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EFFECT OF LUBRICANT ON THE POROSITY OF BRONZE (CU-SN) BASED

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RINGKASAN: *Sifat keliangan merupakan ciri yang penting menentukan kebolehan sesuatu galas pelincir-diri. Di dalam kajian ini, kesan bahan pelincir terhadap sifat kelinciran galas pelincir-diri (Cu-Sn) akan diterokai. Zink stearate (ZnS) serta lithium stearate (LiS) telah digunakan sebagai bahan pelincir di dalam kajian ini. Keputusan menunjukkan bahawa peratusan keliangan, dimensi keliangan serta cantuman keliangan untuk Cu-Sn-LiS adalah agak lebih tinggi berbanding dengan Cu-Sn-ZnS. Cu-Sn-LiS berhasil membentuk keliangan bercabang dengan permukaan sempadan yang tidak rata, manakala Cu-Sn-ZnS berhasil membentuk keliangan yang agak kurang bercabang serta permukaan sempadan yang lebih sekata. Ini menunjukkan bahawa sifat keliangan sistem Cu-Sn banyak dipengaruhi oleh bahan pelincir yang digunakan.*

ABSTRACT: Porosity is one of the most important parameters influencing the performance of self-lubricating bearing. The effect of lubricant on the porosity of Cu-Sn based self-lubricating bearing was investigated. Zinc stearate (ZnS) and lithium stearate (LiS) were used as lubricants. Results indicated that dimension of pores on Cu-Sn-LiS were slightly bigger while interconnected porosity and percentage of pores were slightly higher than of Cu-Sn-ZnS. Cu-Sn-LiS formed branching pores with irregular boundaries. Consequently, Cu-Sn-ZnS formed less branching pores with rounded boundaries. Hence, lubricant does effect the porosity of Cu-Sn system.

KEYWORDS: Copper, tin, zinc stearate, lithium stearate, self-lubricating bearing, interconnected porosity, pores dimension, pores shape, pores distribution, lubricant.

INTRODUCTION

Copper-tin (Cu-Sn) based self-lubricating bearing has been manufactured by Powder Metallurgy (PM) technique, since the early nineteen hundreds. In PM technology, a lubricant is used to decrease a friction force, which occurs between the powders and also between the die wall and the powders (Murakoshi *et al.,* 1997). The lubricant is premixed directly with the metal powder. Stearic acid, zinc stearate, lithium stearate and synthetic waxes such as Acrawax are the most popular lubricants. The amount used varies from 0.5 to 1.5 wt%. An addition of lubricant influences the physical and mechanical properties of the material. This is due to the dispersion of the powders by the lubricant.

For self-lubricating bearing, porosity is one of the most important parameter influencing the performance. Porosity in bearing is present as a network of interconnected pores that extend to the surface, like sponge. Distributions of pore dimension on the surface of bearing have significant influence on the interconnected porosity. The distribution of pore dimension on the surface of the bearing can be obtained by means of scanning electron microscopy.

Interconnected pore structure in bearing permits their impregnation with lubricating oil and this provides self-lubricating properties. When friction heat the bearing, the oil expands and flow to the bearing surface. In operation, the oil is 'pumped' from the bearing as the shaft rotates. On cooling, the oil returns into the metal's pores by capillary action. Impregnation or liquid infiltration is achieved by vacuum techniques or by soaking the parts in heated oil. For conventional PM bearing, 10 to 30% by volume of oil can be adsorbed (MPIF Standard 35, 1998).

The primary purpose of this paper is to discuss the effect of lubricant on the porosity of Cu-Sn system. Using ZnS and LiS as lubricants, the percentage and dimension of pores as well as the interconnected porosity and shape of pores were evaluated.

MATERIALS

The formulation used for this research was 90 wt% Cu and 10 wt% Sn. The particle size of Cu powder was in the range of 32 - 53 μm while Sn powder was less than 38 μm. The percentage of ZnS and LiS lubricants used was 1 wt%. The burn-off temperature of ZnS and LiS was 425 and 370°C respectively.

PROCESSING

Figure 1 illustrates a production process of the Cu-Sn system. The Cu and Sn were mixed with the lubricant by double cone mixer at the rate of 50 rpm for 1 hour. The mixed powders were then compacted to a standard rectangular bar with surface dimension of 1.275cm width x 3.184cm length using Universal Testing Machine (UTM) at a pressing force of 70 kN. The green samples were delubricated at 415°C for 90 minutes and sintered at 830°C for 60 minutes under 2% H_2 + 98% N_2 gas atmosphere.

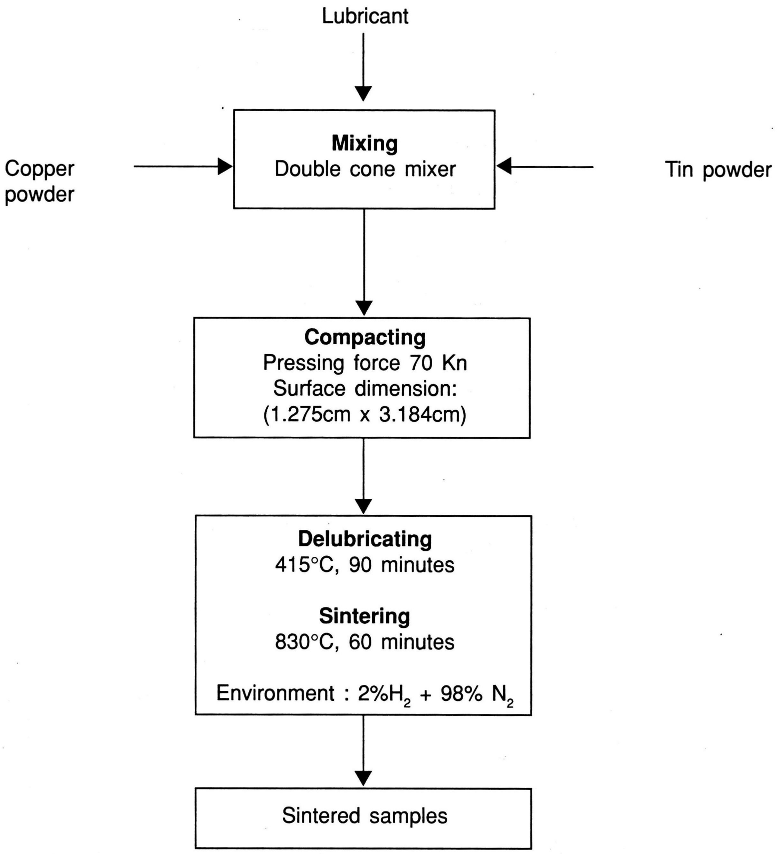
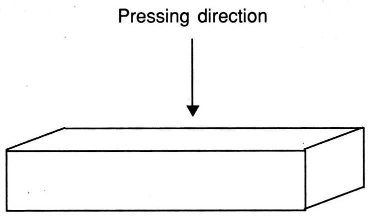


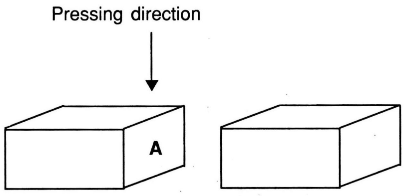
Figure 1. *Production process of Cu-Sn based self-lubricating bearing*

EVALUATION

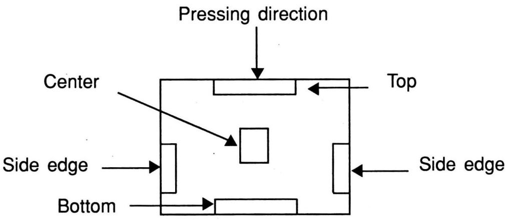
The sintered samples were measured on their bulk density, percentage of pores, pores dimension, interconnected porosity and pores shape. The bulk density was measured by volume and weight of the samples. Percentage of pores was performed using Quantimet 570 image analyser. Scanning Electron Microscopy (SEM) and optical microscopy were used for pores dimension and pore shape determination. Figure 2 illustrates the location where the analyses were determined. Interconnected porosity was evaluated by oil impregnated method according to MPIF Standard 35 (1998).



(a) Analysis location on the surface of the sintered sample.



(b) Sintered sample cross-sectioned at the center.



(c) Location where analysis were performed on area **A**.

Figure 2. *Sintered sample sectioned for porosity analysis*

RESULTS AND DISCUSSION

DENSITY

Table 1 reveals the bulk density of sintered Cu-Sn-ZnS and Cu-Sn-LiS which was 6.89 and 7.15 gm/cm^3 respectively. It was observed that the density for sintered Cu-Sn-LiS and Cu-Sn-ZnS was almost similar. Sweet et al. (1991) stated that, during compaction, lubricant remains between particles and this reduces interparticle contact. Interparticle contact is important to bond the particles into dense material, hence, the ability of lubricant to burn-off and escape during sintering is important.

Table 1. Properties of sintered Cu-Sn-ZnS and Cu-Sn-LiS based self-lubricating bearing

Sample Label	Bulk Density (gm/cm^3)	Average Percentage of Pores %					Interconnected Porosity %
		Surface	Cross Section				
			Side Edge	Center	Toy/ Bottom	Average	
Cu-Sn-ZnS	6.89	72.66	12.27	8.96	11.96	11.06	3.38
Cu-Sn-LiS	7.15	73.71	12.16	10.88	14.60	12.55	5.48

PERCENTAGE OF PORES

Randomly, 5 spots were analysed on the surface of the sintered samples as shown in Figure 2(a). As Table 1 illustrates, the average percentage of pores on the surface of Cu-Sn-LiS and Cu-Sn-ZnS was almost similar, which was 73.71 and 72.66% respectively.

The sintered samples were then cut into two (Figure 2(b)) and 5 locations were analysed on the cross section area as shown in Figure 2(c). The cross section surface was ground and polished before being observed under the image analyser. For samples made of Cu-Sn-ZnS, the percentage of pores on the side edge, centre and top/bottom were 12.27, 8.96 and 11.96% respectively, while for samples made of Cu-Sn LiS, the percentage of pores on the side edge, centre and top/bottom were 12.16, 10.88 and 14.60% respectively. The results are shown in Table 1.

The results indicate that the overall percentage of pores on the cross section surface of Cu-Sn-LiS and Cu-Sn-ZnS was almost similar. However, it was observed that the average percentage of pores for Cu-Sn-LiS was slightly higher than that of Cu-Sn-ZnS. This is due to the different in burn-off temperatures of the lubricants. At a temperature of about 350°C, the amount of ZnS burned off was larger then LiS. Sweet *et al.* (1991), revealed that at 350°C, 86% of ZnS is burned off, but only 75% of LiS is burned off. Therefore, the unburned LiS in the pores retard surface diffusion between powder particles and hence, more pores were observed in Cu-Sn-LiS than in Cu-Sn-ZnS.

For both Cu-Sn-LiS and Cu-Sn-ZnS, it was observed that the percentage of pores at the centre was lower than that at the top/bottom or side edge zone. This phenomenon leads to the existence of density gradient between the centre and the side edge or top/bottom zone of the sample.

PORE DIMENSION AND SHAPE

Figures 3(a), 3(b), 3(c), 3(d), 4(a), 4(b), 4(c) and 4(d) show the micrographs of pores shape present at the cross section surface and the outer side edge surface of Cu-Sn-LiS and Cu-Sn-ZnS respectively.

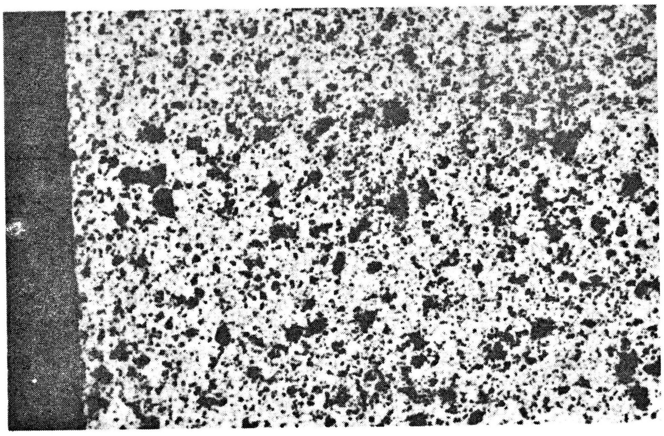


Figure 3(a). *Micrograph at the side edge of the cross section area of sintered Cu-Sn-LiS. (Magnification 50x)*

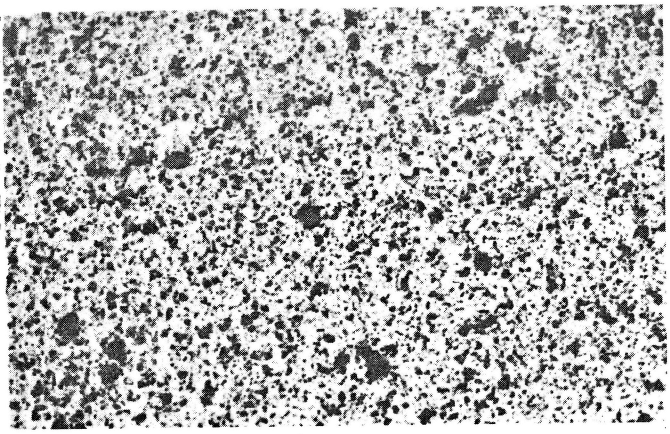


Figure 3(b). *Micrograph at the centre of the cross section area of sintered Cu-Sn-LiS. (Magnification 50x)*

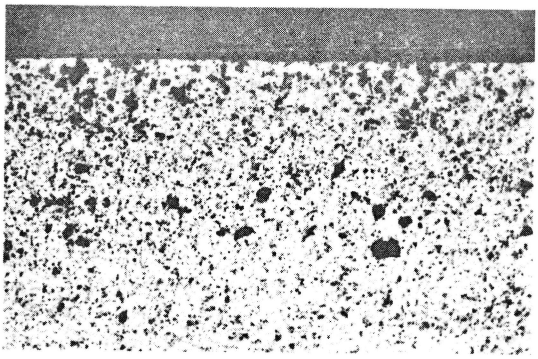


Figure 3(c). *Micrograph at the top/bottom of the cross section area of sintered Cu-Sn-LiS. (Magnification 50x)*

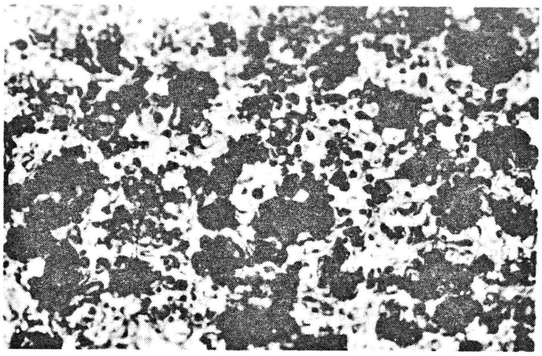


Figure 3(d). *Micrograph at the surface of sintered Cu-Sn-LiS. (Magnification 200x)*

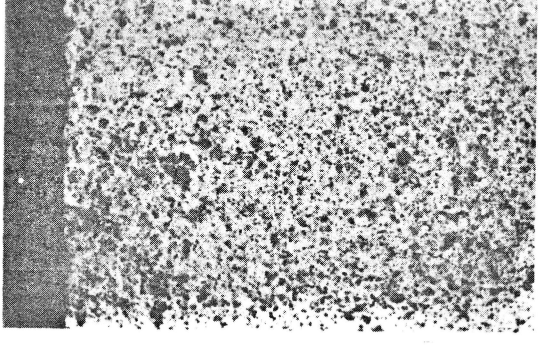


Figure 4(a). *Micrograph at the side edge of the cross section area of sintered Cu-Sn-ZnS. (Magnification 50x)*

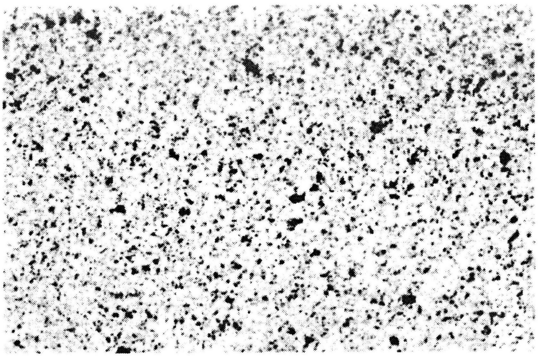


Figure 4(b). *Micrograph at the centre of the cross section area of sintered Cu-Sn-ZnS. (Magnification 50x)*

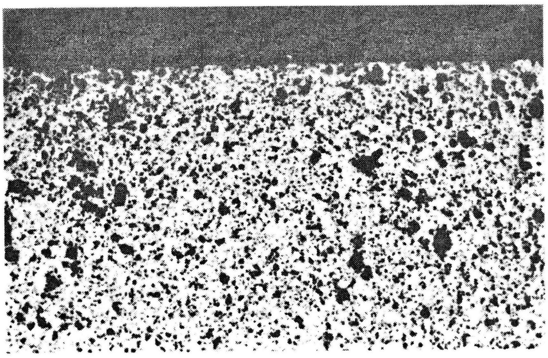


Figure 4(c). *Micrograph at the top/bottom of the cross section area of sintered Cu-Sn-ZnS. (Magnification 50x)*

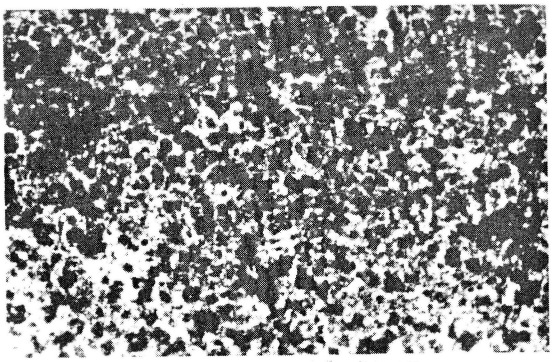


Figure 4(d). *Micrograph at the surface of sintered Cu-Sn-ZnS. (Magnification 200x)*

Three types of pores were observed in the sintered sample containing LiS and are described as follows:

1) Small rounded pores with an average diameter of 4.65 μm.
2) Small elliptical pores with an average aspect ratio of 1.74:1.
3) Big pores.

Sample containing ZnS also exhibited combination of three types of pores and are described as follows:

1) Small rounded pores with an average diameter of 3.51 μm.
2) Small elliptical pores with an average aspect ratio of 1.51:1.
3) Big pores.

Comparing the effect of LiS and ZnS lubricant on the pores shape and dimension, it was found that the size of small rounded and elliptical pores in Cu-Sn-LiS was slightly bigger than in Cu-Sn-ZnS. Both samples exhibited big pores; however, the shape was also different. For Cu-Sn-LiS samples, the big pores formed branching structure with irregular boundaries, as shown in Figure 3(d). Consequently, for Cu-Sn-ZnS samples, the big pores formed less branching structure and the pore boundaries were more rounded as shown in Figure 4(d). The primary mechanism in the formation of pores rounds boundary is dependent on the ability of lubricant to burn off during heating. In this case, since LiS had less ability to burn-off, the remaining LiS in the pores retarded the surface diffusion. Therefore, the pores are still irregular in shapes even after the long duration of sintering.

Distribution of pores shape in both Cu-Sn-LiS and Cu-Sn-ZnS show that at the centre of the samples, more small rounded and elliptical pores were observed, while bigger pores were observed at the side edge and top/bottom zone of the sample. As explained previously, this is also due to the effect of compaction force and lubricant. During the delubricating process, the lubricant is able to burn and pass through the interstitial gap between the particles from the centre to the side edge and top/bottom surface of the sample. Hence, compaction force and lubricant led to the formation of small rounded and elliptical pores.

Pores shape was very important since it had great effect on the filling and emptying of oil from oilless bush. Pores with irregular boundaries had higher capillary force than pores with smooth and rounded boundaries (German, 1989). Hence, the oil wettability of irregular pores was higher than that of smooth and rounded pores. As a result, LiS gave better pores shape, which is suitable for oilless bush.

INTERCONNECTED POROSITY

The interconnected porosity for Cu-Sn-LiS was found to be 5.48% while Cu-Sn-ZnS was found to be 3.38% as shown in Table 1. It was observed that the interconnected porosity for Cu-Sn-LiS was higher than in Cu-Sn-ZnS.

CONCLUSION

The processing of Cu-Sn based self-lubricating bearing by PM technique with LiS as a lubricant exhibits higher percentage of pores, higher interconnected porosity and bigger pores compared to that with ZnS. The burn-off behaviour of the lubricants left Cu-Sn-LiS with irregular pore boundaries while Cu-Sn-ZnS with rounded pore boundaries. Therefore, Cu-Sn-LiS is suitable for self-lubricating bearing due to its interconnected porosity and irregular pore boundaries.

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