Study on Aging Treatment Temperature of a Special Aluminum brass

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Abstract. Aging treatment of ZCuZn25Al6Fe3Mn3 was conducted by muffle furnace. We studied the variation of the microstructure and properties of ZCuZn25Al6Fe3Mn3 with the increase of aging temperature. We discovered that the microstructure consists of an equiaxed β phase + a star-like Fe phase + a finely distributed phase of the dispersed phase. No distributed phase was observed when the aging temperature was low. As the aging temperature rises, the punctate phase appears, and the number of punctate phases is the highest at 500 °C. Above 500 °C, continue to raise the temperature, point-like phase aggregation grows into granular phase. As the aging temperature rises, the hardness of the alloy rises first and then decreases, the weight loss of the alloy decreases first and then rises. At 500 °C, the hardness of the alloy is the highest, reaching 263 HV, and the weight loss is the smallest, about 0.3990 g. Observing the wear morphology, the wear mechanism under dry friction conditions is known as abrasive wear and adhesive wear. The optimum aging treatment process for ZCuZn25Al6Fe3Mn3 is 500 °C × 2 h air cooling.

1. Introduction
ZCuZn25Al6Fe3Mn3 is a wear-resistant cast brass. Due to its load carrying capacity, it has a friction reducing effect when paired with steel materials. It is usually used to make parts such as bushings [1]. It belongs to Cu-Zn-Al-Fe-Mn copper alloy multi-complex brass, which can be strengthened by solution treatment and aging treatment [2]. At present, there is no exploration of the heat treatment process of ZCuZn25Al6Fe3Mn3 in the research. In this experiment, the variation of microstructure and properties of ZCuZn25Al6Fe3Mn3 was studied and the best aging process for ZCuZn25Al6Fe3Mn3 was obtained.

2. Methods and Materials
The aging treatment of the sample is carried out in a muffle furnace. First, the sample of solution treatment is 880 °C + 1 h + WC, and then aging treatment at 5 temperatures. The test parameters are shown in Table 1.
Wear test equipment is sliding wear tester. The test parameters are shown in Table 2. Hardness test equipment is Vickers hardness testing machine. The microstructure was observed with OM. Phase component detection device is an energy spectrum analyzer. Wear profile observation device is SEM.

The compositions (wt%) of ZCuZn25Al6Fe3Mn3 are as follows: 58.571%Cu, 2.861%Mn, 2.930%Fe, 0.194%Si, 0.722%Pb, 0.176%Sn, 6.967%Al, 27.579%Zn.

| Experiment group | Aging temperature | Aging time | Cooling method |
|------------------|-------------------|------------|----------------|
| 1                | 420°C             | 2h         | AC             |
| 2                | 460°C             | 2h         | AC             |
| 3                | 500°C             | 2h         | AC             |
| 4                | 540°C             | 2h         | AC             |
| 5                | 580°C             | 2h         | AC             |

| Ring specimen     | Hardness of ring specimen | Text force | Rotating speed |
|-------------------|----------------------------|------------|----------------|
| 45 steel          | 40HRC                      | 200N       | 200r/min       |

3. Results and analysis

3.1. Microstructure Analysis

In Figure 1, We discovered that the microstructure consists of an equiaxed β phase + a star-like Fe phase + a finely distributed phase of the dispersed phase. The energy spectrum analysis of the matrix phase and the star phase is shown in Table 3. From table 3, We know that main constituent elements of the matrix phase compose of Cu, Zn element. The constituent elements of the star shape phase is Cu, Zn, Al, Mn, Fe, Si element and the Fe, Al element is the main element. It is speculated that the star phase is Fe₃Al phase which is a intermetallic compound phase. As the aging temperature rises, the precipitated phase appears and gradually increases. The number of precipitated phase is highest at 500°C. The number of precipitated phase decreases and the size of precipitated phase increases when the aging temperature increase continuously. After solution treatment, alloying elements such as Fe, Al, and Mn are dissolved in the matrix. This causes the substrate to be metastable, and this metastable state becomes unstable under the excitation of external energy input and the second phase is resolved [3-4]. The externally supplied driving energy per unit time is small when the aging temperature is low, it causes the solute atom to diffuse slowly and the precipitated phase to form slowly. Macroscopically, we can see small quantity precipitated phases and the size is small. The external driving energy provided per unit time is sufficient, the solute atom diffusion rate is accelerated, and the aggregated GP area is increased when the aging temperature increases. Extended holding time, GP areas become precipitate phase. Macroscopically, we can see more small-sized precipitates. The excitation energy is further input, and the small and similar phase precipitates begin to gather and grow. The morphology changes from a point to a granular shape, the size of the precipitated phase becomes larger while the number is reduced.
Figure 1. Microstructure of ZCuZn25Al6Fe3Mn3 500×.(a) aging at 420°C; (b) aging at 460°C; (c) aging at 500°C; (d) aging at 540°C; (e) aging at 580°C

Table 3. Elemental content of each phase (wt %).

| Phase       | Cu  | Zn  | Al  | Mn  | Fe  | Si  |
|-------------|-----|-----|-----|-----|-----|-----|
| Matrix phase| 64.02 | 28.46 | 4.35 | 2.63 | 0.54 | /   |
| Star phase  | 10.77 | 3.70 | 12.1 | 5.18 | 66.99 | 1.26 |

3.2. Hardness Analysis

From figure 2, as the tempering temperature rises, hardness of ZCuZn25Al6Fe3Mn3 fluctuations from 240HV1 to 263HV1. Below 500°C, the hardness value is on the rise. At 500°C, the hardness is the highest, reaching 263HV1. Continue to improve the temperature, the hardness of ZCuZn25Al6Fe3Mn3 is decreasing. Mechanical properties of the alloy depend on the morphology, size and distribution of
the diffuse phase and the matrix microstructure [5-6]. Aging treatment results in a diffuse distribution of precipitated phases in the alloy matrix. Most of these precipitates are hard particle phases. The hard particle phases increase the strength and hardness of the alloy. In this study, the ZCuZn25Al6Fe3Mn3 matrix structure is $\beta$ phase and the hardness of $\beta$ phase is high. At 500 °C, the size of the precipitated phase is modest, the number is largest, and the dispersion is distributed. The alloy structure is in the equilibrium point of the precipitation phase hardening effect and the weakening of the hardness of the alloy elements to the matrix. At this time, the aging effect is theoretically optimal. We can find that the hardness of ZCuZn25Al6Fe3Mn3 is maximum. Continue to rise the tempering temperature, the alloying elements in the matrix continue to precipitate which weakens the matrix, the size becomes larger, the degree of dispersion decreases, the number of precipitated phases becomes smaller at the same time. It will be over-aged, resulting in a decrease in hardness.

![Figure 2. The hardness of ZCuZn25Al6Fe3Mn3.](image)

### 3.3. Wear Analysis

![Figure 3. Wear loss of ZCuZn25Al6Fe3Mn3.](image)

It can be seen from Fig. 3 that the grinding loss fluctuations from 0.3900 g to 0.7000g. With the aging temperature rises, the wear of aluminium brass decreases first, and the grinding loss is 0.3990g at 500 °C. Above 500 °C, the grinding loss of ZCuZn25Al6Fe3Mn3 is increasing. Material grinding
loss is positively correlated with hardness, the hardness of material is high and the wear resistance is good [7]. The wear properties of the alloy related with the distribution and performance of the phases in the microstructure [8]. In this experiment, The grinding sample is in dry friction condition. When the aging temperature rising, the number of precipitated phases increases and the dispersion is good. At 500 °C, the hardness of the matrix and the phase of the precipitate are in an optimal state, and the wear resistance reaches a peak. Figure 3 is the wear profile of ZCuZn25Al6Fe3Mn3 under dry friction conditions. We found that the wear profile showed different grooves, and some peeling deformation metal adhered to the wear surface. This shows that under the ring-block wear condition, the wear mechanism of the ZCuZn25Al6Fe3Mn3/45 steel friction pair is abrasive wear and adhesive wear.

4. Conclusion

(1) The microstructure of ZCuZn25Al6Fe3Mn3 consists of an equiaxed β phase + a star-like Fe phase + a finely distributed phase of the dispersed phase. the number of punctate phases is the highest at 500 °C.

(2) The hardness of ZCuZn25Al6Fe3Mn3 increases first and then decreases with the increase of aging temperature. The weight loss of the aluminum alloy decreases first and then rises. At 500 °C, the hardness of the alloy is the best, reaching 263HV1, the wear loss of the alloy is the least, reaching 0.3990g, and the wear mechanism is abrasive wear and adhesive wear.

(3) The best aging treatment process for ZCuZn25Al6Fe3Mn3 is 500 °C × 2 h AC.

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