Research on the squeeze cast technology of the castings with large ratio of height to thickness

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Abstract: The squeeze cast technology is only applicable, at present, to the castings with a ratio of height to thickness less than 3.5. Researching the squeeze cast technology for castings with a large ratio of height to thickness will broaden the applicable range of the advanced casting technology. This paper describes a study of the temperature distribution during solidification for castings with a ratio of height to thickness of 7 by the methods of experiment and computer simulation. The shrinkage porosity distribution in the castings and the mechanical properties of the castings were also researched. The experimental and simulated results show that increasing squeeze force, or enhancing mold temperature, cannot reduce the shrinkage porosities in the castings. When castings solidify in a sequential manner and the squeeze force effectively acts on the surface of the liquid metal, the shrinkage porosities in the castings are eliminated and mechanical properties are clearly improved.

Key words: squeeze cast; castings with large ratio of height to thickness; sequence solidification; shrinkage porosity

1 Introduction

Squeeze cast is a near-net shape casting technology. In the squeeze cast process liquid metal fills and solidifies under high pressure, which enhances the castings’ feeding and forming capacities effectively, and this significantly increases the inherent quality and appearance quality of the castings. It is important for us to study squeeze cast technology in order to save raw materials, decrease energy consumption and improve the quality of castings [1-4].

The squeeze cast process is only applicable, at present, to the castings with a ratio of height to thickness less than 3.5. When the ratio is larger, zones which are away from the punch pin will appear shrinkage porosity and the mechanical properties of the castings, especially ductility and toughness, will decrease significantly [4,5]. Researching the squeeze cast technology for castings with a large ratio of height to thickness will broaden the applicable range of the advanced cast technology.

ZA27 alloy has many advantages, such as good mechanical properties, strong wear resistance and a ready supply of the raw materials. Working in the conditions of low speed and heavy-load, acting as wear resisting parts, ZA27 alloy has partly replaced copper alloy. But because of the wide crystallization temperature range of ZA27 alloy, shrinkage porosity is likely to appear in the ZA27 alloy castings under the general casting conditions, which leads to the reduction of the toughness and ductility [6,7]. This paper describes a study of the temperature distribution during solidification for castings with a ratio of height to thickness of 7 by the methods of experiment and computer simulation. The shrinkage porosity distribution in the castings and the mechanical properties of the castings were also researched.

2 Experimental methods

The chemical components of ZA27 alloy are 27 % Al, 1.6 % Cu, 0.02 % Mg and the rest is Zn. The alloy is melted in a 36 kW resistance crucible furnace in preparation for casting by a YH61-500G squeeze machine.

Figure 1 is a sketch of preparing a casting with squeeze cast technology. The pouring temperature is 650 °C and the liquid metal solidifies under pressure. Tensile samples are obtained from the casting shown as in Fig.2 and the samples are numbered 1, 2, 3, 4 in order.

3 Experimental results and analysis

3.1 Shrinkage porosity distribution in the castings when heating the mold uniformly

After the mold is uniformly preheated to 140 °C, liquid
After solidification the casting is cut along a longitudinal section and Fig. 3 (a) shows the section. There are a lot of shrinkage porosities in the black zone near the axial line in the lower part of the casting. Figure 3 (b) is a simulation of the casting’s temperature field and the gray zone is the last solidifying zone. Figure 3 shows that there are many shrinkage porosities in the last solidification zone.

Tensile samples are obtained according to Fig 2. Table 1 shows the measured results of the mechanical properties of the casting. In the table, the mechanical properties of sample 3 are the lowest, which is the sample from the position of the shrinkage porosities.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength (MPa)</td>
<td>417</td>
<td>419</td>
<td>360</td>
<td>410</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>11.4</td>
<td>10.8</td>
<td>3.7</td>
<td>9.8</td>
</tr>
</tbody>
</table>

In squeeze casting the top part of the casting solidifies more quickly, because pressure makes the top of the casting have tight contact with the mold, consequently the interface thermo-resistance is much smaller. Besides, the higher pressure, which acts on the top of the casting, results in the density and heat conductivity of the metal increasing and quickens the cooling speed of the metal.

In order to eliminate the shrinkage porosities in the casting, the specific pressure is increased from 350 MPa to 750 MPa and the mold temperature is maintained at 140 °C, when carrying out the squeeze cast experiment. The experimental results show no obvious change in the shrinkage porosity distribution in the castings. Moreover, when the specific pressure is maintained at 350 MPa and the mold temperature is increased to 180 °C, the shrinkage porosity distribution in the castings shows no obvious change either. Thus it can be seen that enhancing the specific pressure or increasing the mold temperature cannot effectively eliminating shrinkage porosity in a casting.

3.2 Effect of outspread angle on feeding shrinkage

The reason that shrinkage porosities are formed in castings with a large ratio of height to thickness is that the castings cannot be effectively fed. Figure 4 shows the effect of outspread angle on feeding shrinkage of a casting. In Fig. 4 (a) the outspread angle is towards the punch pin, so liquid metal forms the feeding entryway in
the scope of the outspread angle. The bigger the outspread angle is, the wider the feeding entryway is and the smaller the feeding difficulty zone \( \mu \) is, so the castings solidify in a sequential manner. When castings solidify in a sequential manner under pressure, the castings will not produce shrinkage porosity. In Fig. 4 (b) the outspread angle is away from the punch pin and the casting solidifies in a reverse sequential manner. If a casting with a large height to thickness ratio solidifies in this manner, the last solidification part is far from the punch pin and a lot of shrinkage porosities will form in the casting. Therefore, a way to eliminate the shrinkage porosities in castings with large height to thickness ratios is to create the condition in which the metal far from the punch pin solidifies first and the metal near the punch pin solidifies last, i.e. to create a sequential solidification condition.

In order to eliminate shrinkage porosities in the castings, the solidification characteristics of the castings under three different conditions have been investigated.

(1) If the top surface of the casting is in a thermal insulation state, the metal near the punch pin will solidify last, which is in favor of solidifying in a sequential manner. Figure 5 (a) is the simulated result under this condition, and the gray zones in the figure are the sites of last solidification, which are located at the top center and the lower axial line of the casting. In this condition, with two last solidification zones, shrinkage porosities will still form at the site on the lower axial line of the castings.

(2) The temperature distribution during solidification has been simulated in a casting where the temperature of the mold is non-uniform. Suppose the top temperature of the mould is 180 °C, the bottom temperature of the mold is 15 °C, the temperature distribution along the height of the mold is as shown in Fig.6 and the punch pin is not heated, that initial temperature is 15 °C. Figure 5 (b) is the simulated result, which shows that the location of last solidification is near the top center of the casting axial line.

(3) The two conditions described above do not make the castings solidify in a sequential manner.

Here, the temperature distribution during solidification has been simulated in a casting made by combining the two previous conditions. Suppose the casting’s surface next to the punch pin is in a thermal insulation state, the bottom temperature of the mold is 15°C and the temperature distribution along the height of the mold is as shown in the Fig.6. Figure 7 is the simulated result. It shows that the bottom of the casting solidified first and the casting solidified in a sequential manner. During the process of solidification, the squeeze force acts on the surface of the liquid metal at all times, so the casting solidifies under better feeding conditions.

A squeeze casting experiment was carried out with the optimized processing. The upper part of the mold was heated by Si-C poles and other parts of the mold were not heated. After the liquid metal was in the mold cavity, a piece of asbestos was put on the surface of the molten metal before pressure was applied to the casting. The
function of the asbestos between the punch pin and the casting was to act as thermal insulation.

As shown in Fig.2 samples were taken from different parts of the castings. The measured results were that the tensile strength was 400-420 MPa; the elongation was 10% -13% and there were no obvious shrinkage porosities in the castings.

The above results show that the castings with large height to thickness ratios easily produce shrinkage porosity defects in the squeeze cast process, which results in the mechanical properties, especially ductility, decreasing significantly. Neither increasing the specific pressure of squeeze casting nor enhancing the mold temperature can effectively improve the feeding capacity of castings with large height to thickness ratios. The outspread angle is a key factor in determining the feeding capacity of castings. Forming the outspread angle towards the punch pin is in favor of improving the feeding capacity of the castings. When the castings solidify in a sequential manner and the squeeze force effectively acts on the surface of the liquid metal, the porosities in the castings are eliminated and the mechanical properties are significantly improved.

4 Conclusions

When castings with large height to thickness ratios are produced by squeeze cast technology, shrinkage porosities are easily formed at zones away from the punch pin, resulting in the mechanical properties of the parts, especially ductility, decreasing sharply. Increasing the specific pressure of squeeze casting and enhancing the temperature of the mold cannot effectively eliminate the shrinkage porosities in the castings with large height to thickness ratios. The outspread angle is a key factor in determining the feeding capacity of castings. Forming the outspread angle towards the punch pin is in favor of improving the feeding capacity of the castings. When the castings solidify in a sequential manner and the squeeze force effectively acts on the surface of the liquid metal, the porosities in the castings are eliminated and the mechanical properties are significantly improved.

References


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