

Effect of the Manufacturing Parameters on Tribological Properties of Compacted Copper and Bronze Powders

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ABSTRACT:In this study, compacted copper and bronze powders were used for tribological investigation. Two different sintering time (1 and 3 hours) was selected for copper samples under 735 ± 1 MPa molding pressure. And two different sintering time (1 and 3 hours) with two different molding pressure (320 ± 1 MPa and 735 ± 1 MPa) were used to manufacturing the bronze samples. In addition, a casted bronze sample was performed for tribological investigation, too. Tribological behaviors and porosity properties of the manufactured samples was investigated. The porosity of the samples was decreased with increasing sintering time. Nevertheless, wear resistivity increased with decreasing sintering time and increasing molding pressure. Tribological tests were performed with a computer aided pin-on-disc experimental setup under dry sliding conditions about 50 ± 5 N from 1 hour to 5 hours. And wearing surfaces were investigated with Scanning Electron Microscope (SEM) and mechanisms of the wear was detected.

KEYWORDS:Copper, Bronze, Sintering, Wear, Friction, Pin-on-disc

I. INTRODUCTION

An important group of components for units consist of friction (Kostornov and Fushchich 2005). Tribological systems depends on the required certain value and stability of friction coefficient and high resistance to frictional wear (Juszczak, Kulasa et al. 2014). It is possible to reduce the friction with two way. First one was the use lubricant from outside as oil, second one was the use of self-lubricating materials as bronze (CuSn10). Because most of the studies in industrial components should have good mechanical properties with better tribological properties (A. Baradeswaran 2014). The need for a recent wear resistant material for high performance tribological applications has been one of the major propellant power for the tribological development of ceramic particulate reinforced materials (M. Uthayakumara 2013). However, hard and non-deformable ceramic particles into matrix causes a loss in ductility and toughness (R. Sathiskumar 2014). Moreover, these particles could give some damages to the counter surface.

Copper-based materials are widely used in many industrial applications because of their good wear resistance and friction ductility, remarkable corrosion resistance, as well as self-lubrication properties, such as sliding bearings, sleeves, brushes and other components (Ghorbani, Mazaheri et al. 2005).

Wear and friction are the common problem in industry (Unal and Mimaroglu 2012, Canakci, Cuvalci et al. 2014). And wear shows itself in two different way, abrasive and adhesive. (Cuvalci and Bas 2004, Cuvalci and Celik 2011). Adhesive wear cause surface deformation with separation of the surface by layers but the abrasive wear cause separation of the particles from surface by scratching (Patnaik, Satapathy et al. 2009).

Main motivation and the novelty of this study was the manufacturing compacted copper and bronze powders with different manufacturing parameters and investigation of effects on the frictional systems. System was performed without lubricant addition with a pin-on-disc wearing test machine.

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II. MATERIALS AND METHODS

In this study, two different material groups were manufactured. First group was produced with copper powders. Second one was produced with 10% tin alloyed bronze (CuSn10) powders. In addition, a casted bronze was also performed as an observation group for bronze samples. 0.1 mg precisions balance was used for weighting operations. Manufacturing parameters and wearing parameter was given Table 1.

Table 1. Manufacturing and wearing parameters.

	Sintering Time (h)	Molding Pressure (MPa)	Sintering Temperature (°C)	Wearing Time (h)	Wearing Load (N)
Copper (pure)	1 3	735 735		-	-
Bronze (compacted powder)	1 3 3	735 735 320	900	1-5	50 ±5
Bronze (casted)	-	-	-		

Samples were sintered at 900 °C. Argon atmosphere were selected for preventing the dirtiness during sintering process. Different sintering time and molding pressure were applied. Hardness of the samples was measured by Brinell Hardness (HB) method. Samples experimental density was measured with Formula 1.1.

$$\rho = m/V \tag{1.1}$$

Where, ρ (g/cm^3) density, m (g) mass and V (cm^3) volume. Bronze and copper theoretical density was given in literature as $8.7 \text{ gr}/\text{cm}^3$, $8.96 \text{ gr}/\text{cm}^3$, respectively. Porosity of the samples was calculated with Formula 1.2.

$$\% \text{ porozite} = (\Delta\rho/\rho_0) \times 100 \tag{1.2}$$

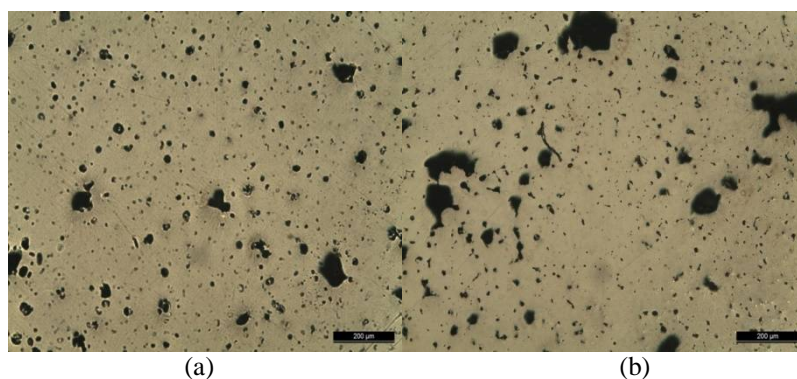
Where, $\Delta\rho$ difference between theoretical density and experimental density, ρ_0 theoretical density.

Pin-on-disc wear method was run for wearing process. Samples were cut suitable for sample (pin) holder about 10mm x 10mm x40mm. Pin track diameter was selected as 100 mm. with 100 rpm working speed. Cold work tool steel disc was used for wearing. Running in process was applied before wearing. Running in and experiments were carried out 50 ± 5 N load.

III. RESULT AND DISCUSSION

Optical Investigation

Optical investigation of the compacted bronze samples were given in Figure 1.



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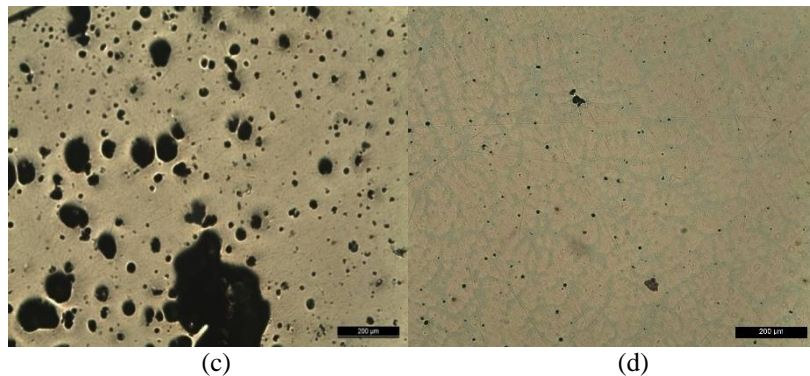


Fig. 1 Bronze powder Samples (a - 735 MPa molding pressured 1 hour sintering, b - 735 MPa molding pressured 3 hours sintering, c - 320 MPa molding pressured 3 hours sintering, d- Casted Bronz)(10x)

Investigated macrostructure images show that the effect of the molding pressure and sintering time. Samples porosity was decreased with increasing sintering time (fig.1 a and b). In addition, porosity was increased with decreasing molding pressure (fig. 1 b and c).

Hardness investigation

Brinell Hardness of the samples were given in Table 2. Hardness value was calculated in average min. 5 measurements. Bronze samples showed that the decreasing hardness value with increasing molding pressure and sintering time. Table 2 shows the average hardness value of the samples.

Table 2. Average Hardness value (BH)

Sample	1 h sintering	3 h sintering
Copper - pure (735 MPa molding pressure)	32	-
Bronze (735 MPa molding pressure)	48	37
Bronze (320 MPa molding pressure)	-	35

Density and Porosity Investigation

Investigation of the porosity was calculated for copper and bronze samples and the values of the porosity was given in Table 3.

Table 3. Bronze and coppers porosity ration

Sample	Molding Pressure (MPa)	Sintering time (h)	Porozite (%)
Copper	735	1	10.05
Bronze	735	1	18.21
	735	3	13.21
	320	3	27.83

The Wear Behaviors

Investigation of the wear behaviors were performed with a computer controlled pin-on-disc wear experimental setup. And the wear performances were investigated with dry sliding method in atmospheric conditions. Figure 2 shows that wear performance of the bronze and casted samples at different molding pressure and sintering time.

Samples wear loss were measured hour by hour and total wear loss were calculated. Wear loss were increasing with increasing wear time. And Figure 2 shows that manufacturing effects on wearing. 735 MPa molding pressure with 3 hours sintering time manufactured sample shows that almost same wear performance or wear resistivity with casted bronze sample. Manufactured 735 MPa molding pressure and 1 hour sintered sample wear performance was also showed good wear performance. But the last sample (320 MPa molding pressure with 3 hours sintering time) shows that the maximum wear about almost 0,5 mg.

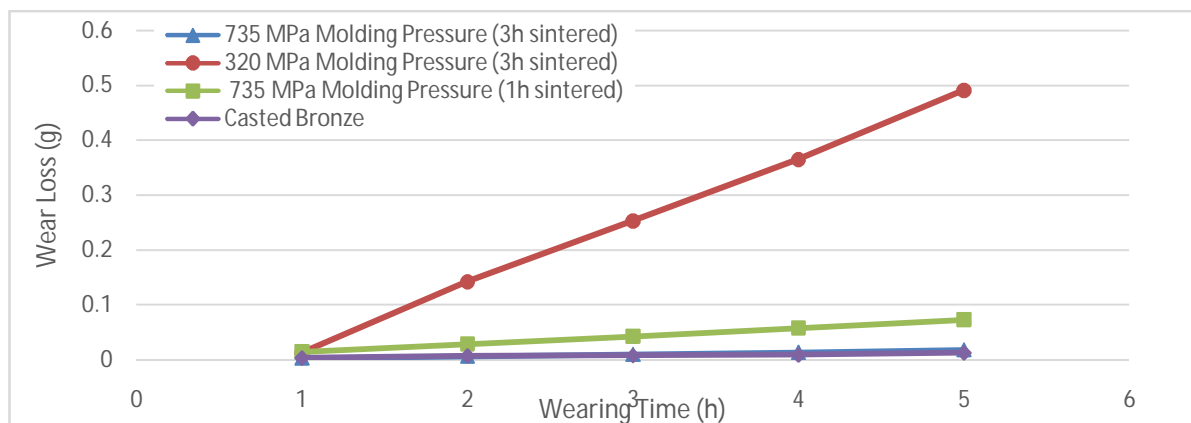


Fig. 2 Compacted powders of Bronze and casted Bronze samples wear behaviors

SEM Investigation

Samples worn surface were imaged with Scanning Electron Microscope (SEM) for detecting the wear mechanisms after all total wearing process (at the end of the 5 hours wearing). Figure 3 shows the imaging of the bronze worn surface which was molded 735 MPa and sintered 1 hour.

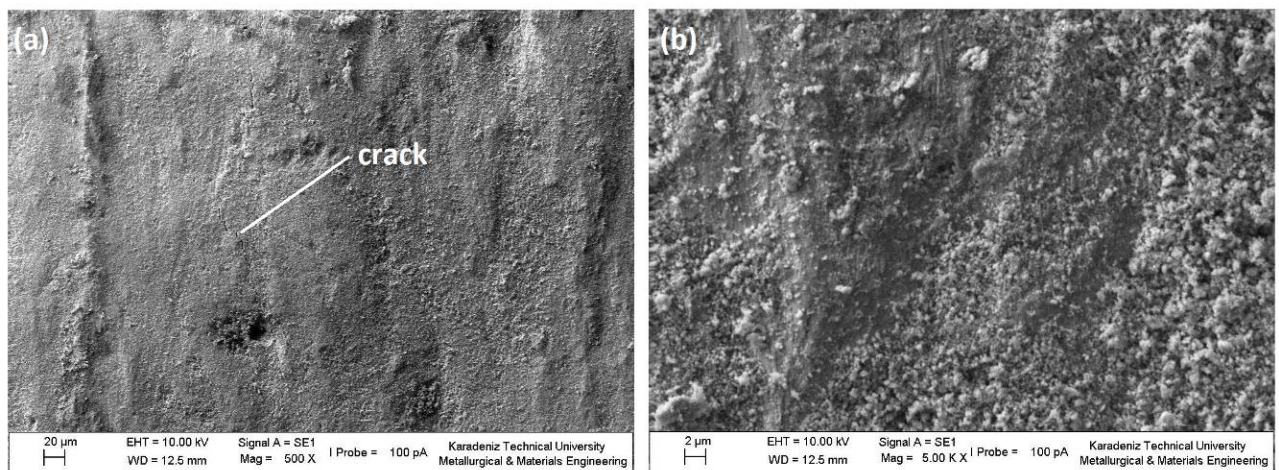


Fig. 3 735 MPa molding pressured with 1 hour sintered bronze sample (a-500x, b-5000x)

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Bronze sample of the 1 hour sintered after 735 MPa compacted was showed cracks and scratch (abrasive wear mark) above the worn surface (Fig. 3-a). Some particles were detected on the surface. These particles prevent the deep scratch but cannot totally prevent the abrasive wearing.

Figure 3-b shows the particles.735 MPa molding pressured and 3 hours sintered bronze sample's SEM images was given in Figure 4.

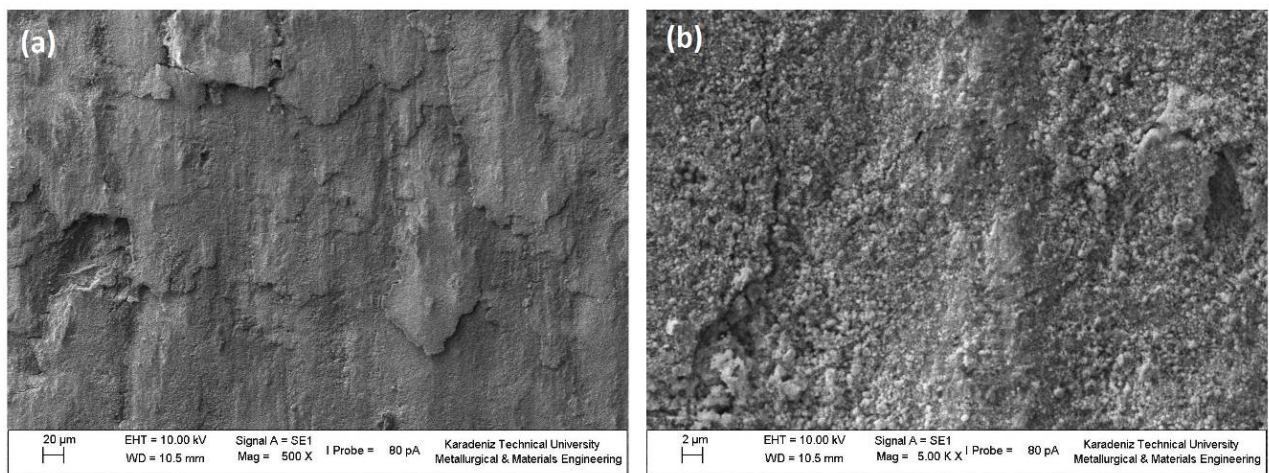


Fig. 4 735 MPa molding pressured with 3 hours sintered bronze sample (a-500x, b-5000x)

Figure 4-a shows the crust on the worn surface. Crust mean on the wearing surface is the typical mark of adhesive wear. Actually there are some abrasive wear marks on the surface like scratch but the main mechanism was the adhesive. Extended sintering time was turned into wearing mechanism from abrasive to adhesive.

Figure 4-b shows cracks and particles on the surface. But behavior of the particles showed that as a rolling element on the surface for this manufacturing conditions. So the wear loss was decreased with the changing mechanism of the wear. It can be also seen from wear loss graphic in Figure 2. Molding pressure effect can be seen in Figure 5.

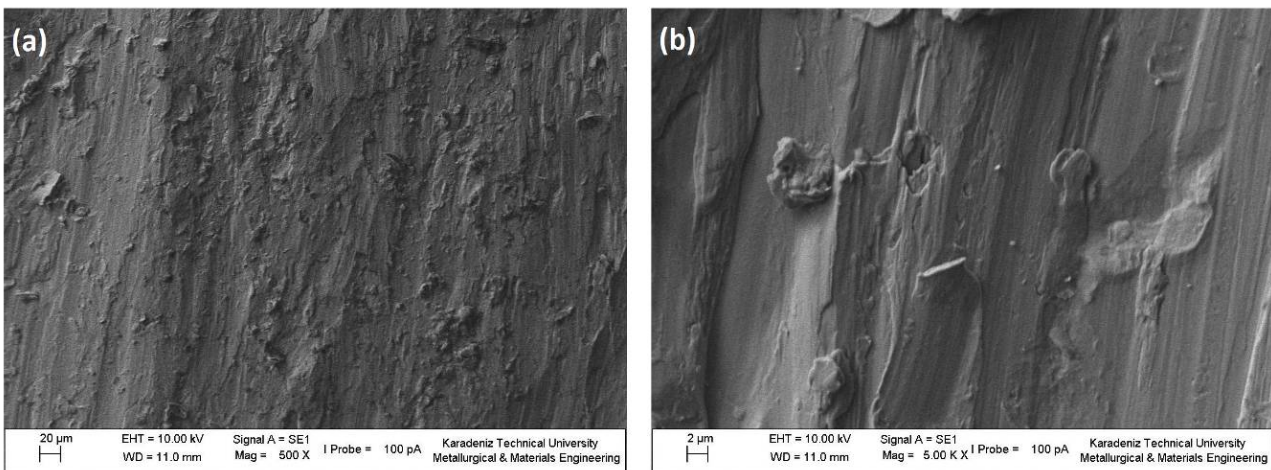


Fig. 5 320 MPa molding pressured with 3 hours sintered bronze sample (a-500x, b-5000x)

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Figure 5 shows that abrasive wear mechanisms totally. Bigger particles and deep scratches was observed on the surface. Decreasing molding pressure with a long sintering time caused a softer structure. And hardest counter surface eroded the samples surface abrasively easier than other compacted samples. Casted bronze sample SEM images was given in Figure 6.

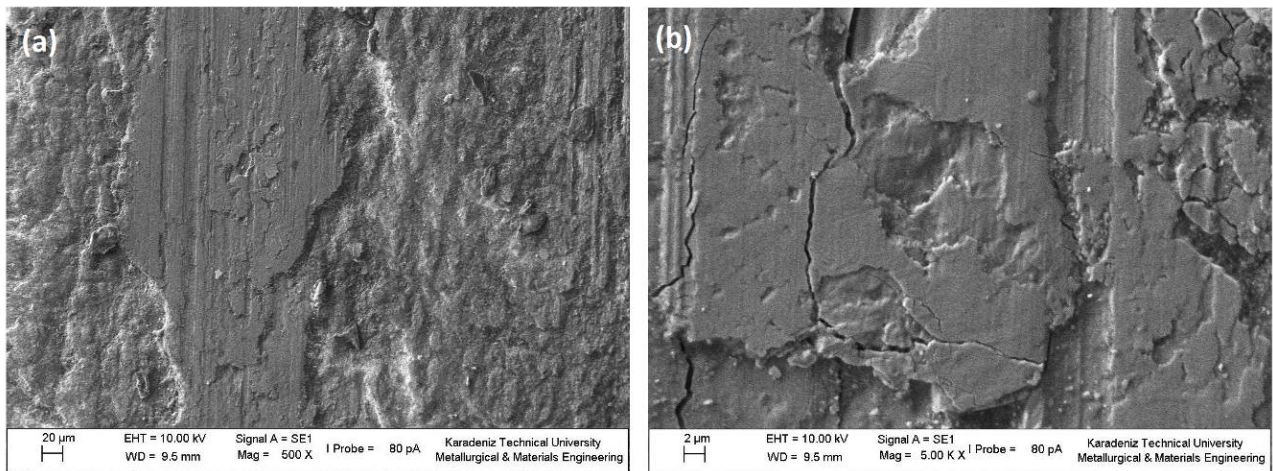


Fig. 6Casted bronze sample (a-500x, b-5000x)

Casted bronze sample was showed a mixed wearing mechanism. Particularly adhesive or abrasive wear marks was occurred. For example Figure 6-a shows adhesive wear marks as crust. But the Figure 6-b shows abrasive wear marks as deep scratch.

IV. CONCLUSION

In this study, casted bronze, compacted bronze and copper samples was investigated. All sample's porosity and hardness values were measured. Casted bronze and compacted bronze samples was also performed with a computer aided pin-on-disc wear experimental setup and the following conclusion were found.

- 1.) Bronze samples porosity was decreased with the increasing molding pressure.
- 2.) Hardness and porosity was decreased with increasing sintering time.
- 3.) Hardest structure were obtained with 735 MPa molding pressure.
- 4.) Wear loss was increased with decreasing molding pressure (parallel to the hardness).
- 5.) Biggest wear loss was obtained 320 MPa molding pressure with 3 hours sintering time.

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