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# Studying the tribological behavior of the Counterface Materials 60/40 Brass alloy under Dry Sliding Contact

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**Abstract.** Wear due to friction is a complicated matter and cost the international economy millions of dollars. Also, it affects the accuracy of the sliding parts, due to material loss. This study tries to find out the involving factors. The present work is an attempt to find a relation between the materials and friction coefficient and wear mechanism of '60/40' Brass alloy under dry sliding condition, the normal load is (8, 15 and 22) newtons. Experimental was achieved using a pin on disc (P.O.D) tribometer, and sliding velocities (0.5, 1.3 and 1.8) m/s for sliding time (0- 60 sec).and each case study, under dry condition. The lost metal and the friction coefficient were measured at the same moment. This was done for three different materials. These three materials are steel 300, 500 and 600 Mpa. Results proved that material types highly affect wear and friction.

## 1. Introduction

It is known that the pure metal has low mechanical properties, thus improving these mechanical properties require mixing different materials which produce so-called alloys and metal matrix composites (MMCS). Pure copper material .normaly is not used as a bearing liner material this is because of its low mechanical specifications and hardness. The copper likes other metal is mixed with other metals to produce more than 1000 different alloys, each of them has different industrial characteristics according to its content. Several studies have been conducted to know the new properties of these alloys. Copper and white materials base alloys are utilized considerably, as a bearing liner material, the tribological and mechanical specifications of the bearing lining were manufactured from copper 'CuSn10' copper and 'CuZn30' copper base has been studied by [1], the values of wear rate of the coarse surfaces low 'CuSn10, CuZn30' and pure Sn. These values are higher for pure Cu and pure Zn bearings, the highest bearing temperatures were for CuZn30 and CuZn30 bearings while the lowest temperatures were for the pure Zn, Pure Cu, and pure Sn bearings. The external load effect was studied for Cu–SiC (12%) and Copper-SiO<sub>2</sub> (9%) composites [2], The lost materials is increased with the sliding distance for both, composites. Cu-SiC (12%) .Composites showed comparatively better abrasion reluctance compared with 'Cu -SiO<sub>2</sub>' (9%) composite, the rise in wear rate for 'Cu-12%SiC' composites is nearly 5-6 times compared with 'Cu- SiO<sub>2</sub>' 9% composites. The wear rate is increased gradually with the load increase. The influence of load on wear rate is greater than the sliding speed and the sliding distance. The properties of many copper compounds with PECS techniques against chromium steel and alumina were studied [3], it is found that the coefficient of friction, wear rate and wear mechanism is great dependence on the counterface material. The friction coefficient is the highest for 'Cu-TiB<sub>2</sub>' and lowest for 'Cu-Cu<sub>2</sub>O', where is the highest wear rate was for Cu- diamond compounds and the lowest rate of Cu-Cu<sub>2</sub>O, all compounds were found to perform better than normal copper.



Regarding copper-based alloy which is used for manufacturing thrust washer bearing. Has been investigated under dry conditions for various loads and speeds [4]. Pin on disc tribometer is used then wear analysis results are obtained. It was found that the wear of copper bases materials is directly proportional to the pressure where it was inversely proportional to the sliding speed. The wear rate increases with the increase of the external load. Adding Lead to Copper reduces the wear resistance and improves friction behavior. Separation shaft from the lining by the lubricant film(graphite) preventing direct contact and hence decrease wear [5]. Experimental results showed that increasing graphite content reduces brass friction. In order to study friction and corrosion behaviors under mixed lubrication conditions of two types of alloys: bronze 'CuSn9P' and brass 'CuZn39Pb2', [6], tests have been completed using a pin-on-disc tribometer, The results showed that the friction coefficient and wear rate of the brass alloy is much higher than that of bronze alloy for different surface roughnesses. Two zones have been recognized, the first is compatible with the unstable friction and the second zone has a constant coefficient of friction. Comparing friction behavior between the mating surfaces, brass-steel, and copper-steel, is investigated [7], ball-on-prism tribometer is used for this purpose. The results showed that the friction coefficient is not a function of the vertical load and the number of contact points. While at a high sliding speeds range it was observed that increasing the sliding speed cause an increase of the coefficient of friction, linear wear rate increases with the external load, sliding speed, contact points number, The coefficient of friction for the copper-steel pair decreases with the increase of the external load. Reaching the highest sliding speed has no effect on the number of contact points. The linear wear rate decreases with the increase of the sliding speed and increases with the increase in the number of contact points. Inertial braking test bench and temperature measuring instrument are used for measuring the average value of the friction coefficients, transient friction coefficients, and friction temperatures of the two tested specimens Cu-coated and Cu-uncoated graphite particles [8], The results showed that with copper-coated graphite lubrication, the hardness and relative density can be improved, thermal conductivity and inter-bonding between graphite and matrix are significantly increased, The friction temperature of sample copper-coated in each case is well below the Cu-uncoated sample temperature, because of the large lost material effect on the surface of sample Cu-uncoated. let's wear rate is more serious than the wear rate of sample Cu-coated. The experimental study proved that the increase in the graphite fraction reduces friction. Moreover, the effect of 'graphite content and grinding time on mechanical and tribological properties of Cu-graphite composites which are prepared by powder metallurgy technique[9], It was visible that increasing grinding period leads to an increase in the mechanical properties decreases in wear magnitude and minor increase in the COF for all compositions. The aim of this research is to study the mechanical behavior of copper under various laboratory conditions and to determine the effect of load, slipping speed, and disc hardness on coefficient of friction and wear rate.

## 2. The experimental Procedure

For the case of two surface contact under the external load influence which was friction coefficient and wears rate tests achieved using tribometer type 'DUCOM's Wear and Friction Monitor ED – 201' for this purpose, has been used as shown in figure (1).

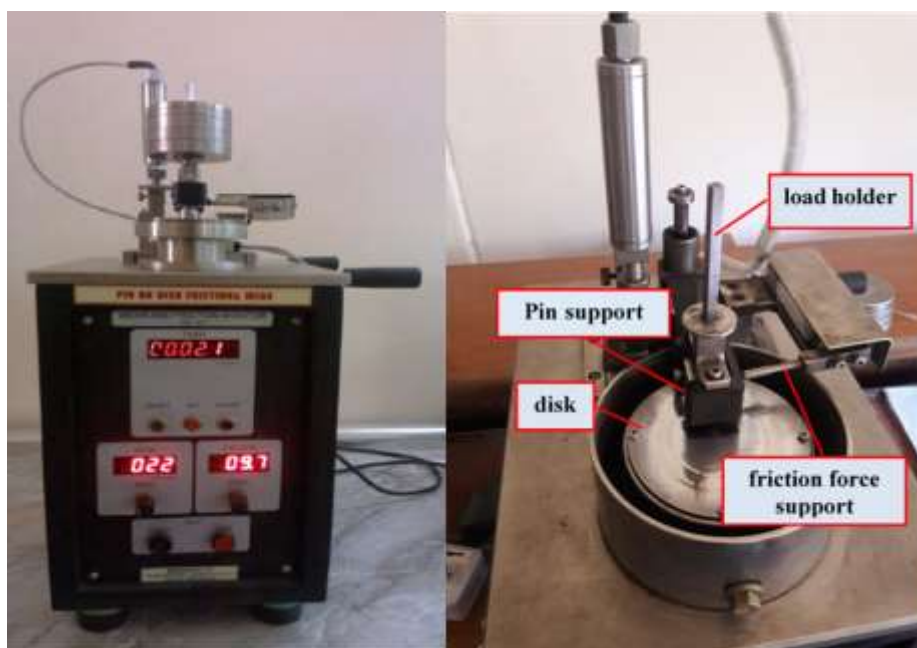


Figure 1. Pin-on-disc tribometer type 'DUCOM's Wear and Friction Monitor ED – 201'

The components of the 60/40 Brass alloy were analyzed using a SHEMADZU/XDR-6000 device and compared to the international standard as shown in Table (1), The SEM figures type Olympus CX21i was used to analyze the sample images after the tests were carried out.

| Table 1. Chemical content of 60/40 Brass alloy |                   |                            |
|------------------------------------------------|-------------------|----------------------------|
| Element                                        | Prescribed values | Values obtained by testing |
| Copper (Cu)                                    | 59.5 - 61.5       | 58.17                      |
| Tin (Sn)                                       | max 0.2           | 0.051                      |
| Lead (Pb)                                      | max 0.3           | 0.0990                     |
| Al                                             | max 0.05          | -                          |
| Ni                                             | max 0.3           | -                          |
| Iron (Fe)                                      | max 0.2           | 0.762                      |
| Other                                          | total 0.2         | 0.027                      |
| -                                              | Zn - remainder    | 40.891                     |

The tests were done in the Mechanical and Chemical Engineering Departments at the College of Engineering, Tikrit University.

The used discs are made of high carbon steel. And these disks have different values of hardness, 300, 500 and 600 Mpa. And their diameters are 100 mm. After every 10 minutes of running the pin sample is examined and the lost weight due to wear is counted. And each sample test consumed an hour period. The samples were prepared using a 10 mm diameter rod. And, this rod is made of 60/40 brass, each sample length is 92 mm. these dimensions suit the specifications of the device (pin-on-disc). The sample's surface roughness is ( $0.25\mu\text{m}$  C.L.A) while disc surface roughness is ( $0.35\mu\text{m}$  C.L.A).

Roughness was measured using (Talysurf-Hobson) device. After each run the sample is examined without making any change using a naked eye and scanning electron microscope (SEM) type (JEOL-JSM-T20) for this purpose. Acetone is a cleaning fluid used to clean samples before and after each wear test. The test was carried out at temperature 25 °C

To determine the friction coefficient in this paper the Coulomb's equation (1) was used, which associate load and friction coefficient as a time depended on the functional ratio of friction force and load [11]:

$$F_{\mu}(t) = \mu(t) \cdot F_n(t) \xrightarrow{\text{yields}} \mu(t) = \frac{F_{\mu}(t)}{F_n(t)} \quad (1)$$

where:  $F_{\mu}$  – friction force[N];  $F_n$  – external normal force [N];  $\mu$  – friction coefficient [-].

The wear rates have been measured by the means of the lost weight. A sensitive digital scale of (0.0001mg) error. Type (Mettler HK 160) have been used for this purpose.

Archard's Wear Law is the most common wear model used to calculate the wear rate [12]:

$$\frac{V}{s} = K \cdot F_n \quad (2)$$

Where ( $V$ ) is the wear volume [ $\text{m}^3$ ], ( $K$ ) is the specific wear rate [ $\text{mm}^3/\text{Nm}$ ], ( $F_n$ ), is the external normal load and ( $s$ ) is the sliding distance[m]. Equation (2) is often reformulated like:

$$k = \frac{V}{F_n \cdot s} = \frac{\Delta m}{F_n \cdot v \cdot t \cdot \rho} = \frac{\Delta m}{F_n \cdot v \cdot t \cdot \rho}, \text{ where, } V = \frac{\Delta m}{\rho}, s = v \cdot t, v = \omega \cdot r, \omega = \frac{2 \cdot \pi \cdot n}{60} \quad (3)$$

Where  $\Delta m$  is the lost material [g],  $v$  is the linear velocity of the disk in the contact area with the pin [m/sec],  $t$  is the sliding time [sec],  $\omega$  the angular velocity of the disk [rad/sec],  $n$  is the angular velocity of the disk [rpm] and  $\rho$  is the density of pin material [ $\text{Kg}/\text{m}^3$ ].

For three various normal loads of (8, 15 and 22) Newton were executed and three various sliding speeds (95, 250 and 350 rpm) of disk i.e. various relative linear velocities (0.5, 1.3 and 1.8) m/s specimen, at atmospheric condition. At least three times each test was performed and repeated to ensure the correctness and accuracy of the results. Before each test, the contact face of the samples and ring surface test is scratched by a grade of emery paper to found ideal contact between samples and disc

### 2.1. Effect of disc hardness (counterface)

The program is divided into groups practical for 60/40 Brass alloy. The required time for each wear rate measure is 10 minutes and two minutes for friction coefficient measurement. And this is shown in Table (2).

| Table 2. An experimental program to study the effect of hardness disc |                 |                     |                        |                        |                |         |
|-----------------------------------------------------------------------|-----------------|---------------------|------------------------|------------------------|----------------|---------|
| BRASS ALLOY CuZn40                                                    |                 |                     |                        |                        |                |         |
| No. experience                                                        | Hardness (Mpa)  | Normal load (N)     | Sliding speed (rpm)    | Surface roughness (µm) |                |         |
|                                                                       |                 |                     |                        | Disc                   | pin            |         |
| Disc                                                                  | 300             | 15                  | 350                    | 0.35                   | 0.25           |         |
| Disc                                                                  | 500             |                     |                        |                        |                |         |
| Disc                                                                  | 600             |                     |                        |                        |                |         |
| Table (3). An experimental program to Study effect of sliding speed   |                 |                     |                        |                        |                |         |
| material                                                              | Normal load (N) | Sliding speed (rpm) | Surface roughness (µm) |                        | Hardness (Mpa) |         |
|                                                                       |                 |                     | Disc                   | pin                    | Disc           | pin     |
| 60/40CuZn Brass alloy                                                 | 8               | 95                  | 0.35                   | 0.25                   | 300            | 136.486 |
|                                                                       |                 | 250                 |                        |                        |                |         |
|                                                                       |                 | 350                 |                        |                        |                |         |
|                                                                       | 15              | 95                  |                        |                        |                |         |
|                                                                       |                 | 250                 |                        |                        |                |         |
|                                                                       |                 | 350                 |                        |                        |                |         |
|                                                                       | 22              | 95                  |                        |                        |                |         |
|                                                                       |                 |                     |                        |                        |                |         |
|                                                                       |                 |                     |                        |                        |                |         |

|  |  |     |  |  |  |  |
|--|--|-----|--|--|--|--|
|  |  | 250 |  |  |  |  |
|  |  | 350 |  |  |  |  |

### 2.2. Effect of sliding time

The program is divided into groups practical for 60/40 Brass alloy. time to measure the wear rate is 10 minutes per reading (10,20,30,40,50,60) min, and the taken time is 10 minutes to measure the coefficient of friction per reading (0.5,2,4,6,8,10) min, as shown in Table (3).

## 3. Results and Discussion

### 3.1. Effect sliding speed on coefficient friction:

Laboratory results showed that the friction coefficient decreases as the sliding speed increases. This is shown in Figures 2, 3 and 4. The effect of the flash temperature generated by the sliding surfaces is increased with the increase of the sliding speed [12]. High temperature causes a softening of the peaks of the sliding surfaces. This separates the bonds then reducing the friction coefficient. Rising the surface temperature of the sliding surfaces increases the surface's capability for oxidation. Oxide acts as a lubricant in the contact areas, i.e. the peak of the sliding surfaces, hence reduces friction coefficient.

And continue sliding on each other would flatten a microroughness and developing a microroughness which tend to make the friction coefficient has a constant value. The highest value of the friction coefficient was measured and found to be 0.416 for 18 Newton external, sliding time 4 minutes and sliding speed 95 rpm as shown in figure 4. And the lowest value for the friction coefficient was measured and found to be 0.126 for 6 Newton external load, and 350 rpm sliding speed, and the same stability sliding time 4 minutes as shown in figure 2.

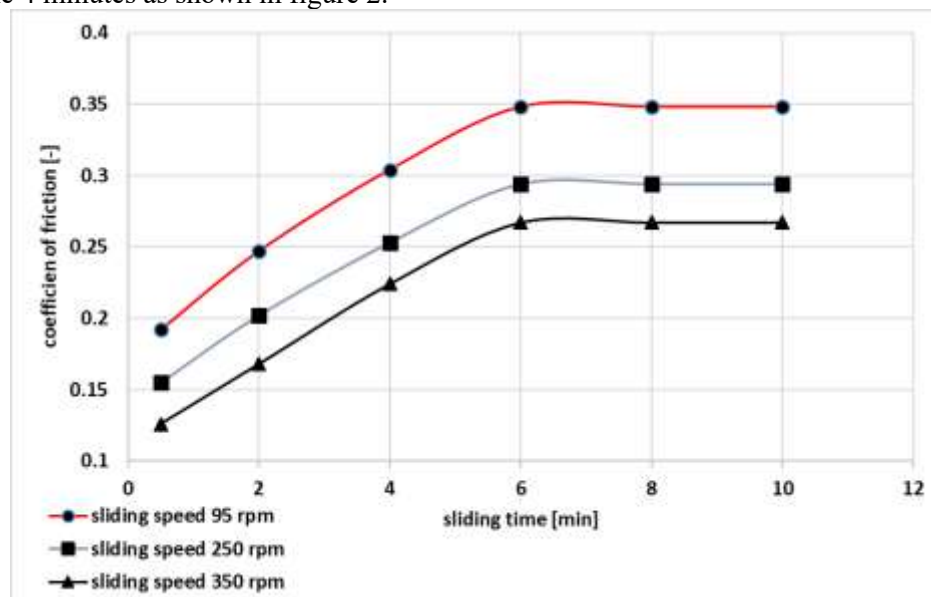


Figure 2. The relationship between sliding time and friction coefficient for 60/40 brass alloy, external load 6 N

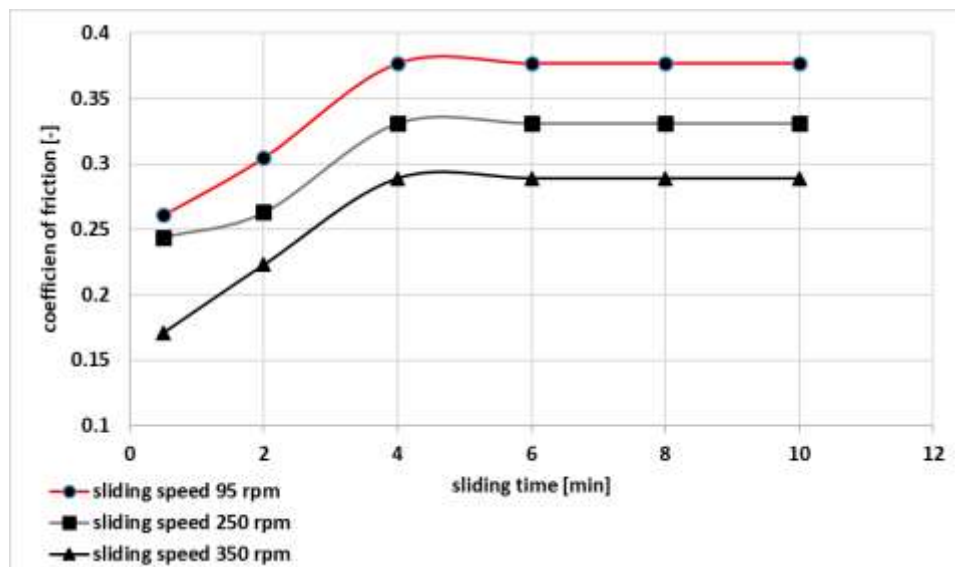


Figure 3. The relationship between sliding time and friction coefficient for 60/40 brass alloy, external load 12 N

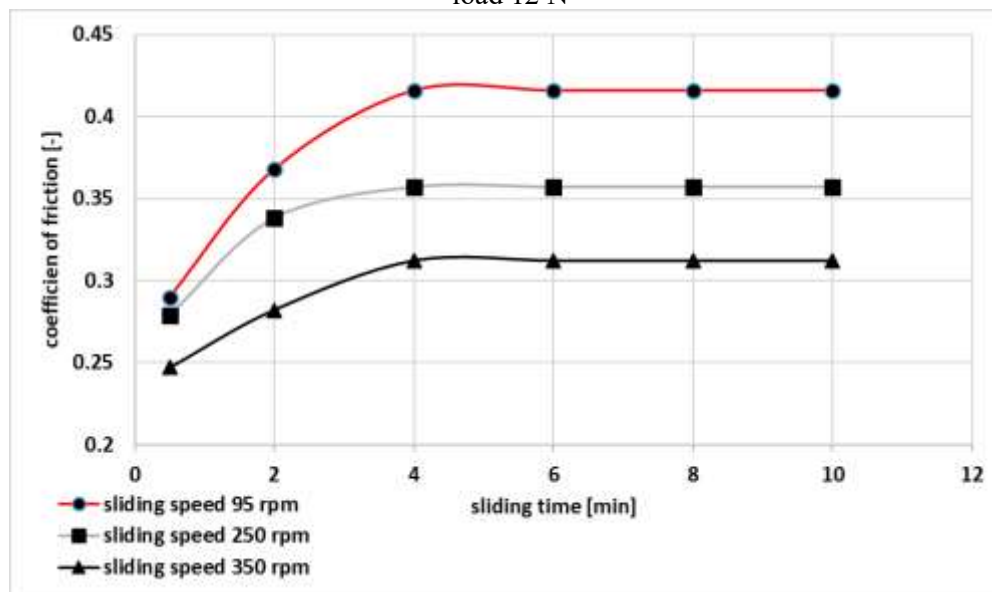


Figure 4. The relationship between sliding time and friction coefficient for 60/40 brass alloy, external load 18 N

### 3.2. The effect of the external load on the friction coefficient:

Low loads increase the temperature in the mating faces of the sliding surfaces. This causes plastic deformities on these faces. A thin layer of solid oxide is formed between them, thus, the friction coefficient of friction tends to be constant, as long as the shear force is less than the oxide layer strength. However, when the external load is increased, fatigue occurs on the oxide layer due to its fragility and hence shear strength is decreased resulting from the removal of the oxide layer, leading to direct contact between the peaks of both contacted surfaces. The welding between the two sliding surfaces requires a large shear force to continue sliding. It has been observed that an increase in the friction coefficient value at high loads as shown in figures (5 and 6). The highest value for the friction coefficient was measured to be 0.416 for 18 Newton external load and 95 rpm sliding speed as shown in Figure (5). And the lowest coefficient of friction was 0.126 for 6 Newton external load and 350 rpm sliding speed as shown in Fig (7). Experiment time was (4–6) minutes for each load and speed set. It was found that the

friction coefficient of the copper alloy is generally has a low value. And this may be justified due to the existence of a lead that works as a lubricant hence reduces the friction force.

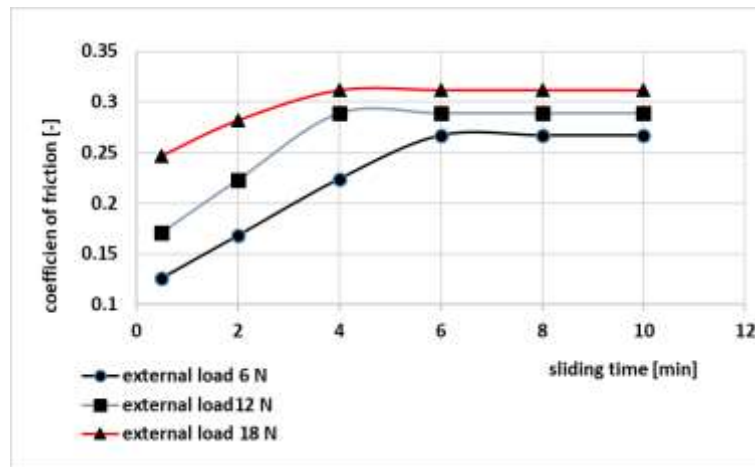


Figure 5. The relationship between external load and friction coefficient for 60/40 brass alloy, speed 350 rpm

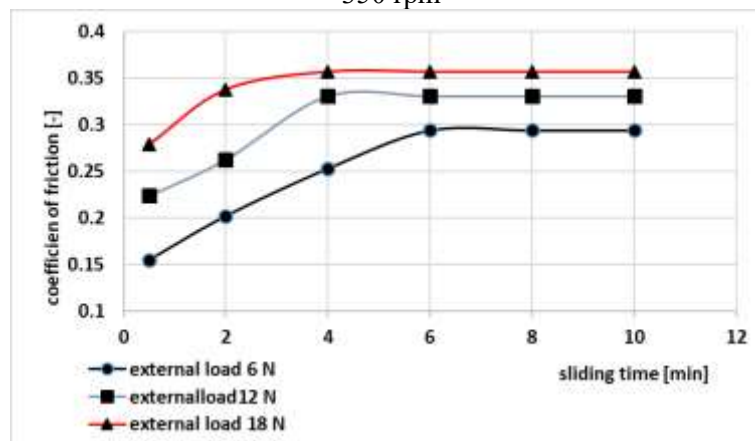


Figure 6. The relationship between external load and friction coefficient for 60/40 brass alloy, sliding speed 250 rpm

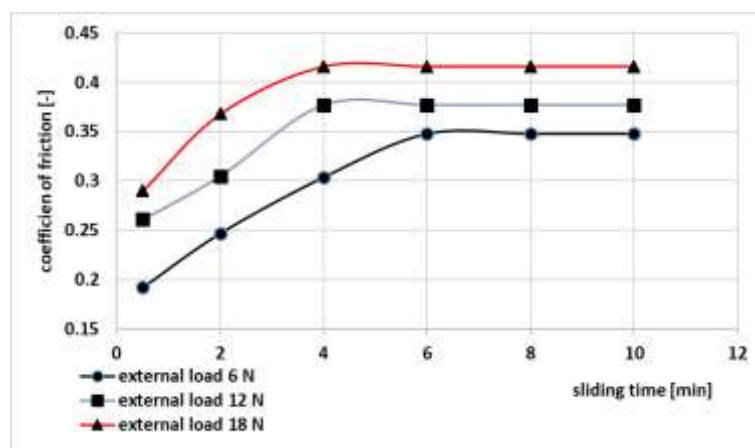


Figure 7. The relationship between external load and friction coefficient for 60/40 brass alloy, sliding speed 95 rpm

### 3.3. The effect of the external load on the wear rate (lost material).

Increasing load causes an increase of the plastic deformation process at the peaks of the contact surface bumps and thus increases the density of the dislocation [13]. Because of the increase in the dislocations, the small gaps are made and grow to be a micro-cracks on the metal surface. These cracks extend towards weak areas and gathering into a large crack as shown in fig.8.

The link between them would happen. Abrasion wear removes thin layers from the mating surface as shown in fig 9.

The adhesion between the bumps of the two contact sliding surfaces depends mainly on the load values, At low load A protective surface film is formed when the sliding occurs, This leads to a lack of contact between the sliding contact surfaces where a shear force is required to break the bond between the bumps leading to a decrease in the wear rate at low loads. However, a breakage of the oxide layers leads to a pure metals connection (weld), which makes the required shear force to separate the bumps higher, leading to higher wear rate at higher loads, as shown in figures 10,11 and 12.

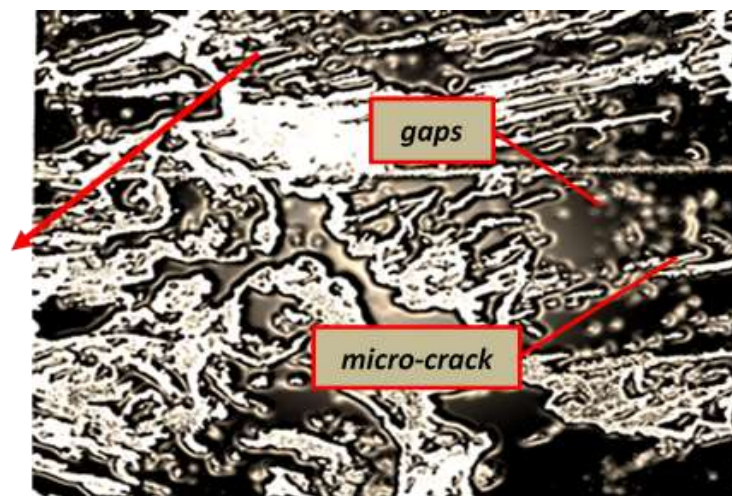


Figure 8. Micro-cracks on the surface of Brass CuZn40 sample surface for 15 Newton external load and 350 rpm sliding speed. Power magnification is (X700) (The red arrow indicates the direction of the disc rotation).

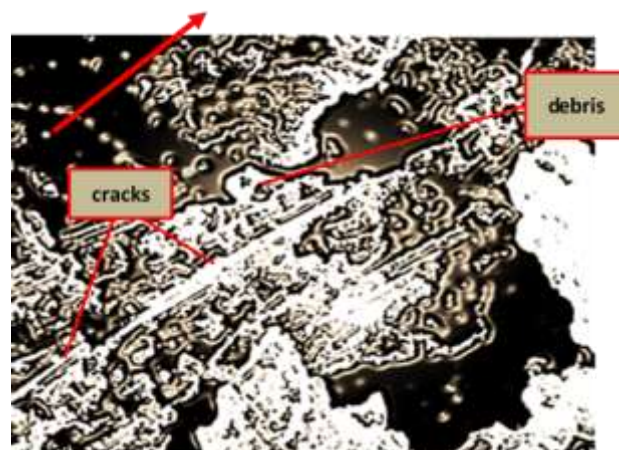


Figure 9. The debris the wear of the 60/40 CuZn alloy brass when the normal load (18N), sliding speed is (95rpm), power magnification (X280).

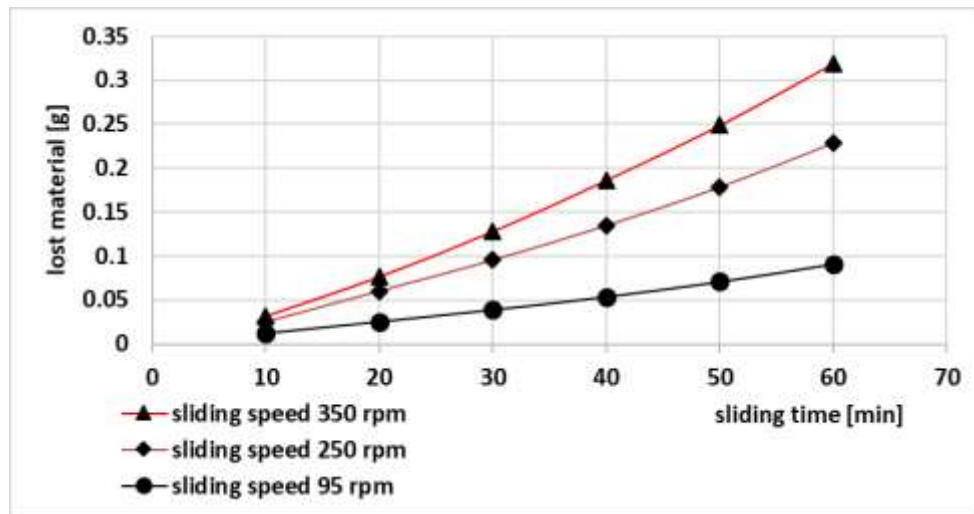


Figure 10. Effect sliding time on lost material, different sliding speed, external load 6N.

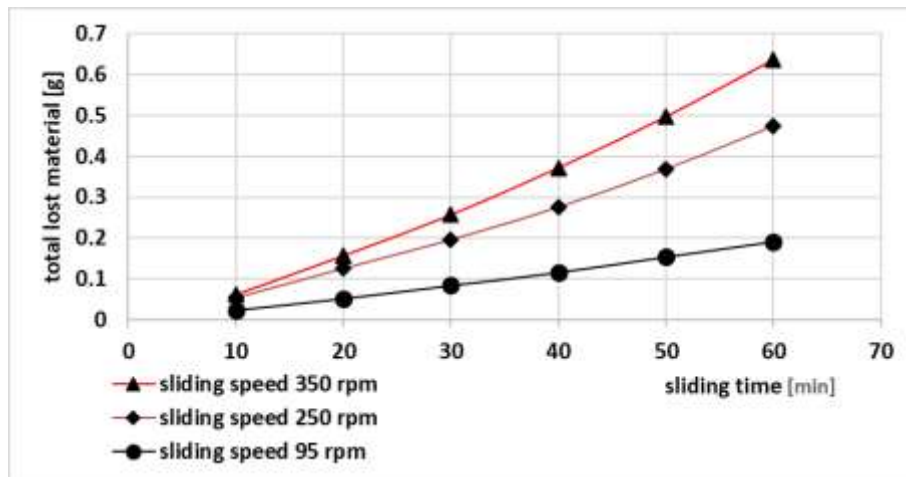


Figure. 11. Effect sliding time on total lost material, different sliding speed, external load 12N.

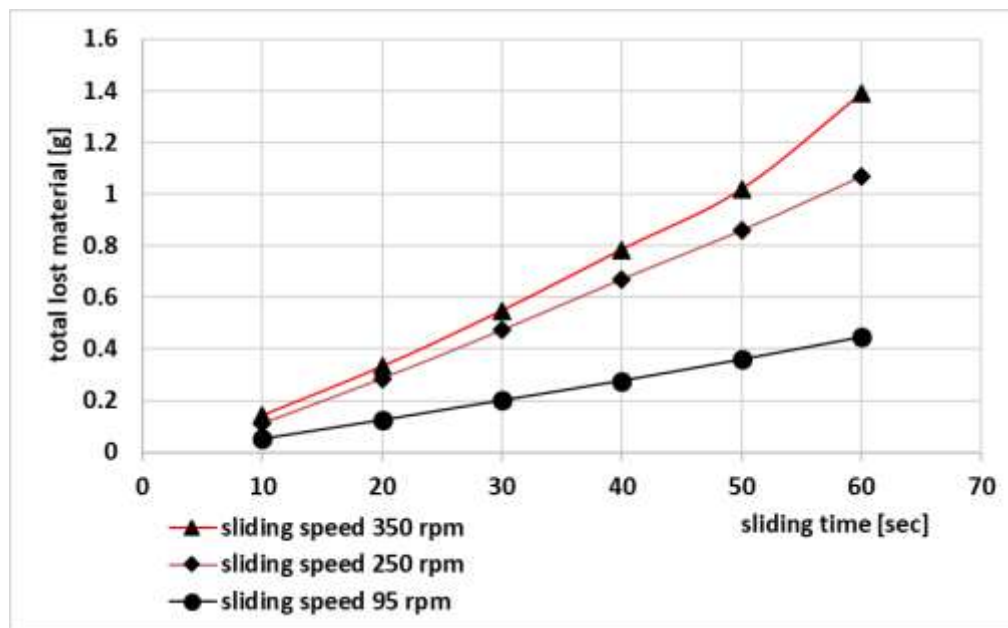


Figure 12. Effect sliding time on total lost material, different sliding speed, external load 18N.

Increasing the ratio of zinc in the copper alloys increases the possibility of oxidation on the contact surfaces. Thus, breaking the oxide and throwing it away increases the rate of corrosion. In low loads, the oxide is removed from the contact surfaces, where the required shear force is less than the resulting from the external load. At the impact of high loads, a thin layer of the copper alloy surface is removed as a result of the abrasive mechanism of the debris resulting from the peak removal of the contact surface bumps. This is evident from the lost material amount as shown in Figs. 10, 11 and 12 for sliding speeds 350 rpm sliding time 10 minutes and external load 18, 12 and 6 Newton. The lost material increases for the same sliding speed 350 rpm and for the same sliding time 10 minutes for external loads (18~ 12 Newton by 2.5 times, external load (18 ~ 6) Newton by 4.7 times and external load (12~ 6) Newton by 2 times. It could be observed from Fig. 13, the curves may be divided into two zones, the light wear zone which ends with a load of 12 Newton for all sliding speeds, and the transition wear zone which starts at 12 Newton and ends at 18 Newton. It is also noticed that the loss of the material diverges (increases) with the increase of the amount of the load's value, and if the load is increased more than 18 Newton this may lead to entering the severe wear zone, especially at the speeds of (350 and 250) rpm.

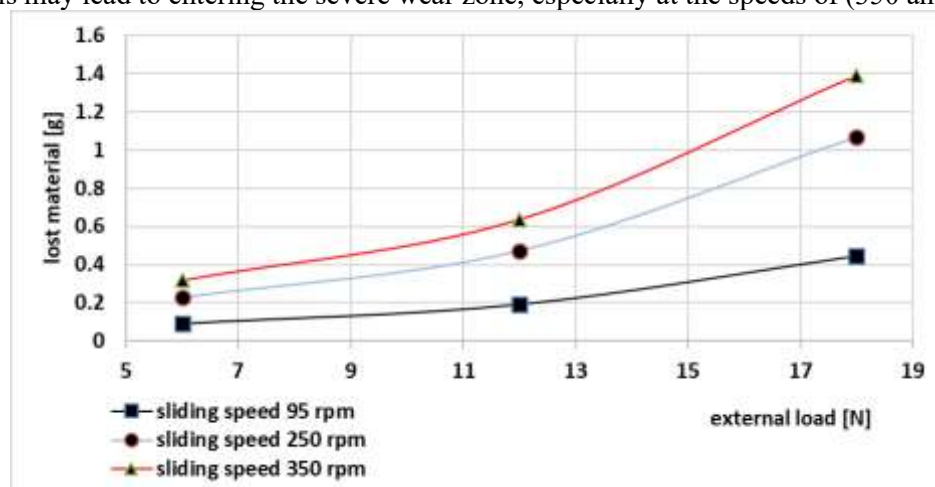


Figure 13. Effect external load on total lost material, sliding time 60 min

### 3.4. Effect of the disc hardness on lost material and friction coefficient

The loss of the material increases with the hardness of the disc. For disk hardness of 600 Mpa, the lost material was 0.380584 g, while for the disk hardness of 500 Mpa, the lost material was 0.39152 g, all these for 40 minutes run. While for 60 minutes run, the lost material at least, for a disk hardness of 600 Mpa followed by that of 500 Mpa and then by the one of 300 Mpa which is the biggest. This was concluded from figure 14. As well as the loss of material for the disc hardness of 300 Mpa, at the operation start moment, at least after 40 minutes. Therefore, when the disk hardness value is close to that of the sample hardness, this would lead to an increase in the material loss value and vice versa. This is explained by the fact that, wherever the disk hardness is high, this cause cut the bumps peaks. The copper surface, resulting in a flat surface sample, resulting in low lost material, but it increases the friction force due to the increase in the real contact area, This increases the friction coefficient as shown in Figure 15.

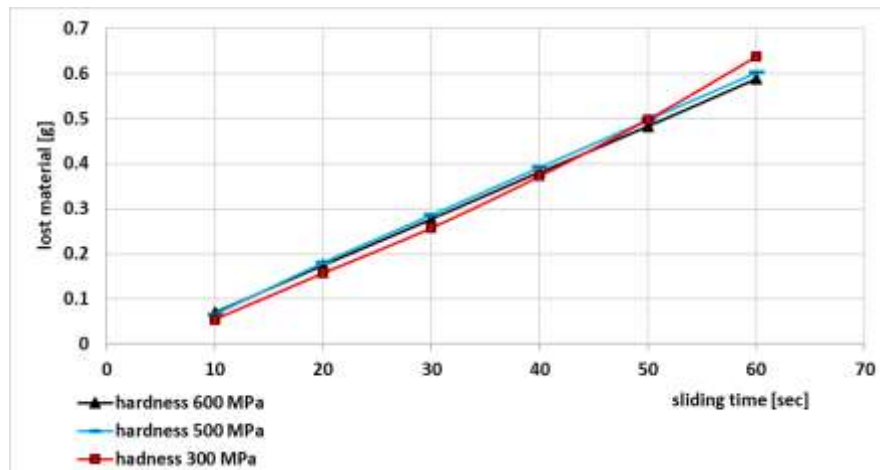


Figure.14. Effect of disk hardness on wear rate for 60/40 brass alloy, load 12.522N, sliding speed 350 rpm

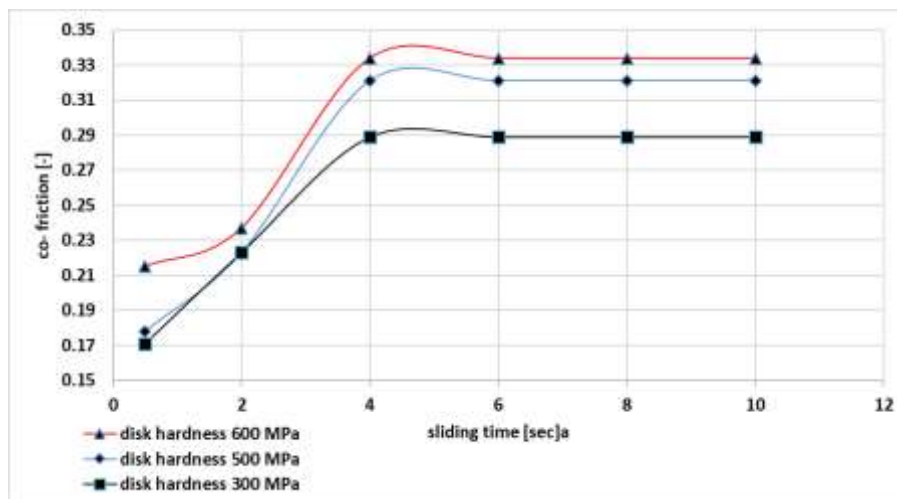


Figure 15. Change friction coefficient with change disc hardness

#### 4. Conclusions

- The friction coefficient value depends on the nature of the alloy metal structure and the type of friction mechanism. The friction coefficient is reduced when a lubricant element is existing between the two sliding surfaces. In this research lead played an important role in reducing the coefficient of friction.

- The friction coefficient decreases when the sliding speed is for short period of time while the load is stable. The friction coefficient increases when the load increases and the sliding speed is stable.
- A low friction coefficient does not mean low wear rate.
- The friction coefficient value depends on the disc hardness, which is increased when the hardness increase.
- Lost material is increased with the increase of the disc hardness to a certain extent then followed by a low lost material with the increase of the hardness, also to a certain extent.

## 5. Reference

- [1]. Bekir Sadık Unlue, Enver Atikb, Evaluation of the effect of alloy elements in copper-based CuSn10 and CuZn30 bearings on tribological and mechanical properties, Journal of Alloys and Compounds 489, 262–268, 2010.
- [2]. Tejas Umali, Amarjit Singh, Y. Reddy, Abrasive wear behavior of copper-SiC and copper-SiO<sub>2</sub> composites, International Journal of Modern Physics, Vol. 22, 416–423, 2013, DOI: 10.1142/S2010194513010465.
- [3]. Riina Ritasalo et al.: Comparison of the wear and frictional properties of Cu matrix composites prepared by pulsed electric current sintering, Proceedings of the Estonian Academy of Sciences, 63, 1, 62–74, 2014, DOI: 10.3176.
- [4]. Saurabh M. Dhaneshwar Mrs. S. B. Desai, Wear Analysis of Crankshaft Thrust Washer Bearing Material, International Journal for Research in Technological Studies (IJRTS) Vol. 1, 2348-1439, 2014.
- [5]. Nada Bojic, Dragan Milicic, Milan Banic, Miodrag Milicic, Effect of coverage of graphite on self-lubricating plain bearings, SERBIATRIB '15 14th International Conference on Tribology, Belgrade, Serbia, 2015.
- [6]. Salima Senhadji1, Farid Belarifi, François Robbe-Valloire, Experimental investigation of friction coefficient and wear rate of brass and bronze under lubrication conditions, SERBIATRIB '15 14th International Conference on Tribology, Belgrade, Serbia, 2015.
- [7]. Viktor Krasnik, Josef Schlattmann, Experimental investigation of the friction and wear behavior with an adapted ball-on-prism test setup, SERBIATRIB '15 14th International Conference on Tribology, Belgrade, Serbia, 2015.
- [8]. Xin Zhang et al, Study on the Tribological Performance of Copper-Based Powder Metallurgical Friction Materials with Cu-Coated or Uncoated Graphite Particles as Lubricants, Materials, 2018; DOI:10.3390/ma11102016.
- [10]. Chuanlin Tao et al, Tribological Mechanism of Friction and Wear Reduction Using Oil-Based ZnO Nanofluid Applied on Brass, European Scientific Journal January, Vol.15, ISSN: 1857, 2019, Doi: 10.19044.
- [11]. Bojić, N. Milčić, D., Banić, M., Milčić, M. (2015). Effect of coverage of graphite on self-lubricating plain bearings, 14th International Conference on Tribology SERBIATRIB '15, p. 309-313.
- [12]. Biswajit Bera, Adhesive Wear Theory of Micromechanical Surface Contact, International Journal Of Computational Engineering Research (ijceronline.com) Vol. 3 Issue. 3. 2013.
- [13]. M. Jianga, B. Devincre, G. Monnet, Effects of the grain size and shape on the flow stress: a dislocation dynamics study, International Journal of Plasticity, Elsevier, 2018.