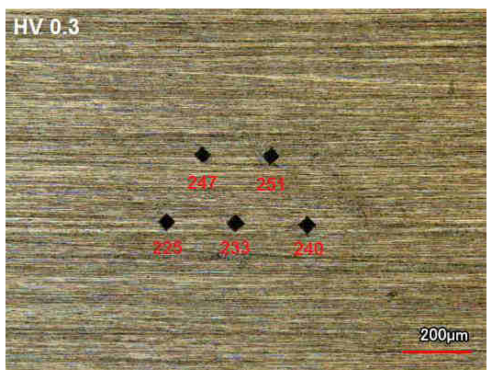


Figure 16. Microhardness values obtained for CuAl10Fe3 sample.

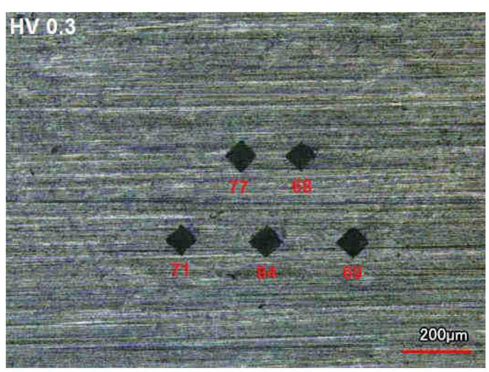


Figure 17. Microhardness values obtained for AlSi12 sample.

Table 4 and Figure 2 show that the lowest volume loss and wear rate value is attributed to the CuAl10Fe3 sample.

One can be observed, that almost all the COF evolutions reached the steady state stage after a distance of 15 m and they are stable, except the AlSi12 sample, which reach at the start, a high value (μ = 1.581) and afterwards it fluctuates up to the end of test (Figures 3, 4, 5).

From the Figures 6 ÷ 11, one can be seen that the abrasive wear of the 100Cr6 ball is more aggressive in the case of the AlSi12 sample. For all the sliding wear tracks, the abrasive wear is combined with the adhesion wear and the pull-out phenomenon was occurred.

The highest microhardness value is attributed to the CuAl10Fe3 sample (Figures 15 ÷ 17). Because the hardness value is an important factor, it can be concluded that help the CuAl10Fe3 sample to have a good tribological behavior at those tests. For other studies of the authors, regarding the cavitation erosion resistance, this is also attributed to the CuAl10Fe3 alloy, which is superior of materials like Sn, Al or Fe alloys, but inferior like stainless steels [17-23].

4. Conclusion

From all the samples, it can be concluded, that the CuAl10Fe3 sample has the best dry sliding wear behavior followed by the CuSn12 and AlSi12 samples.

The COF evolution for the CuAl10Fe3 sample is stable at a mean value of 0.266 (the smallest). Also, the pairs material (100Vr6 vs CuAl10Fe3) have a good behavior, which can be seen also from the wear rates and from volume loss.

Beside the dry sliding wear tests, the hardness was also measured and the highest microhardness value was attributed to the CuAl10Fe3 sample, which help this alloy to reach good resistance.

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