Study on Macrosegregation of Squeeze Casting Based on Multiphase Flow Model

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Abstract: Multiphase flow model was used to simulate the extrusion casting process of Al5Cu0.4Cu alloy. Pouring temperature, mold temperature, extrusion pressure and delay time before extrusion all have influence on Cu segregation in squeeze casting, and the influence of pressure is particularly important. The variation of Cu macrosegregation in castings was observed. The segregation of Cu is mainly due to the forced filling of Cu rich liquid phase and pressure at the solid-liquid interface. Compared with the results of experiment of casting, it is proved that the model simulation is more accurate.

Keywords: multiphase flow model; macrosegregation; simulation

1 Introduction

The macroscopic segregation of castings is mainly due to the inhomogeneous composition caused by the relative motion of solid and liquid phases during casting solidification [1]. This relative motion is mainly caused by convection of thermal solutes during solidification, flow caused by volume contraction, flow caused by floating or sinking of free crystals, and flow caused by different processes [2]. Although the squeeze casting process can effectively improve the segregation of castings, it is still inevitable to produce segregation. The pressure has a particularly important impact on the macro segregation of castings, and the change of pressure can effectively improve the segregation of castings.

In this paper, the distribution of copper element in squeeze casting $Al_5Cu_{0.4}Mn$ was studied by multiphase flow model and compared with experimental results. By comparing the results of experiment with simulation, It provides a basis for Al-Cu alloy squeeze casting to reduce macro segregation.

2 Experimental procedure

The experimental materials, shown in Table 1, contained very little Si(< 0.04%, mass fraction) and Fe(< 0.1%, mass fraction) and other unavoidable trace impurities by spectral composition analysis. It was squeeze cast to form cylindrical ingots with diameter φ=68mm and height *H*=57 mm. Because the pouring temperature and mold temperature mainly affect the temperature gradient and cooling rate of the metal, thus affecting the alloy structure. The higher pouring temperature and mold temperature will make the grain coarser, and the larger the grain size, the more serious the macroscopic segregation of Cu. So the extrusion parameters are shown in Table 2.

Table 1. Composition of alloy (wt. %)

Al	Cu	Mn
bal	5	0.4

Table 2. Main parameters of squeeze casting

No.	Pouring temperature /℃	Die temperature /℃	Applied pressure /Mpa
1	730	200	0
2	730	200	25
3	730	200	50

Result and discussion

Macrostructure of casting

The microstructure of squeeze casting ingots 1 to 3 is shown in Figure 1. With the increase of the pressure, the shrinkage and porosity of the ingot gradually weakened. This is because the increase of pressure made the metal liquid continuously flow to the central paste area, and the liquid was successfully forced to fill through the forced drive of pressure, thus reducing the shrinkage hole and porosity.

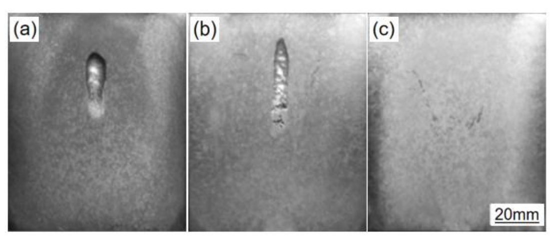

Figure 1 Macrostructure of casting:
(a)1; (b) 2; (c) 3

Composition of casting

A multiphase flow model was used to simulate the squeeze casting process of No. 2, and the final local Cu positive segregation was selected as shown in Figure 2. 20 positions were taken from each ingold for composition testing, which were the spectral components of five different heights along the radial direction (*R* = 4 mm, 12 mm, 20 mm, and 28 mm), and the equal height schematic diagram of Cu element distribution was obtained by fitting, as shown in Figure 2(1/4 ingot). It can be seen that the Cu segregation of $Al_5Cu_{0.4}Mn$ alloy after squeeze casting is mainly concentrated in the upper center of the ingot. This is caused by the forced extrusion of the low melting point copper rich liquid phase to the core of the casting.

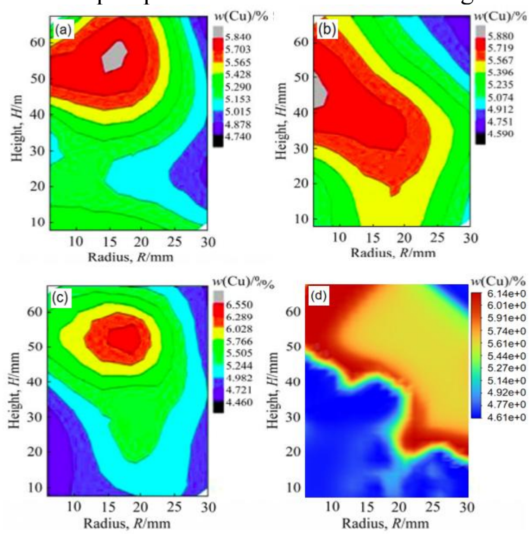

Figure 2 Local schematic of the distribution of Cu elements in an ingot: (a) 1; (b) 2; (c)3; (d) simulation result

Effect of pressure on Cu segregation

Cu segregation mainly depends on the release rate of Cu atoms at the front of the solid-liquid interface, the amount of Cu rich liquid phase and the flow state.

Zhong Yong et al. [3] pointed out that under high pressure, liquid with low melting point will flow into the dendritic gap, which will weaken the segregation, and with the increase of pressure, the segregation will gradually weaken. Bo Shuming et al.[4] pointed out that plastic deformation and metal liquid flow were compensated under pressure in the process of squeeze casting, so that the solid phase and interdendritic liquid phase were flowing toward the solid-liquid two-phase area, liquid phase area and shrinkage hole area with low resistance, so as to carry out forced shrinkage. In squeeze casting, the interdendritic liquid phase is forced to the core of the casting through the dendritic channel under the effect of pressure filling, and the abnormal positive segregation phenomenon is presented.

The comparison between the experimental segregation maximum and the simulated segregation maximum is shown in Table 3, which shows that the simulation results are more reliable.

Table 3. The experimental values are compared with the simulated values

	Experiment value	Value of simulation	Error value
Maximum segregation value of Cu	5.88	6.14	4.4%

4 Conclusion

In squeeze casting with different process parameters, the macrosegregation of the casting can be effectively weakened by changing the pressure. The multiphase flow solidification model has small error between simulation and actual situation under pressure and is more reliable.

Acknowledgments

We would like to acknowledge the financial support from the National Natural Science Foundation of China (No. 52074131)

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