Wear and Friction Analysis of Sintered Metal Powder Self Lubricating Bush Bearing

J. K. Khare, Abhay Kumar Sharma, Ajay Tiwari, Amol A. Talankar

Abstract**—**Powder metallurgy (P/M) is the only economic way to produce porous parts/products. P/M can produce near net shape parts hence reduces wastage of raw material and energy, avoids various machining operations. The most vital use of P/M is in production of metallic filters and self lubricating bush bearings and siding surfaces. The porosity of the part can be controlled by varying compaction pressure, sintering temperature and composition of metal powder mix. The present work is aimed for experimental analysis of friction and wear properties of self lubricating copper and tin bush bearing.

Experimental results confirm that wear rate of sintered component is lesser for components having 10% tin by weight percentage. Wear rate increases for high tin percentage (experimented for 20% tin and 30% tin) at same sintering temperature. Experimental results also confirms that wear rate of sintered component is also dependent on sintering temperature, soaking period, composition of the preform, compacting pressure, powder particle shape and size.

Interfacial friction between die and punch, between inter powder particles, between die face and powder particle depends on compaction pressure, powder particle size and shape, size and shape of component which decides size & shape of die & punch, material of die & punch and material of powder particles.

Keywords**—**Interfacial friction, porous bronze bearing, sintering temperature, wear rate.

I. Introduction

THE self lubricating oil impregnated bush bearings were first invented by Walter Chrysler in 1930. The invention was made to overcome the problem of providing continuous lubrication to solid bushes used in machines which were having very short life due to fast wearing out in absence of continuous lubrication. To solve the problem, Chrysler used sintered metal powder bush with 19% porosity and impregnated these bushes with oil. The results were astonishing as the product proved to possess low friction and wear resistant properties. The bush, when heated due to friction against moving shaft, released small quantity of oil from pores, which formed hydrodynamic layer due to wedging action and restricted friction between bush and shaft surfaces. The oil is again absorbed by the bush in the pores, on cooling.

The experiment became very successful and Chrysler formed a separate division named Chrysler Amplex for manufacturing of Self lubricating bush bearings. There was heavy requirement of these bushes all over the world and the self lubricating bush manufacturing was a great success of that era.

They supplied these self lubricating bush bearings to GE, Pneumatic Scales, Smith and Wesson, Sikorsky Aircraft and for use in Indian motor cycles. They are currently in operation under the name of LM-TARBEL, after merger with other companies in North America.

II. Design/Methodology

Under the present experiment, bushes and pins have been made of different composition of copper and tin powders and have been compacted under moderate pressure to impart enough porosity [9]. These green compacts have been sintered at different temperatures with different holding time. These sintered parts have been impregnated with lubricating oil in a hot bath. Test for wear and friction properties of these sintered an oil impregnated pins have been carried out on a pin and disc friction and wear testing machine. P/M can produce near net shape parts hence reduces wastage of raw material and energy, avoids various machining operations [6].

High purity metal powders (Cu-99% pure and Sn 99% pure) were purchased from market. The powders were blended and mixed in different weight percentages. Proper homogeneous mixtures were prepared by mixing in a mechanical mixer. Green powder performs were made by compacting the powder mix in a specially designed die and punch at a pressure of 210 MPa [7], [8]. The reason of selecting this pressure was to ensure high porosity and survivability [3] during ejection of green compacts.

Fig. 1 Die and Punch Set

A. Sintering

The green compacts (Bushes and Pins) of different weight percentages were sintered in a Muffle furnace at different sintering temperatures and different holding time. Following

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weight percentages, sintering temperature and holding time were taken.

TABLE I
SINTERING TIME AND HOLDING TIME FOR DIFFERENT SAMPLES

Sl.No.	Weight %	Sintering temp. (°C)	Holding time (min)
1	Cu-10Sn	400	120
2	Cu-10Sn	500	60
3	Cu-10Sn	600	45
4	Cu-20Sn	400	120
5	Cu-20Sn	500	60
6	Cu-20Sn	600	45
7	Cu-30Sn	400	120
8	Cu-30Sn	500	60
9	Cu-30Sn	600	45

The sintered components were allowed to cool in the muffle furnace itself until the normal atmospheric temperature was achieved. The pins and bushes were cleaned with cloth and fine emery paper to expose the metallic surface.

Fig. 2 Sintered Bushes

B. Oil Impregnation

Cleaned sintered bushes and pins were immersed in SAE 30 lubricating oil kept at 80°C for two hours, under vacuum. After oil impregnation these bushes and pins were wrapped in butter paper to preserve the impregnated oil [2].

III. TESTING OF WEAR AND FRICTION

Fig. 3 Wear and Friction Tester

Test for wear and friction was conducted on pin on –disc wear and friction testing machine [4]. The machine consists of a hard steel disc which could be rotated at desired speed. Pin is clamped tightly on the one end of adjustable lever. Track radius of rotation of pin on disc can be adjusted so that desired sliding speed can be achieved by adjusting track radius and disc rpm. Load can be applied on the pin by attaching load on free end of the lever through a pulley so the pin is pressed against the disc with the force exerted by the weight. The lever is kept horizontal and reading in the controller is adjusted to zero by control knob. The wear and friction tester is interfaced with a dedicated computer which takes the readings in microns for any reduction in length of the pin due to abrasion [2]. The software can plot the graph of wear and friction.

The load of 20 N was applied and rotating speed of disc was adjusted to 1000 rpm. Test time was selected as 25 minutes for each specimen the result of wear and friction were recorded in the computer and graphs were plotted.

IV. RESULT AND DISCUSSION

Fig. 4 shows the trend of wear for specimens containing different weight percentages of tin [10] each sintered for 120 minutes at 400°C. First specimen containing 10% tin and balance 90% copper when tested on wear and friction tester shows very less wear (less than 5 microns in 25 minutes). Second specimen containing 20% tin showed more wear (about 20 microns in 25 minutes). The third specimen containing 30% tin showed even more wear (100 microns in 25 minutes).

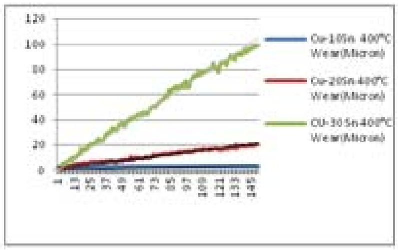

Fig. 4 Wear results of sample sintered at 400ºC

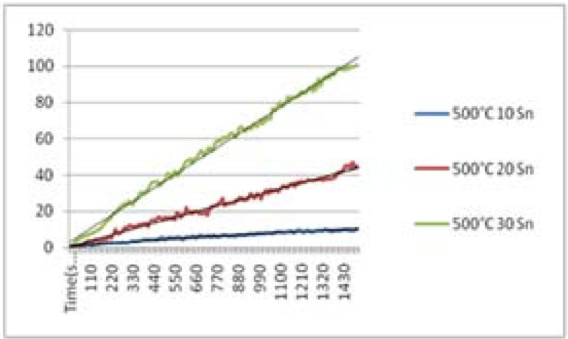

Fig. 5 Wear results of sample sintered at 500ºC

Fig. 5 shows the trend of wear for specimens containing different weight percentages of tin each sintered for 60 minutes at 500°C. First specimen containing 10% tin and balance 90% copper when tested on wear and friction tester shows very less wear (less than 9 microns in 25 minutes). Second specimen containing 20% tin showed more wear (about 42 microns in 25 minutes). The third specimen containing 30% tin showed even more wear (100 microns in 25 minutes).

Fig. 6 shows the trend of wear for specimens containing different weight percentages of tin each sintered for 45 minutes at 600°C. First specimen containing 10% tin and 90% copper when tested on wear and friction tester shows very less wear (less than 5 microns in 25 minutes). Second specimen containing 20% tin and 80% copper exhibited more wear (about 40microns in 25 minutes). The third specimen containing 30% tin and 70% copper showed even more wear (72 microns in 25 minutes).

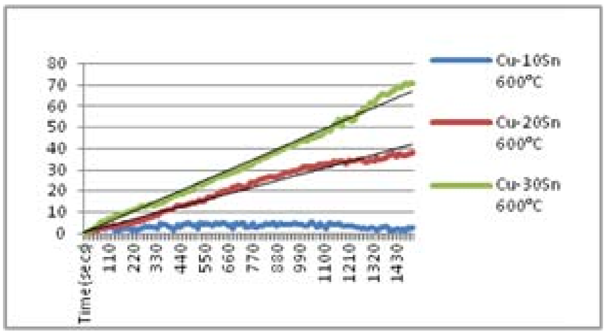

Fig. 6 Wear results of sample sintered at 600ºC

TABLE II
WEAR OF VARIOUS SAMPLES AT DIFFERENT SINTERING TEMPERATURES AND HOLDING TIME

Effect of tin % on wear									
	Temperature 400°C 120 minutes			Temperature 500°C 60 minutes			Temperature 600°C 45 minutes		
	Cu-10Sn	Cu-20Sn	Cu-30Sn	Cu-10Sn	Cu-20Sn	Cu-30Sn	Cu-10Sn	Cu-20Sn	Cu-30Sn
Max. Wear (μ)	5	60	100	9	48	100	5	40	78

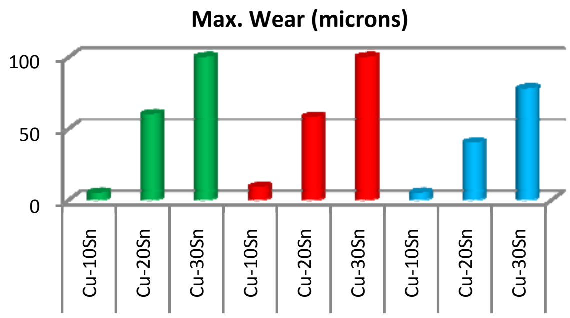

Fig. 7 Wear of various samples at different sintering temperatures and holding time

A. Porosity

The porosity of the sintered product plays an important role in providing self lubricating property as more porous the product more oil it will absorb. The porosity is defined by [5],

$$\text{Porosity} = \frac{\text{density of wrought alloy} - \text{density of sintered product}}{\text{density of wrought alloy}} * 100$$
$$= \frac{(\rho A - \rho c)}{\rho A} * 100$$
$$= [1 - \frac{\rho c}{\rho A}] * 100$$

where ρ_A= density of wrought alloy and ρ_C = density of sintered component

Also density of wrought alloy can be calculated by:

$$\rho_A = \Sigma\, \rho_{i.}\, x_i$$

where ρ_i= density of individual constituting metal and xi = mass fraction of that individual metal in the alloy

The porosity of sintered components sintered at varying temperatures is tabulated below and also plotted in the bar chart. It is seen that for each composition the porosity of the sintered component decreases with increase in sintering temperature. The reason of decrease in porosity with increase in sintering temperature is increase in molecular energy at higher temperature which allows the molecules to vibrate and densifies the molecules in the component, thus decreasing porosity.

TABLE III
POROSITY OF VARIOUS SAMPLES AT DIFFERENT SINTERING TEMPERATURES AND TIME

Effect of Sintering temperature on porosity									
Temp °C	400	500	600	400	500	600	400	500	600
Porosity%	38.06	37.66	37.41	37.91	37.49	37.31	37.65	37.37	37.17

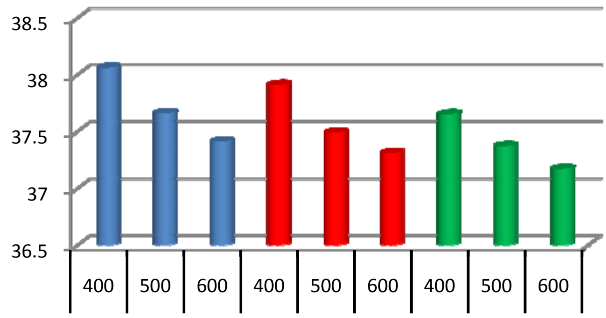

Fig. 8 Porosity of various samples at different sintering temperatures and time

Porosity of sintered component is also tabulated at varying tin percentage at same sintering temperature. It is noted that for each sintering temperature the porosity of the component decreases with increase in tin percentage in the component. The reason for decrease in porosity with increase in tin percentage is hidden in principle of liquid phase sintering. Where a particle of one metal with low melting point melts and wets the particles of metal with higher melting point. And on cooling it forms stronger bond [1]. If the percentage of tin in copper is increased the pores are filled by the molten tin particle and porosity is reduced.

TABLE IV
POROSITY OF VARIOUS SAMPLES AT DIFFERENT SINTERING TEMPERATURES AND TIME

Effect of tin % on porosity									
	Temp. 400^{O}C 120 Mnts			Temp. 500^{O} C 60Mnts			Temp. 600^{O} C 45 Mnts		
Tin %	Cu-10Sn	Cu-20Sn	Cu-30Sn	Cu-10Sn	Cu-20Sn	Cu-30Sn	Cu-10Sn	Cu-20Sn	Cu-30Sn
Porosity %	38.06	37.91	37.65	37.66	37.49	37.37	37.41	37.31	37.17

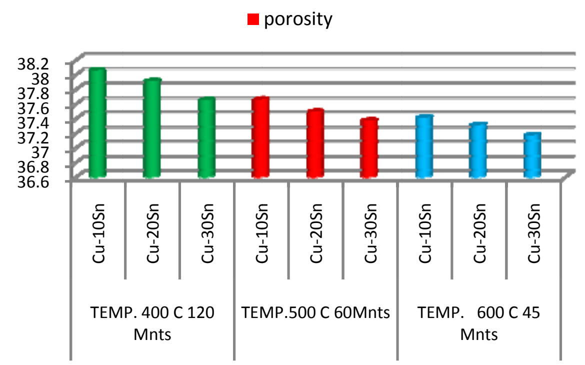

Fig. 9 Porosity of various samples at different tin percentages

V. CONCLUSIONS

From the above following inference is drawn;

(i) Wear rate of sintered component increases if tin percentage is increased more than 10% at same sintering temperature.

(ii) Wear rate of sintered component decreases with increase in sintering temperature for same composition of tin and copper.

(iii) Porosity of sintered component decreases with increase in sintering temperature.

(iv) Porosity of sintered component decreases with increase in tin percentage for same sintering temperature and compaction pressure.

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