Analysis of the performance of ordinary die casting and vacuum die casting of magnesium alloy

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Abstract: The general die casting and vacuum die casting of magnesium alloy radiator were simulated by FLOW-3D simulation software, and the defects and entrainment results in the filling process were compared, and the product was trial-produced. By analyzing the microstructure and mechanical properties of ordinary die casting and vacuum die casting, the test results show that vacuum die casting can obtain magnesium alloy die casting with complete filling and excellent appearance, and its mechanical properties and elongation are increased by 14.2% and 43.7% respectively compared with ordinary die casting.

1. Introduction
Casting molding is one of the main processing methods of magnesium alloy, and pressure casting is the most common processing molding process of magnesium alloy, accounting for about 90% of the total processing volume. Die-casting molding filling speed is faster, magnesium alloy gold due to its own small heat capacity, easy to form in the process of filling the volume of gas, and finally form a pore, resulting in shrinkage shrinkage. Shrinkage and shrinkage can not be solved by heat treatment, thus affecting the overall mechanical properties of die casting and application occasions, so how to reduce the shrinkage of die casting, improve its density has been the focus of research [1-3]. The vacuum die casting can reduce the gas inside the cavity to a certain extent, which can reduce the rolled gas defects of the casting to a certain extent and improve its application [4-6]. In this paper, the magnesium alloy radiator die casting is simulated and analyzed by the simulation software FLOW-3D, and the defects and air entrainment distribution positions of the radiator vacuum die casting and General die casting are compared and verified by experiments.

2. Casting Model Analysis
The radiator die casting model is shown in Figure 1(a). The physical parameters of AZ91D magnesium alloy used in this paper are shown in Table 1, and the results of meshing after importing the model into the simulation software can be displayed completely, as shown in Figure 1(b).
Tab.1 Mg-6Al-1Sm-xBi physical parameters

| Density (g·cm⁻³) | Thermal conductivity (W·m⁻¹·K⁻¹) | Latent heat of melting (kJ·kg⁻¹) | Specific heat (kJ·kg⁻¹·K⁻¹) |
|------------------|----------------------------------|---------------------------------|-----------------------------|
| 1.702            | 84                               | 341.6                           | 1.42                        |

Fig.1 Structure Diagram of Magnesium Alloy Die Castings

3. Simulation and Analysis of Results

3.1 Die Casting Filling Analysis
Through extensive preliminary experiments, the optimal die-casting process parameters [7-8] were selected to simulate the filling of AZ91D magnesium alloy heat sink at a casting temperature of 680°C.

The filling process of magnesium alloy die casting is shown in Figure 2, from the simulation software simulation results can be seen, die casting in the filling process, the metal liquid from the gate into the full pouring system, and then fill the cavity from near to far. When the metal liquid touches the cavity wall, it is hindered by different degrees of turbulence and liquid splash, and as the metal liquid fills the cavity, it fills the cavity. Due to the filling process, there are different degrees of turbulence and spattering of the metal liquid, resulting in different degrees of oxidation inclusions and shrinkage of the die casting.
3.2 Simulation Analysis of Ordinary Die casting and Vacuum Die Casting

Under the best process in Table 2, the defect field simulation analysis of ordinary die casting and vacuum die casting, the results are shown in Figure 3. From the simulation results, it can be seen that the ordinary die casting oxidation inclusions are widely distributed, mainly concentrated in the center and both sides of the casting, and the degree is higher than the vacuum die casting in Figure (b). While the vacuum die casting of the inclusions defects, mainly concentrated in the overflow groove, the overflow groove can be removed after forming, a small amount of distribution in the center of the casting, the distribution range is small, the degree of inclusions defects is low.

Also in Table 2 under the best process, the ordinary die casting and vacuum die casting for the volume gas field simulation analysis, the results are shown in Figure 4. From the simulation results, it can be seen that the common die casting volume gas area is mainly concentrated in the heart of the die casting, near the sprue also has a small amount of volume gas, volume gas than the figure (b) of the vacuum die casting high. Vacuum die castings are mainly concentrated in the spillway area, a small amount of distribution in the center of the casting, the overall volume of air volume is less. It is
concluded that the organization of vacuum die casting is more dense.

![General Die Casting](image1.jpg) ![Vacuum Die Casting](image2.jpg)

**Fig.4 Air entrainment simulation results**

4. **Analysis of The Organization and Properties of Die Castings**

In the above-mentioned best process, the ordinary die casting and vacuum die casting were trial production, using the same process, the main difference is that one has a vacuum and the other does not have a vacuum, the final macroscopic photo of the die casting is shown in Figure 5. From the figure can be observed that the appearance of ordinary die casting and vacuum die casting are more complete, almost can not see any difference. However, due to the ordinary die-casting without vacuum, die castings inevitably have more rolled gas defects, which is particularly evident after heat treatment.

![Macro photo of die castings](image3.jpg)

**Fig.5 Macro photo of die castings**

From the simulation results, it can be seen that the defects and rolled gas of the radiator die casting are mainly concentrated in the heart. Therefore, we respectively take the ordinary die casting and vacuum die casting of the same position of the heat sink, the preparation of metallographic samples for comparative studies, heat sink sampling as shown in Figure 6.
From the microstructure of Figure 7, it can be observed that the distribution of pores in ordinary die castings is wide and larger, and the presence of oxidation inclusions; while vacuum die castings also exist pores, but the distribution of pores is smaller and smaller pores. Relatively speaking, magnesium alloy vacuum die casting heat sink on the pore defects, less than ordinary die castings, oxidation inclusions are also significantly reduced, the organization is also more dense.

Take the heat sink in the same position of ordinary die casting and vacuum die casting, respectively, for mechanical property testing, the tensile strength and elongation obtained as shown in Table 2. From the table, it can be seen that the tensile strength of the vacuum die casting compared to the ordinary die casting tensile strength increased by 14.2%, elongation increased by 43.2%.

### Tab.2 Comparison of mechanics performance between die casting and vacuum die-casting radiator

|                     | Vacuum Die Casting | General Die Casting |
|---------------------|--------------------|---------------------|
| σ₀/Mpa              | 225                | 197                 |
| δ/%                 | 5.3                | 3.7                 |

### 5. Conclusions

(1) Through the simulation software FLOW-3D, the filling simulation, defect field simulation and roll gas simulation are carried out for ordinary die casting and vacuum die casting, to understand the oxidation inclusions and roll gas of vacuum die casting is lower than that of ordinary die casting, to know the filling pattern of AZ91D magnesium alloy radiator, the main location of oxidation inclusions
and roll gas distribution.

(2) Through the test, we know that the appearance of vacuum die casting is intact and dense, and the tensile strength of vacuum die casting is 14.2% higher than that of ordinary die casting, and the elongation is 43.7% higher.

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References
[1] Peng,Y., Wang,S.C., Zheng,K.H. (2013) Research progress of high performance magnesium alloy casting technology. J. Casting Technology., 34: 203-204.
[2] Chen,X.H., Geng,Y.X., Liu,J. (2013) Research progress of functional materials of magnesium and magnesium alloys. J. Journal of Materials Science and Engineering., 31: 148-152.
[3] An,S.J. (2013) Study on vacuum die-casting process and tissue properties of magnesium alloy. D. Master's thesis, 2013.
[4] Wei,W., Alan A, Zhai, T.G., et al. (2012) Improved bending fatigue and corrosion properties of a Mg-Al-Mn alloy by super vacuum die casting. J. Scripta Material., 67: 879-882.
[5] Qi,W.J., Song,D.F., Cai,C. (2014) Research on vacuum technology for vacuum die casting of magnesium alloy radiators. J. Casting., 63: 328-329.
[6] Chen,S.T., Qi,W.J., Song,D.F. (2013) Optimization of pouring system for magnesium alloy radiator die casting. J. Special casting and non-ferrous alloys., 33 (12):1134-1136.
[7] Song,D.F., Qi,W.J., Wang,H.Y., et al. (2015) Study on die-casting process of magnesium alloy heat sink for LED. J. Casting., 64: 403-404.
[8] Li,X.B., Cao,W.T., Bai,Y.J. (2010) Study on the heat dissipation performance of AZ91D. J. Journal of Henan University of Technology., 29:685-688.