Vol. 38, No. 1 (2016) 102-107

Tribology in Industry

www.tribology.fink.rs

RESEARCH

Experimental Investigation of Friction Coefficient and Wear Rate of Brass and Bronze under Lubrication Conditions

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Keywords:

Friction
Wear
Lubrication
Plastic deformation
Copper and brass.

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A B S T R A C T

The present study is conducted in order to compare the frictional and wear behaviour under mixed lubrication of two pins: bronze (CuSn9P) and brass (CuZn39Pb2), sliding on a steel disc (XC42). The selection of this type of brass and bronze was made because they are not large differences in microhardness, however, have a completely different microstructure. All tests were carried out by using a pin-on-disc tribometer, with a plane contact mode and a pure sliding velocity. The results indicate that friction coefficient and the wear coefficient of brass are significantly higher in comparison to bronze for the two studied roughness (Ra = 2 and 0.15 μm). We also note that for the brass the friction is slightly affected by the roughness of the discs, and the running time is reduced. Regarding bronze, the friction passes from 0.17 for the rough disc (Ra = 2 μm) to 0.02 for the smooth disc (Ra = 0.15 μm) with a time of running about 2000 s; the low value of friction corresponds to the transition to a hydrodynamic regime. The analysis of the microstructure of brass shows a high shear of the surface layers, with a severe plastic deformation, which is not the case for the bronze that is not affected by observable deformations.

1. INTRODUCTION

It is known that loaded contacts in relative movement give rise to wear phenomenon, which depends on several parameters such as: roughness of rubbing surfaces, nature and microstructure of materials [1-4]. However, wear results at a micro geometrical scale by weight loss and sublayers deformation that lead to the formation of a third body called debris [5-7]. The later plays a significant role in the wear process. In this context, we propose the study of friction and wear behaviour of bronze and brass that are copper alloys which we know by experiment their behaviour. These alloys have good mechanical characteristics such as self-lubrication, resistance to wear and oxidation. However, we do not have information's concerning the changes in the metallographic structure occurring on the surface and volume, when these two materials have hardness nearly equal and machined with the same roughness, but a different microstructure. Our work attempts to fill this lack of information by an experimental study of the influence of roughness on the frictional and wear behaviour under lubrication conditions of two couples, consisting of bronze pins (CuSn9P) and brass (CuZn39Pb2) sliding on a steel disc (XC42) with two different roughness (Ra = 0.15μm and Ra = 2μm). All tests were carried out under a constant pressure (10 MPa) and a pure sliding velocity (0,5 m/s).

2. EXPERIMENTAL DEVICE

This study was conducted with a pin-on-disc tribometer where the contact can be continuously immersed in lubricant bath maintained at a regulated temperature (25 °C) (Fig. 1), and a sliding velocity from 0.1 to 3 m/s.

3. EXPERIMENTAL PROCEDURE

The characteristics of specimens and test conditions are summarized in Table 1. The tests carried out give us access to calculate the coefficient of friction as a function of time and thereafter measuring the weight loss. Two tests are conducted for each condition.

It is worth noting that the corresponding time was determined from preliminary tests to reach the steady state of the friction coefficient.

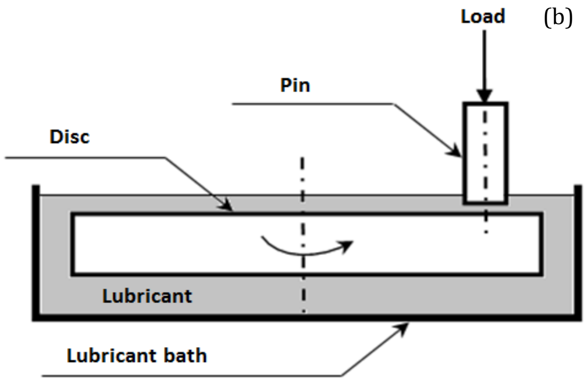
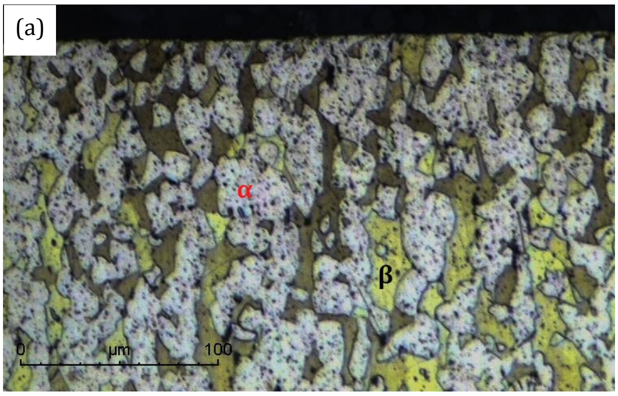


Fig. 1. (a) General view of the tribometer and (b) pin-on-disc configuration.

Figure 2 shows the microstructure of the cross section of pins at virgin state. It is observed that the microstructure of brass pins (CuZn38Pb2) has a two-phase structure α and β, black spots on the surface of brass are Pb inclusions (Fig. 2a). On the other hand, bronze pins CuSn9P have a single-phase structure (phase α) with relatively large grains.

Table1. Characteristics of specimen's conditions of the tests.

Geometrical and micro geometrical characteristics				**Micro hardness Hv**	**Lubricant**	**Conditions of the tests**		
	Materials	Ra (μm)	ϕ (mm)			pressure (MPa)	velocity (m/s)	Temper-ature (°c)
Pin	CuZn38Pb2	0.436	5	170	Neutral 100 η = 0.034 Pa.s	10	0.5	25
	CuSn9P	0.185		190				
Disc	XC42	0.15 / 2	65	250				



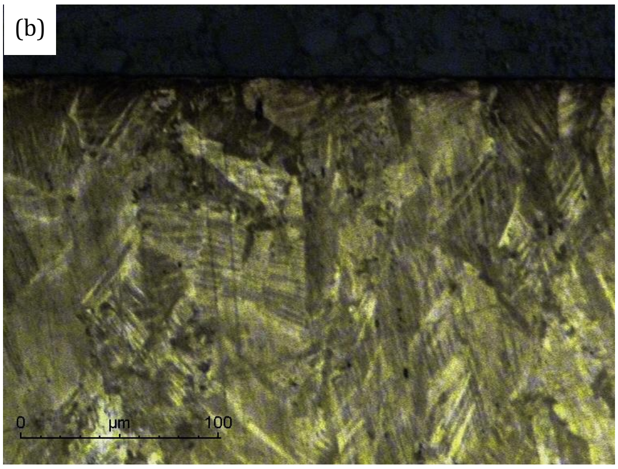


Fig. 2. Microstructure of samples at a virgin state: (a) brass and (b) bronze.

4. RESULTS AND DISCUSSION

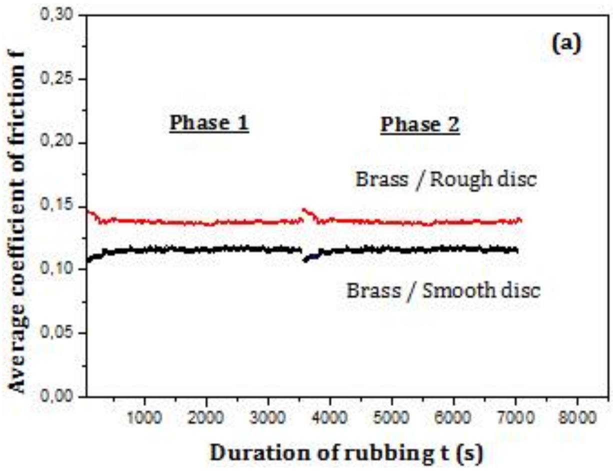
4.1 Frictional behaviour

The determination of friction coefficient has been made by introducing different processing machine errors that do not exceed 6 % [8].

Figure 3 shows the influence of discs roughness on the evolution of the average friction coefficient *f* with time. Two distinct zones can be easily identified in each phase of tests:

- A first zone of instability: corresponds to the running-in, accentuated for Bronze/smooth disc.
- A second zone of stability: during this zone, which follows the preceding state, the coefficient becomes relatively constant.

The results show that for brass (Fig. 3a), the friction is slightly affected by the roughness of discs, and the running-in time is reduced for the roughness of *Ra* = 2 μm. For bronze (Fig. 3b), the influence of the roughness is more important. The friction passes from 0.17 for the rough disc (*Ra* = 2 μm) to 0.02 for the smooth disc *(Ra* = 0.15 μm) with a running-in time of about 2000s. This low value of friction corresponds to the transition to a hydrodynamic regime [9-10].



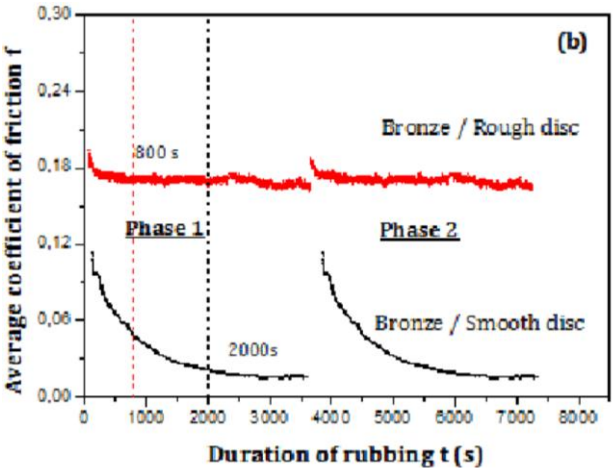


Fig. 3. Evolution of the average coefficient of friction versus duration of rubbing: (a) brass/steel and (b) bronze/steel.

4.2 Wear behaviour

The study of the wear behaviour has been made on two aspects, the first one is the study of the wear coefficient, and the second one is the analysis of the microstructure and microhardness in volume.

The wear coefficient *K* is calculated with the general Archard law:

$$K = \frac{\Delta V}{F.L}$$

The average values of the wear coefficient presented by the histogram in Fig. 4 allow us to see that:

- The wear coefficient of brass was significantly higher in comparison to that of bronze for the two studied roughness and in the two phases of tests.
- For the roughness *Ra* = 0.15 µm the value of the brass wear coefficient is approximately one hundred times greater than that of bronze, whereas for roughness *Ra* = 2 µm this value decreases to be thirty (30) times the value of wear of bronze.

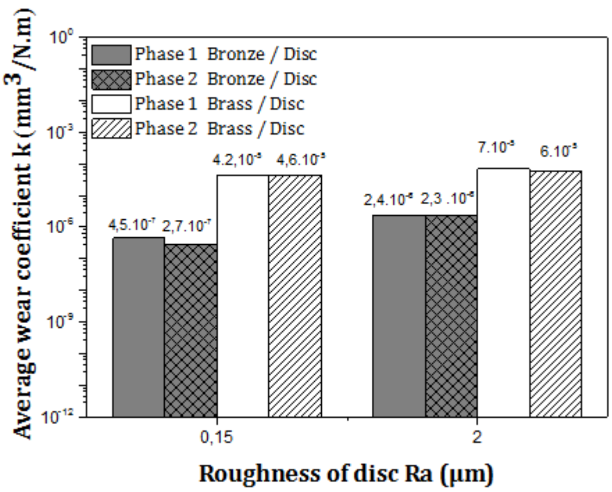


Fig. 4. Average wear coefficient of brass and bronze pins versus disc surface roughness (*Ra* = 0.15µm, *Ra* = 2 µm).

4.3 Analysis of friction induced the microstructure transformation

To show the influence of wear in volume, observations were carried out on an optical microscope of an orthogonal cutting to the track of wear of brass pins (Fig. 5a) and bronze (Fig. 5b), as well as, microhardness measurements (Fig. 6).

Microstructure

Cross-sectional observations reveal the formation of a strong shearing of the phase α in the subsurface layers up to 70 µm in depth (Fig. 5a). This sever deformation is observed on all surface around the plough grooves that are formed on the surface of brass after friction. While the deformation of the phase β, is not quantifiable on a micrometric scale.

This result was found for the two studied roughness. As regards, the bronze, represented by the photo of Figure 5b, does not show observable deformations of subsurface layers.

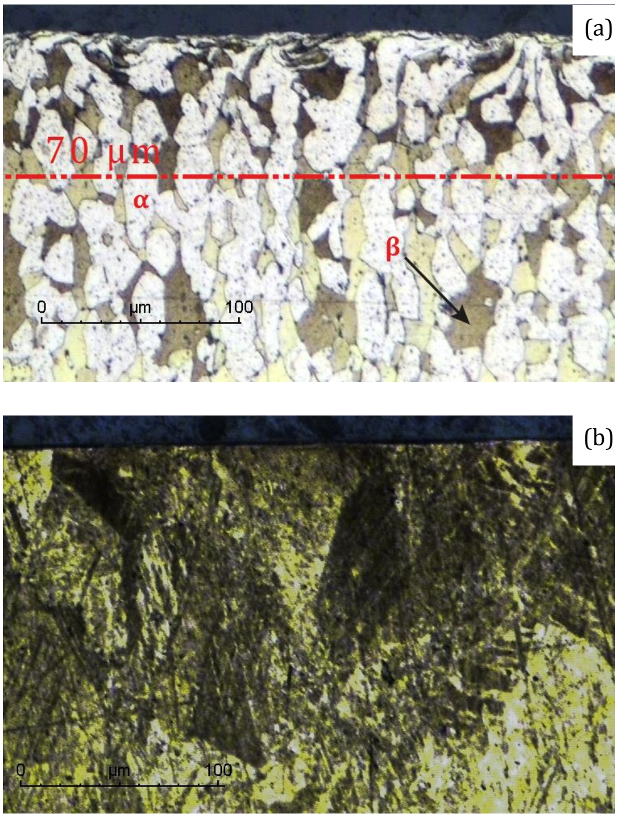


Fig. 5. Microscopic image of an orthogonal cutting to the track of wear after friction of: (a) brass and (b) bronze.

Microhardness

The figure 6 shows the evolution of the microhardness depending on the depth from the contact surface, after test in mixed lubrication.

It is noticed that for brass microhardness shows a decrease until a depth of about 70 µm to become constant (Fig. 6a), which is observed for the two studied roughness.

On the other hand, the microhardness of bronze (Fig. 6b) sliding on the smooth disc (*Ra* = 0.15 µm) is relatively constant (~ 186 Hv), which indicates that wear does not affect considerably the volume of material. For the bronze pin rubbed against the rough disc (*Ra* = 2 µm) a slight variation of microhardness depth is observed.

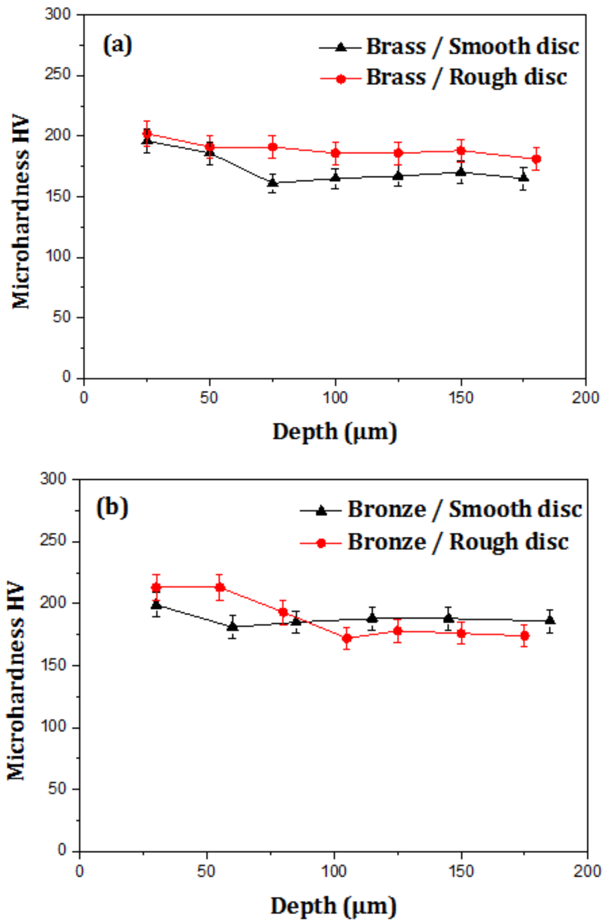


Fig. 6. A variation of the microhardness of subsurface layers versus a depth of: (a) Brass and (b) bronze samples after friction.

5. CONCLUSION

This study allowed us to improve the conclusion of the friction behaviour and wear under lubrication conditions of two couples: brass / steel and bronze / steel with two different roughness of disc, that consists to:

- The influence of the disc roughness on the coefficient of friction is more important for bronze than for brass.
- It is found that under the same conditions, brass has a very high wear coefficient compared to that of bronze.
- Brass is more sensitive to wear and presents a high roughness at the end of test.
- The friction of the brass is accompanied with a severe plastic deformation of subsurface layers.

This study shows the necessity to introduce the analysis of surface states, which has just been started, to give an experimental representation to this phenomenon which is not sufficiently known until now.

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NOMENCLATURE

f: Friction coefficient	[--]
F: Applied load	[N]
K: Wear coefficient	[mm^3/Nm]
L: Sliding distance	[m]
P: Contact pressure	[MPa]
Ra: Average Roughness	[10^{-6} m]
t: Time:	[s]
V: Sliding velocity	[m/s]
ΔV: Volume of material lost	[m^3]
η : Dynamic viscosity of lubricant	[Pa.s]