# The Influence of Deformation Heat Treatment on the Structure and Wear Resistance of CuZnPb Brass

*F.A. Sadykov, V.A. Valitov, and N.P. Barykin*

**The influence of different deformation heat treatments on structure and wear resistance under dry sliding was studied under sliding velocity of 0.79 m/c, pressure of 0.2 to 1.0 N/mm$^2$, and sliding distance of 1500 m. It was established that the deformation heat treatment led to the creation of a microcrystalline structure (2 to 3 μm) by recrystallization in the alloy. The wear rate of the alloy with the microcrystalline structure was 1.5 to 2.0 times less and 25 to 30% less than in the β-phase state and the initial state, respectively.**

Keywords
brass, deformation, dry sliding, heat, microhardness, structure, wear intensity

## 1. Introduction

AT PRESENT the problem of obtaining a necessary structure to regulate physical, mechanical, and other properties is an important one. It is known that a fine-grained structure increases such properties as strength, hardness, and fracture toughness (Ref 1,2). More recently there appeared data on the positive effect of the fine-grained structure on the increase of wear resistance of materials (Ref 3,4).

One of the ways for obtaining a fine-grained structure is deformation heat treatment, based on a severe plastic deformation and subsequent annealing. In this connection, we studied the influence of deformation heat treatment on the forming of a microcrystalline structure, hardness, and wear resistance of CuZnPb brass.

## 2. Experimental Details

Hot-rolled brass (Cu-39.4wt%-Zn-0.89wt% Pb) was used for the investigation. The deformation treatment was performed by one of following methods: compression, rolling, or forging. The compression of the specimens was carried out by "Shenck" dynamometer under the following conditions: $T$ = 100 to 600 °C, $\varepsilon = 10^{-3}$ to $10^{-4} c^{-1}, \varepsilon = 75\%$. The rolling of the specimens was performed under the following conditions: $T$ = 250 °C, $\varepsilon = 75\%$. The forging ($\varepsilon$ = 75 to 80%) of the specimens was carried out by using a press at 250 °C. After the above-mentioned treatments some of the specimens were annealed at 250 to 300 °C for 2 h.

The specimens were tested for wear with dry friction using a disk-on-shoe test machine at room temperature (20 to 24 °C) in air accordingly to the method used in previous work (Ref 4) under the following conditions: sliding velocity, 0.79 m/c; pressure, 0.2 to 1.0 N/mm$^2$; and sliding distance, 1500 m. The shoes were made of brass and were rough specimens. Optical and scanning electron microscopies were used to study the structure and worn surfaces.

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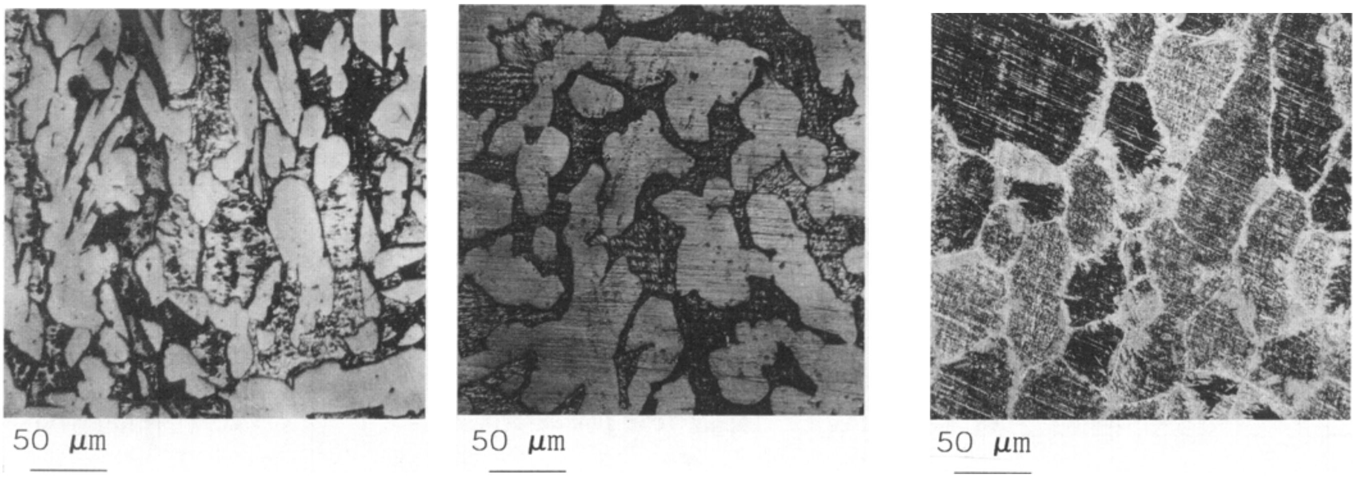
## 3. Results and Discussion

In the initial state, brass consists of large α- and β-phase grains (25 to 40 μm) with lead precipitates in the grain bodies (Fig. 1a). A dendrite structure can be seen, confirming that a bainite transformation occurred. The microhardness is 1.6 kN/mm$^2$. The annealing at 600 °C for 2 h leads to the disappearance of the dendrite structure and the coagulation of α- and β-phases (Fig. 1b). After that the microhardness decreases to 1.2 kN/mm$^2$. The water cooling from 840 °C leads to the formation of a large-grained β- phase structure (Fig. 1c.). The microhardness is 1.0 kN/mm$^2$.

The compression of the specimens at various temperatures was performed for the determination of the necessary temperature conditions for deformation heat treatment. The curves of "true stress/true strain" that were thus obtained are plotted in Fig. 2. Analysis of the curves shows that there is hardening and softening at temperatures less and more than 300 °C, respectively. The softening of the structure indicates the recovery and recrystallization in brass at such temperatures.

The microstructure of the specimens after compression is depicted in Fig. 3. As one can see, there is a considerable stretching at temperatures below 300 °C (Fig. 3a). At temperatures above 300 °C the stretching of the grains is smaller (Fig. 3b). The recrystallization with the formation of the microcrystalline grains (3 to 4 μm) takes place at temperatures above 300 °C. However, recrystallization occurs in the regions near grain boundaries in most cases, which perhaps is caused by the difficulty of diffusion in α- and β-phases (Ref 5). Recrystallization by annealing at 300 °C creates microcrystalline grains (2 to 3 μm) in the whole volume of the alloy (Fig. 3c). The growth of the recrystallized grains of both phases occurs after the annealing at 600 °C (Fig. 3d). Analogous behavior is observed after rolling as well as after forging.

The microhardness data confirm recovery and recrystallization in the alloy (Fig. 4). The increase of the annealing temperature of the rolled specimens (curve 1) and the increase of the compression temperature (curve 2) decrease the level of microhardness from 2.0 to 0.8 kN/mm$^2$. These decreases in the microhardness of the specimens after rolling and compression at




(a) (b) (c)

**Fig. 1** Microstructure of brass after treatment. (a) As-initial state. (b) After annealing at 600 °C. (c) After tempering at 840 °C

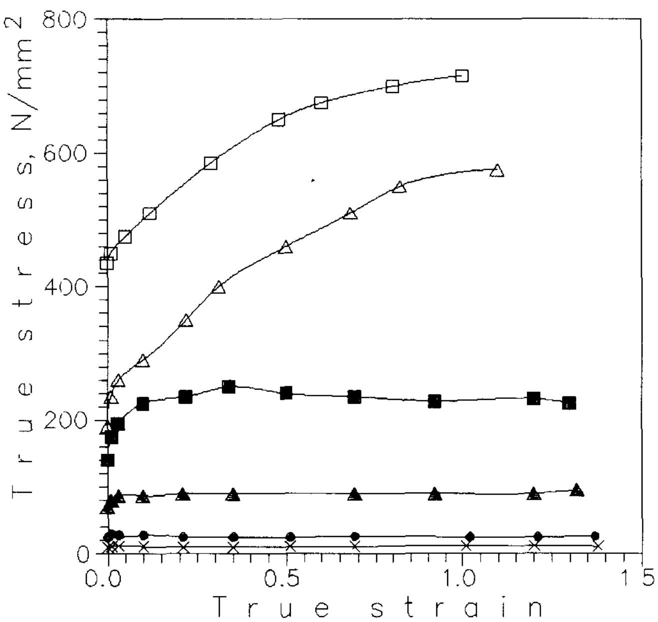



**Fig. 2** Curves of "true stress/true strain" at: (open square) 100 °C; (open triangle) 200 °C; (solid square) 300 °C; (solid triangle) 400 °C; (solid circle) 500°C; and (×) 600 °C.

200 to 400 °C result from not only the different velocity and methodology of the deformation but also, perhaps, the different contributions of dynamic and static recrystallizations.

Investigation of the influence of deformation heat treatment on wear resistance of the alloy is very important. The dependence of wear intensity on pressure and kind of treatment is depicted in Fig. 5. As shown, increase of pressure leads to increase of wear intensity proportionally at a pressure less than 0.6 N/mm$^2$. These results confirm the data of previous investigations (Ref 6,7). However, at pressures above 0.6 N/mm$^2$ the increase of wear intensity becomes much greater and goes out of the region of "mild" wear. In this case, the wear will be in the "adhesive" region of wear (Ref 8). Analysis of the curves in Fig. 5 indicates that the wear intensity in the β-phase state is higher than that in other states for all ranges of a pressure. The wear intensity of the alloy with microcrystalline structure is 1.5 to 2.0 times less and 25 to 30% less than in the β-phase state and the initial state, respectively, at pressures more than 0.4 N/mm$^2$.

The study of worn surfaces and debris particles was performed in order to investigate the wear mechanisms at different states of the alloy. Brass transfer from the shoe to the disk, hardening of the surface layer, and delamination of the debris particles from the specimens were observed in the wear of the alloy in all structural states. This procedure was performed in accordance with that used in other investigations (Ref 6-8). The shape of the particles is depicted in Fig. 6(a). As one can see, the dimensions of the particles vary from a few micrometers to 2 to 3 mm, and the thickness varies from a part of a micrometer to some tens of micrometers. The edge of one particle is depicted in Fig. 6(b). The micrograph of the debris particle from a delamination surface is depicted in Fig. 6(c). Analysis of these micrographs confirms that delamination is the main mechanism of wear of the alloy.

## 4. Conclusions

It has been established that deformation heat treatment leads to the formation of a microcrystalline structure (2 to 3 μm) by recrystallization in brass CuZnPb. The wear of brass with the microcrystalline structure is 1.5 to 2.0 times and 25 to 30% less than in the β-phase and initial large-grained states, respectively.

### Acknowledgment

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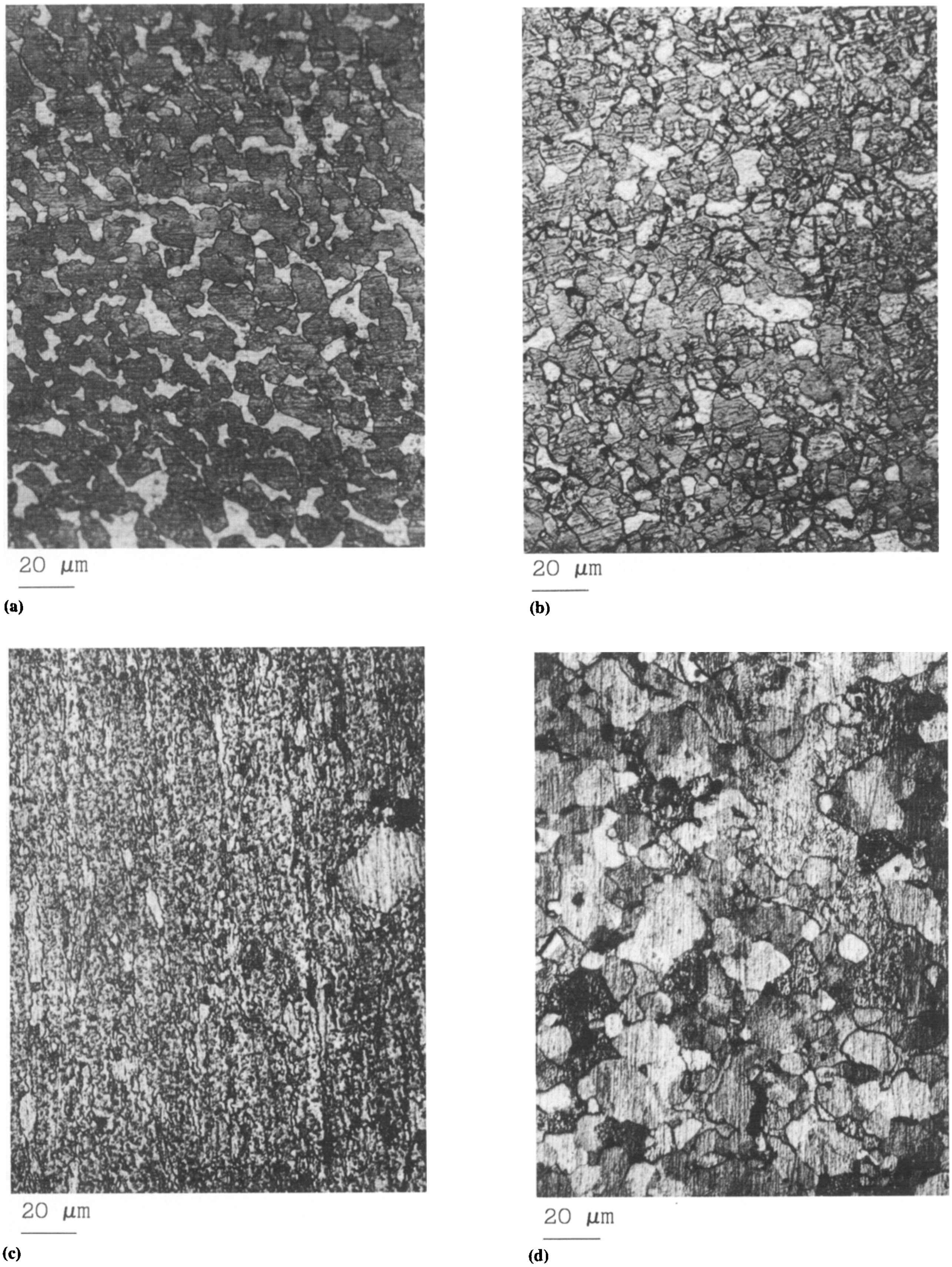



**Fig. 3** Microstructure of brass after compression at: (a) 250 °C; (b) 350 °C; (c) 250 °C followed by annealing at 300 °C; (d) 250 °C followed by annealing at 600 °C

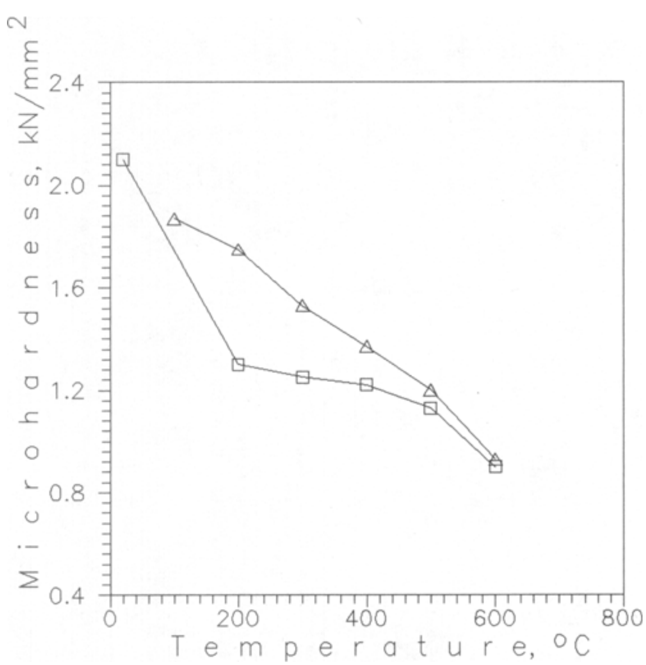



**Fig. 4** Dependence of microhardness on temperature of: (open triangle) compression, (open square) annealing

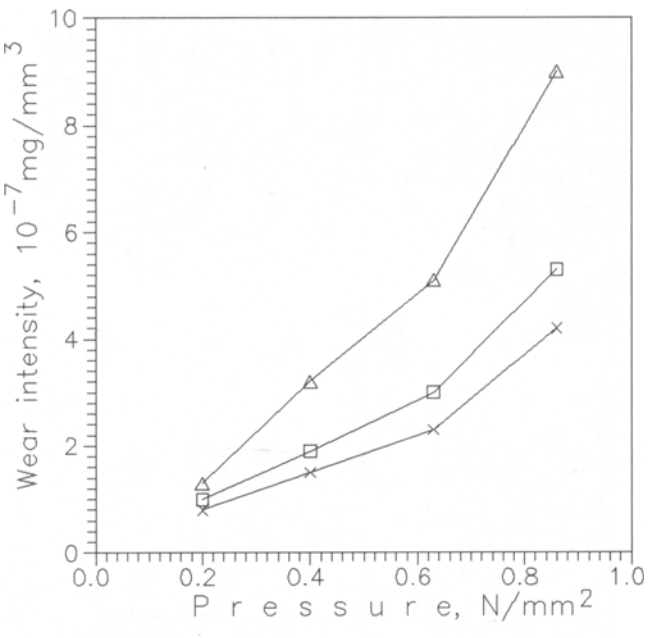
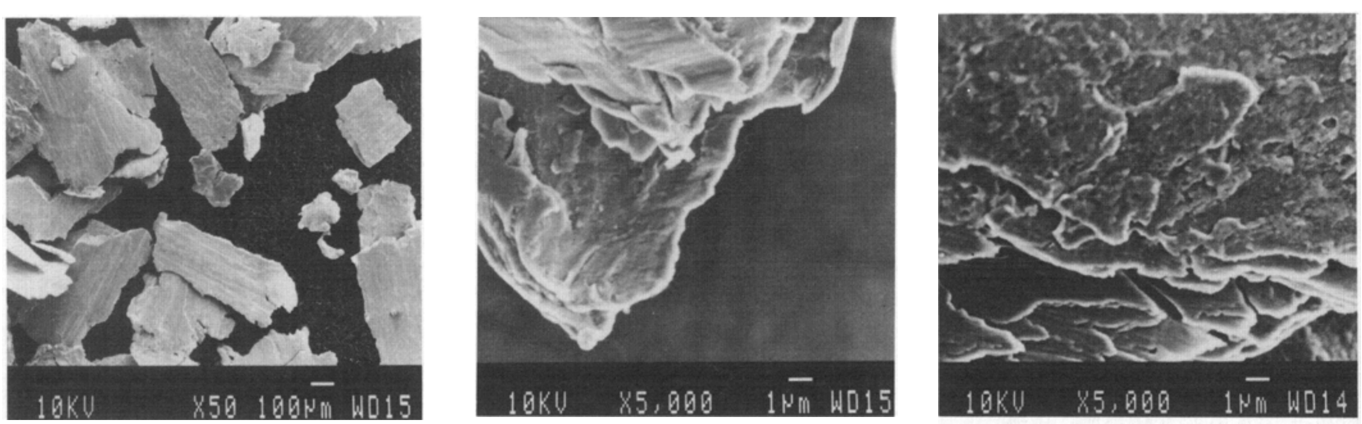



**Fig. 5** Dependence of wear intensity on pressure in: (open square) initial state; (open triangle) β-phase state; (×) microcrystalline state




**(a)** **(b)** **(c)**

**Fig. 6** Morphology of the debris particles. (a) Common view. (b) View of the edge of the particle. (c) View from the delamination surface

## References


1. L.M. Larikov, Structure and Properties of Nanocrystalline Metals and Alloys (in Russian), *Metallophysica*, No. 14, 1992, p 3-9
2. V.Y. Gertsman, R. Birringer, R.Z. Valiev, and H. Gleiter, On the Structure and Strength of Ultrafine-Grained Copper Produced by Severe Plastic Deformation, *Scripta Metallurgica et Materialia*, Vol 30, 1994, p 229-234
3. G.M. Sorokin, About Criteria for the Selection of Wear Resistant Steels and Alloys (in Russian), Zavodskaya Laboratoriya, No. 9, 1991, p 55-59
4. F.A. Sadykov, The Influence of the Structural State on Wear Resistance of Bronze CuAlFe, *Journal of Materials Engineering and Performance*, Vol 4, 1995, p 102-105
5. M.A. Bernstein, B.N. Efremov, and E.V. Jushina, Some Features of the Forming of the Structure of Lead-Brasses in the Process of Post-Deformation Heating (in Russian), *Izvestiya Vuzov. Tsvetnaya Metallurgiya*, No.4, 1989, p 88-93
6. M. Sundberg, R. Sundberg, S. Hogmark, et al., Metallographic Aspects on Wear of Special Brass, *Wear*, Vol 115, 1987, p 151-165
7. J.K. Lancaster, Material-Specific Wear Mechanisms: Relevance to Wear Modeling, *Wear*, Vol 141, 1990, p 159-183
8. T. Akagaki and K. Kato, Effects of Hardness on the Wear Mode Diagram in Lubricating Sliding Friction of Carbon Steels, *Wear*, Vol 141, 1990, p 1-15