Study on Cold Working Hardening and Recrystallization Temperature of Hsn88-2 Alloy

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Abstract: The HSn88-2 alloy was subjected to cold deformation with different degrees ,and the working hardening curve of the alloy was drawn .Through the microstructure observation and test of the tensile strength and elongation of specimens with different thicknesses after annealing, the recrystallization temperature of the alloy was obtained .The results show that the alloy after cold deformation has obvious working hardening effect .The strength of the alloy increases first and then keeps constant with the increasing of working rate ,while the elongation and electrical conductivity exhibit opposite change rule .In addition ,the lower the cold working rate is ,the lesser the initial recrystallization temperature is.

Copper base elastic alloy with high strength, excellent flexibility, fatigue resistance, small elastic hysteresis and other properties, is widely used in medical, aviation and maritime navigation instrument, machinery manufacturing, instrumentation and instrument manufacturing industry [1-5]. At present, copper based elastic alloys are mainly made of beryllium bronze and Tin Phosphorus bronze, beryllium bronze are the most commonly used high elastic alloy, beryllium industrialization and application are greatly limited 6-8], because oxide and dust of beryllium are harmful to the environment and human health. Tin hosphorus bronze because of high Sn content, generally greater than 4%. Sn negative segregation is easy to occur in the production process, it takes a long time to the homogenization of the alloy, which seriously affects the production efficiency. And the price of Sn is expensive, adding high content of Sn means increase cost, which affects the alloy Industrialization and Application.

Adding small amount of Sn element in brass alloy, not only can improve the strength and hardness of alloy, but also can improve the corrosion resistance of alloy, so it is called "the Navy brass". Commonly tin brass brands are HSn60-1, HSn70-1, HSn90-1. Comparing with tin phosphorus bronze, tin brass processing method is relatively simple and the production cost is low, and the conductivity is higher than that of tin phosphor bronze, but the strength and elastic modulus of tin brass were less than tin phosphorus bronze. Therefore, how to design components based on tin brass to replace tin phosphor bronze became the study core of copper alloys.

This paper focuses on the relationship of tin brass tensile strength, elongation and electrical conductivity, and the working hardening curve of the alloy was drawn. Through the different annealing temperature heat treatment of cold-rolled alloy and the research on effects of annealing temperature and microstructure of alloy, recrystallization annealing temperature was obtained, which provided experimental basis for tin brass strip production process and the development of new elastic copper alloy.

1. Test materials and methods

Experimental material is 3.0 mm annealed tin brass strip, chemical composition shown in Table 1. In order to study cold hardening process of alloy strip, annealed strips were rolled with different deformation level, machining process is 3 - 2.7 - 2.4 - 2.1 - 1.8 - 1.67 - 1.2 - 0.9 - 0.78 - 0.65 - 0.58. In order to obtain alloy recrystallization temperature, launched temperature annealing treatment for different sickness strips from 200℃～600℃ for 1 h.

Cut the metallographic sample along the rolling direction, after grinding, polishing, etching with aqueous solution of FeCl3 and HCl, then observe microstructure under the microscope. In addition, using the MTS-810 tester machine and 7501 type eddy current device test tensile strength, elongation and electrical conductivity of different state tin brass strip.

Table 1 Chemical Composition of HSn88-2 alloy, wt%

Alloy elements	Cu	Sn	Fe	Zn
Contents	87.9	1.06	<0.02	remain

2. Test Result and Analysis

2.1 Effect of deformation on alloy

Figure 1 (a) shows curve of different processing rate on tensile strength, elongation and electrical conductivity of HSn88-2 alloy. It shows the alloy work hardening effect increased after cold rolling deformation process. With the increase of the processing rate, the strength of the alloy increases. But the elongation of the alloy decreased with the increase of deformation。 When the processing rate is greater than 70%, the strength of the alloy and the elongation remained constant about 654.7MPa and 4%., this is mainly because after cold rolling, with the increase of deformation degree, the dislocation density in the matrix increased, the interaction between dislocations will occur, dislocation tangles, and dislocation jog forms in motion of dislocation, these factors will hinder the movement of dislocations, the strength of the alloy increases. When the deformation degree increased, inner stress can make the pile up of dislocation occur cross slip, bypassing obstacles and continue to move, make the strength of the alloy tends to be stable. Figure 2 shows dislocation tend to tangle after many dislocation interaction, composed subgrain boundary, the subgrain boundary surrounds a small area of little dislocations and forms "cellular structure".

As shown in the picture, with the increase of deformation, the conductivity of the alloy decreases. When the deformation rate is higher than 70%, the conductivity of the alloy stabilized value is about 28.8%IACS, compared with the undeformed alloy, conductivity reduces about 4%IACS. This is mainly because crystal lattice distortion and crystal defects increase, especially the vacancy concentration increased due to cold deformation, which increases the uneven degree of lattice electric field and electromagnetic wave scattering. In addition, the atomic distance changed after cold deformation process, also has impact on conductivity. When the processing rate is greater than 70%, little change in the crystal lattice distortion and crystal defect degree of alloy. Therefore, the cold deformation has no obvious effect on electrical conductivity.

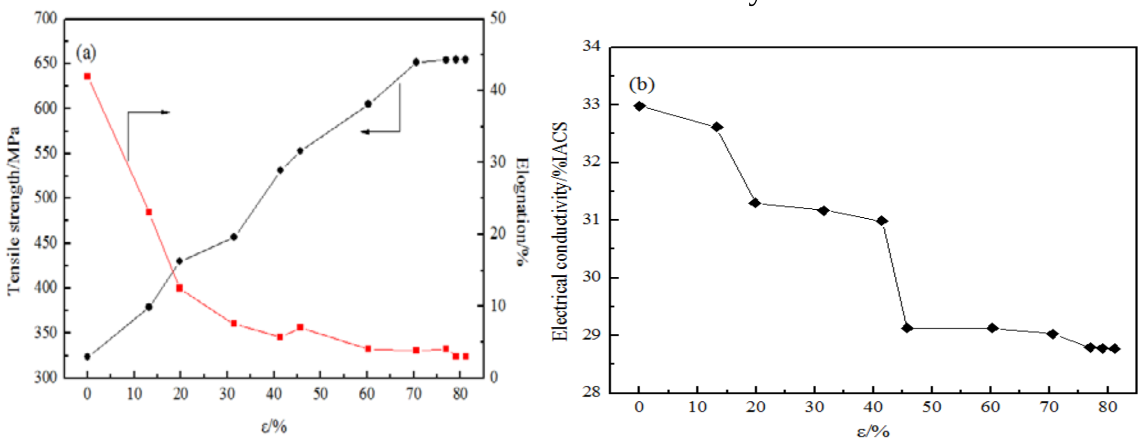


Fig.1 Effect of working rate on tensile strength, elongation and electrical conductivity of HSn88-2 alloy

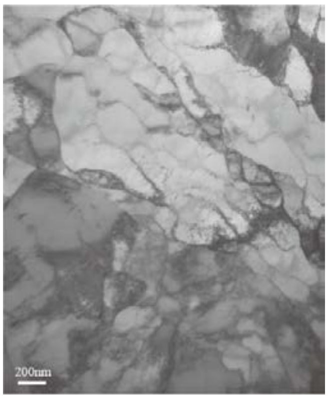


Fig.2 Microstructure of cold-rolled HSn88-2 alloy

2.2 Confirmation of ally recrystallization temperature

Figure 3 shows the curve effect of annealing temperature on alloy tensile strength and elongation of different thickness HSn88-2 alloy. Figure 3 (a) shows when the annealing temperature is 200℃, the strength of the alloy increased. This is mainly because when the annealing temperature is 200℃, the alloy will re-layout atomic arrangement, α1 ordered solid solution turns into α2 solution, so that the strength of the alloy increases. However, with the increase of the annealing temperature, the strength of the alloy decreased slowly, and then sharp decreases, finally slowly decreases. But the elongation of alloys is different with strength, first slowly increases then dramatically increases, finally tends to be stable. Figure 3 (b) shows. According to the maximum part of the slope variation of the strength-temperature curve, the range for the alloy occurs recrystallization temperature range [9]. which can make sure the recrystallization temperature of 20% deformed alloy is 400 to 450 ℃, the recrystallization temperature of 40%, 60% deformed is 350 to 400 ℃, the recrystallization temperature of 80% deformed alloy is 300 ~ 400 ℃. That means the larger the deformation is, the lower the initial recrystallization temperature of the alloy is. This is mainly because cold deformation increases, alloy distortion energy increases, the driving force during recrystallization increased, a corresponding increase of recrystallization nucleation rate and crystal nucleus growth rate, the recrystallized temperature decreases.

Figure 4 shows the microstructure picture of different annealing temperatures on 80% deformed HSn88-2 alloy for 1h. Figure 4 shows when annealing temperature increases, the alloy go through recovery, recrystallization and grain growth process. When the annealing temperature is 200-300, the vacancy disappears and the dislocation rearranges, dislocation offsets, the dislocation density decreases such as shown in Figure 4 (a). With the annealing temperatures continue to increase (greater than 300℃), small equiaxed grains appeared in the vicinity of cold rolling fibrous tissue. The higher the temperature is, the greater volume fraction of grains are. Figure 4 (b) - (d). When the temperature rose to 500℃, the fiber microstructure of the alloy is completely transformed into equiaxed grains. As the temperature rises to 600 degrees (Figure 4 (f)), the microstructure of the alloy shows obviously growth.

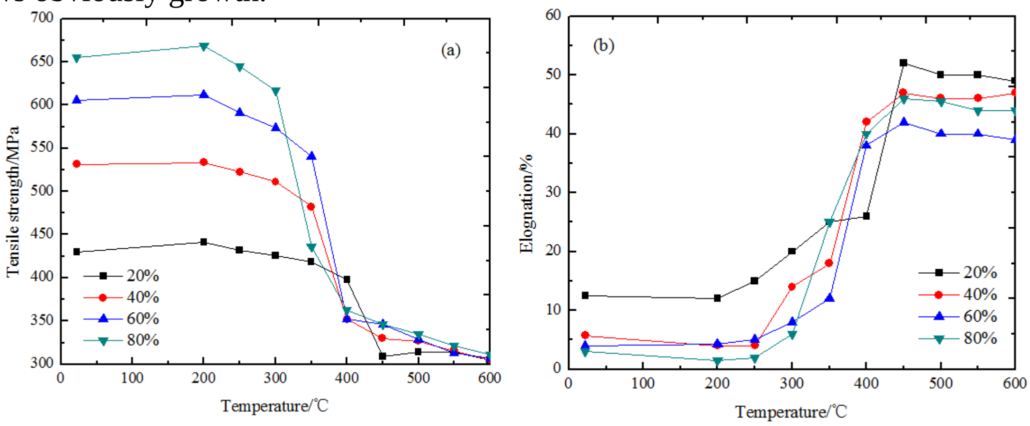
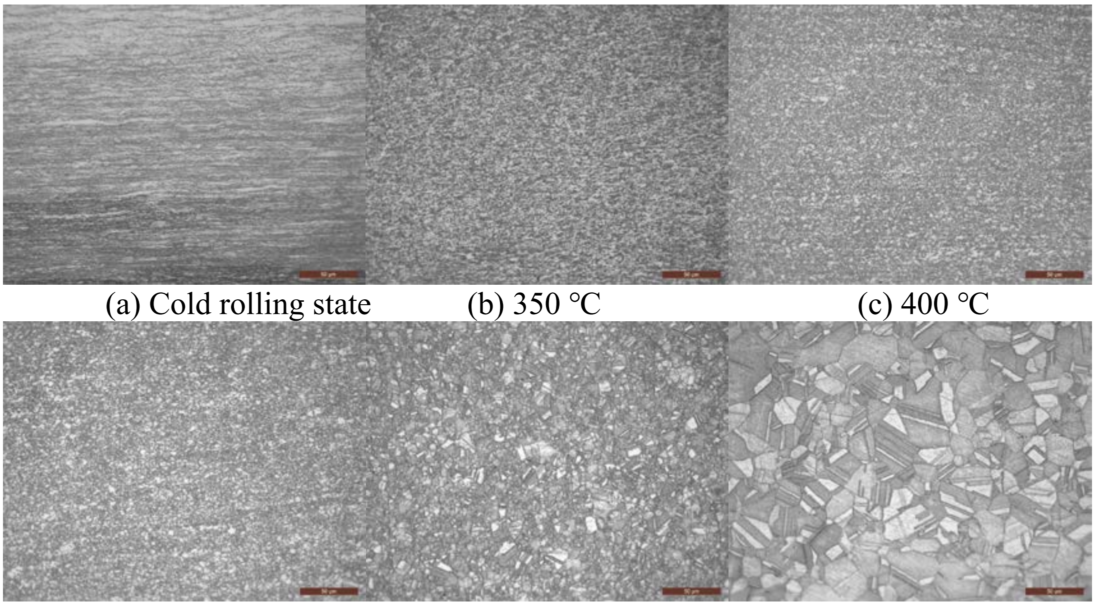


Fig.3 Effect of Temperature on Tensile strength and elongation of HSn88-2 alloy



(a) Cold rolling state (b) 350 ℃ (c) 400 ℃

(d) 450 ℃ (e) 500 ℃ (f) 600 ℃

Fig.4 Microstructure of cold-rolled HSn88-2 alloy at different temperature for 1 h

3. Conclusion

1) The HSn88-2 alloy has obvious working hardening effect after cold deformation. When the processing rate is less than 70%, the strength of the alloy increases with the increase of processing rate, the elongation and electrical conductivity showed the opposite changes. When the processing rate is greater than 70%, the tensile strength, elongation and electrical conductivity tends to be stable;

2) With the increase of deformation degree, the initial recrystallization temperature of alloy is lower.

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