Effect of Silicon and Magnesium Content on Properties of Aluminum Based Sintered Bearing

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ABSTRACT: Because of light weight and low cost, the aluminum-based oiled bearing has become one of the hot research points in the field of oiled bearing. Due to the shortcomings of aluminum itself, such as low hardness and poor weak bearing capacity and wear-resisting, therefore, Cu, Mg, Si and other elements are needed to add into the aluminum matrix to improve the hollow ratio, radial crushing strength and other performance parameters of oil bearing. In this paper, powder metallurgy method will be used to manufacture Al-Cu oiled bearing, with copper content of 7.5% Al-Cu mixed powder as the base, add Silicon first and study the effect of silicon content on the sinter properties. Then, adding magnesium in Al-Cu-Si substrate and the effect of magnesium content on properties will also be discussed. The research shows that when the matrix of the silicon content is 1.0%, and magnesium content is 2.0%, the aluminum-based oiled bearing that was manufactured has good comprehensive properties.

KEYWORDS: Aluminum-based oiled bearing; Hollow rate; Crushing strength; Silicon and magnesium

1 GENERAL INSTRUCTIONS

Compared with copper-based oil bearings and iron-based oil bearings, aluminum-based oiled bearings not only have advantages like good thermal conductivity, light weight, low working temperature, excellent wear resistance, low noise and outstanding corrosion resistance, etc., but also can significantly reduce the cost of oil-bearings. What’s more, recent years, in oil-bearing areas, the development and changes in copper-based alloy and iron-based alloy are small, while the development of aluminum alloy is rapid, alloy designations are increasing and practical application is more and more wide, which indicates that aluminum based alloy is the most promising oil-bearing materials and the development and research in aluminum alloy is an important direction in the field of international oil bearing materials.

Although aluminum-based oiled bearings have many advantages over copper-based bearings and iron-based oil bearings, but in the process of actual use, compared with the copper-based alloy and iron-based alloy or other oiled bearings, the radial crushing strength of aluminum-based oiled bearings is still obviously inadequate [1]. Professor Chi Changzhi and Professor Li Shixin performed the study on hardness and wear properties of sintered bodies. The study showed that the hardness increased with the increase of Si content; in terms of wear performance, the study found that the wear of aluminum-based oiled bearings under lubricated conditions was the result of the alternative or combined action of abrasive wear, fatigue wear and adhesive wear [3]. By observing the microstructure, testing the mechanical property and analysing the fracture morphology, Hu Wenquan [4] studied the hardness and impact toughness of the Al-Cu-Mg alloy. In order to further improve the hollow rate and radial crushing strength of sintered body, silicon powder and magnesium powder were successively added to the mixed powder of aluminum and copper to research the effect of silicon powder and magnesium powder on the various properties of the sintered body.

2. MATERIALS AND METHODS

In the experiment, aluminum and copper mixed powder (Al: 7.5%) was taken as the base. First, the silicon element was added to the base to study the effect of silicon content on the shapes, dimensions and performance of the sintered body. Then, continue to add magnesium to the base of Al-Cu-Si components to get Al-Cu-Si-Mg alloy sintered body.
to study the effect of magnesium on the shapes, dimensions and performance of sintered body. Finally, the optimal Al-Cu-Si-Mg composition ratio of the quaternary alloy was obtained.

3. THE RESULTS

3.1 The effect of Silicon on the properties of the sintered body

Si element can cause shrinkage of the sintered body, compression of the porosity of the sintered body and partially porous or even blocked. Thus, with the increasing content of Si, hollow rate of the sintered body decreases [3]. Figure 3.1 shows the effects of different Si content on the hollow rate of the samples.

As can be seen from Figure 3.1, with the increase of the content of the silicon element in the sintered body, there is a clear downward trend on the hollow rate of the sintered body, and the decreasing range of the hollow rate of the sintered body increases as silicon content increases. Excessively low hollow rate will directly affect the performance of the oil-bearings, resulting in the case of oil-bearing scrap occurred in a short time after work.

Figure 3.2 is the fracture cross-sectional SEM photograph of different Si content, whose base is Al-7.5% Cu. Figure (a) is a sintered sample to which added 0.5% silicon. It can be seen from the figure, when the content of silicon element in the sintered body is low, the hollow rate of the sintered body is high as there are more pores distributed on the cross section of the sample. With the increasing content of Si, from figure (a) to figure (e), we can clearly see that the interior of the sintered body becomes more and more closely. When Si content is 2.5%, as shown in the cross section SEM figure in figure (e), the interior of the sintered body has been very close, and it’s hard to clearly identify the location of the pore, even the blockage situation of the open pore is very serious, which leads to a dramatic decline on hollow rate of the sample and directly affects the normal performance of the oil-bearing.

3.2 The effect of Silicon on the radial crushing strength of the sintered body

Silicon has an important influence on the radial crushing strength of the sintered body as well. Figure 3.3 shows the change of the radial crushing strength of the sintered body with the increase of silicon content.

According to the XRD analysis, the main phrase in the sintered samples are AL, Al2Cu, Al-xSi and Si. It also can be inferred that, in the process of sintering, part of Si and Al forms Al-xSi strengthening phase, while the other part of the Si that doesn’t fuse with Al appears in the base in the form of silicon particles. Figure 3.4 and table 3.1 are the result of EDS test on Al-7.5%Cu-1.0%Si sample. According to the analysis of the result, the element in the base distributes uniformly. So, when silicon particles distributes uniformly in aluminum substrate, the alloy strengthening will be significantly increased because the lattice distortion and stress field, which exist on the interface of silicon particles and aluminum substrate, hinder the dislocation glide.

In the process of sintering, the silica content plays an important role on the strength of the samples. When Si content is lower, the content of Si particles

Figure 3.1. Hollow rate of the samples with different Si content.

Figure 3.2. SEM diagrams of cross section with different Cu content.

Figure 3.3. Radial crushing strength of the samples with different Cu content.
is lower as well. The sintered body is strengthened after being sintered, which leads the Silicon particles distribute uniformly in the sintered body. When the content of silicon is more than 1.0%, the number of silicon particles in the sintered body also increases, however, an excess of silicon particles can cause the sintered alloy to become stiff and brittle, which results in the decrease of the strength and plasticity of the sintered body. Based on the analysis above, when the silicon content is 1.0%, the radial crushing strength of sintered body can get the best performance.

![Figure 3.4. EDS of Al-7.5%Cu-1.0%Si sintered sample.](image)

### Table 3.1. Elemental analysis of Al-7.5%Cu-1.0%Si sintered sample.

<table>
<thead>
<tr>
<th>Element</th>
<th>Wt%</th>
<th>At%</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>03.45</td>
<td>05.91</td>
</tr>
<tr>
<td>Al</td>
<td>89.39</td>
<td>90.64</td>
</tr>
<tr>
<td>Si</td>
<td>00.69</td>
<td>00.67</td>
</tr>
<tr>
<td>Cu</td>
<td>06.47</td>
<td>02.79</td>
</tr>
</tbody>
</table>

#### 3.3 The effect of magnesium on the performance of sintered samples

The results and analysis of the previous experiment shows that when the Al-7.5% Cu aluminum-copper powder is mixed with 1.0% silicon, the comprehensive properties of the sintered samples are the best. The study is continued by adding magnesium to the Al-7.5%Cu-1.0%Si based powder to explore effects of magnesium on the performances of sintered body.

#### 3.3.1 The effect of magnesium on the hollow rate of sintered samples

After magnesium is added, there generates MgO in the interior of the base after sintering. MgO is a kind of fluffy material, which can cause the expansion of the sintered body. After the volume expansion of the sintered body, many of the originally closed pores on the surface will be opened, and the inside tiny pores will be enlarged, many disconnected pores also turns connected between the pores.

The biggest advantage for the expansion of the sintered body brings to the base is the hollow rate can be greatly improved. In all the added elements, magnesium has the greatest impact on the hollow rate of aluminum-based oiled bearing. Figure 3.5 shows the relationship between content of magnesium and the hollow rate. It can be seen in the figure that the relationship between the content of magnesium and the hollow rate almost shows linearly direct ratio when the content of magnesium is 1.0% ~ 3.0%. Thus, the increase of magnesium content can significantly improve the hollow rate of the sintered body.

![Figure 3.5. Hollow rate of the samples with different Mg content.](image)

#### 3.3.2 The effect of Magnesium on the radial crushing strength of sintered samples

Figure 3.6 shows the relationship between the magnesium content and the radial crushing strength of the sintered body. It can be seen in the figure that radial crush strength of sintered body declines with the increase of the content of magnesium. There are two main reasons for the decline of the radial crushing strength of the base: 1. because of the increasing magnesium content, which makes the sintered body over bloated, the internal structure becomes so loose that it weakens the strength of the sintered body 2. The increase of magnesium content results in a product of too much hard phase in the base, which causes fracture effect, resulting in a decline in the strength of the base.

![Figure 3.6. Radial crushing strength of the samples with different Mg content.](image)

#### 4. CONCLUSION

The hollow rate of the sintered body decreases with the increase of the Si content. The radial crushing strength firstly increases and then decreases with the increase of Si content. In the overall results of the experiment, the most appropriate Si content is 1.0%.

The hollow rate of the sintered body increases with the increase of Mg content, which is because there is MgO produced in the process of sintering, and it causes volume expansion to the sintered body.
Radial crushing strength decreases with the increase of Mg content. Comprehensive the results of the experiment, the optimum Mg content is 2.0%.

REFERENCES


