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EFFECT OF INCLINATION ANGLE ON FLOW FIELD AND TEMPERATURE FIELD IN MOLTEN POOL DURING TWIN-ROLL INCLINED STRIP CASTING

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For the twin-roll inclined strip casting, simulate the fluid-thermal coupling in molten pool by mathematical model, and analyze the effect of tilt angle on flow field and temperature field in molten pool. The increase of inclination angle would enhance the asymmetry of temperature field and flow field, which provided a basis for adjustment of control strategy.

Keywords: magnesium alloy AZ31, casting, strip, temperature field, mathematical model

INTRODUCTION

The twin-roll inclined strip casting process is a process of high-temperature metal transformation from liquid phase to solid phase. During this time, variance in temperature directly affects the nucleation and growth of grain, so obtaining the temperature variation is the primary problem in simulation of twin-roll tilt casting. At the same time, the molten pool is asymmetric, and there is strong convection in the molten pool, which also has a significant impact on the formation of solidification structure. Based on the mathematical model of molten pool level in twin-roll inclined rolling in [1], the finite element method is used to simulate the flow and heat coupling in the molten pool, and the influence of inclination angle on the flow field and temperature field in the molten pool is analyzed, which provides basis for adjusting the control strategy.

SIMULATION MATHEMATICAL MODEL

Control equation

In twin-roll inclined strip casting, the molten metal in the molten pool is continuous, and its flow conforms to the continuity equation, momentum conservation equation and energy equation of fluid mechanics [2,3]. The flow of metal melt is turbulent, without considering the initial casting process, simulation can use the model proposed by Launder and Spalding [4,5] to study the flow behavior and heat transfer rule of metal melt in stable state.

Boundary condition

In the entrance area, the velocity boundary is given and the temperature load is applied. The surface of molten pool is under pressure and radiation from protective gas. Without regard to the fluctuation, the normal velocity of molten pool surface is zero. The velocity load and heat transfer boundary conditions are applied on the molten pool boundary contacting with the roller, where the flow velocity can be divided into horizontal component and vertical component . The flow velocity in contacting with the left roller is as formula (1), the other is as formula (2). The surface of the sheet in contact with air is loaded with radiation load.

$$V_x = V_c Y / R \quad V_y = -V_c X / R \tag{1}$$

$$V_x = V_c((2R + H_{out})\sin\beta - Y) / R \quad V_y = -V_c((2R + H_{out})\cos\beta - X) / R \tag{2}$$

Where: V_c is flow velocity, β is tilt angle, X is horizontal coordinate, Y is vertical coordinate, R is roll radius, and H_{out} is sheet thickness.

SIMULATION RESULTS AND ANALYSIS

Tilt angle is a very important parameter for twin-roll inclined strip casting. Its change has an important influence on temperature distribution and velocity distribution in molten pool. Based on the vertical twin-roll inclined strip casting mill independently developed by the magnesium alloy casting and rolling center of Liaoning University of Science and Technology, the influence of different tilt angles on flow field and temperature field in molten pool is studied by using commercial magnesium alloy AZ31 as the calculation material.

Effect of inclination angle on temperature field in molten pool

Figure 1 shows the temperature field in the molten pool under different inclination angles when the height

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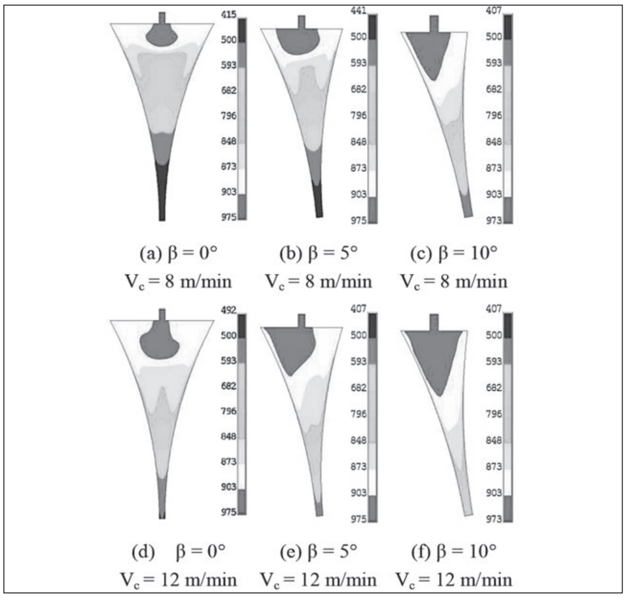

Figure 1 Temperature field at different inclination angle with Hpool = 70 mm

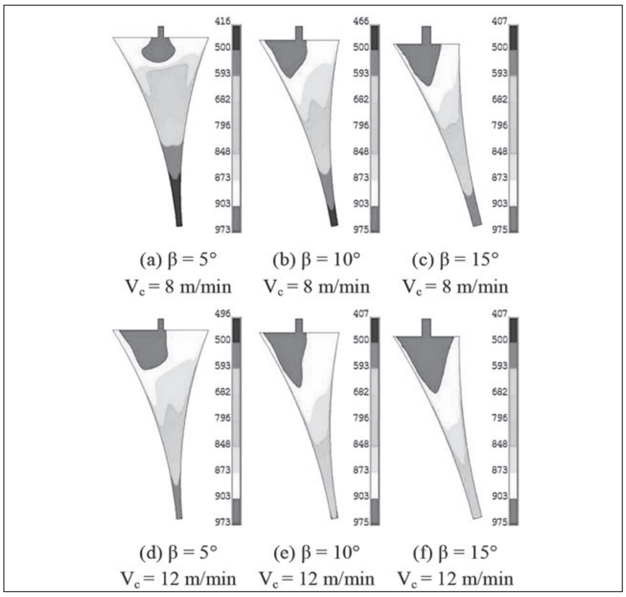

Figure 2 Temperature field at different inclination angle with Hpool = 80 mm

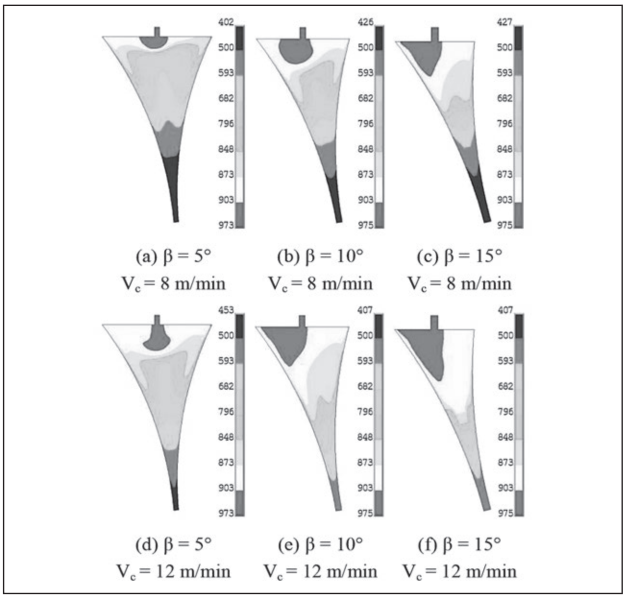

Figure 3 Temperature field at different inclination angle with Hpool = 90 mm

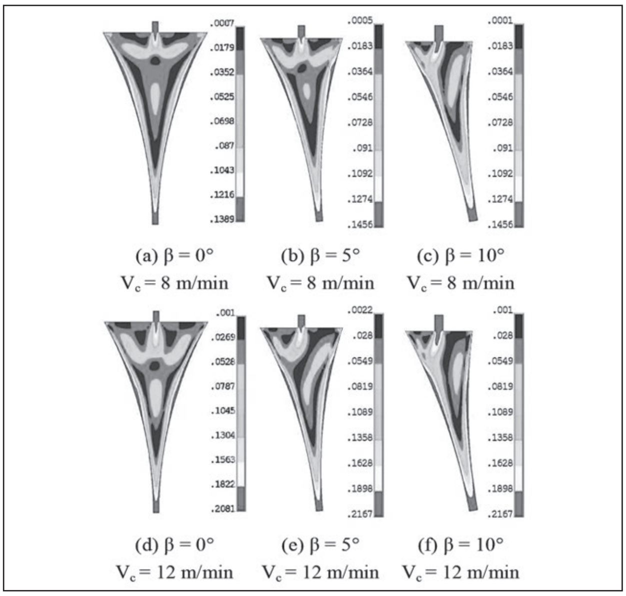

Figure 4 Flow field at different inclination angle with Hpool = 70 mm

of the molten pool is 70 mm. With the increase of inclination angle, the liquid region moves to the left, resulting in uneven temperature field distribution in the molten pool. Since the temperature drop on the right side is faster, the solidified shell first forms on the right side. The solidification front has no solidification convex caused by the low temperature in the central region, showing a V-shaped trend to the molten pool, which makes the metal deformation in the rolling zone around the twin-roll walls uniform and avoids the emergence of the sandwich.

Figure 2 shows the temperature field when the height of the molten pool is 80 mm, and Figure 3 shows the temperature field when the height of the molten pool is controlled at 90 mm. With the increase of the depth of the molten pool, the temperature field distribution remains constant. The liquid region in the middle of the molten pool moves to the left side, and the convex angle core generated during solidification disappears. The shape of the solidification line is similar to the molten pool, and the heat dissipation of the plate is uniform.

As can be seen from the figure, under the condition that other process parameters remain unchanged, the increase of inclination angle will make the solidification point move towards the outlet of the molten pool. When the inlet is located in the middle of the surface, the tilt angle has a significant effect on the temperature field in the molten pool. The increase of inclination angle changes the flow of molten pool, and this flow offsets the irregular temperature distribution caused by asymmetry. Whether the liquid surface height is 70 mm, the inclination angle is 5°, 10°, or the liquid surface height is 80 mm, the inclination angle is 15°, the position of the solidification bonding point is ideal.

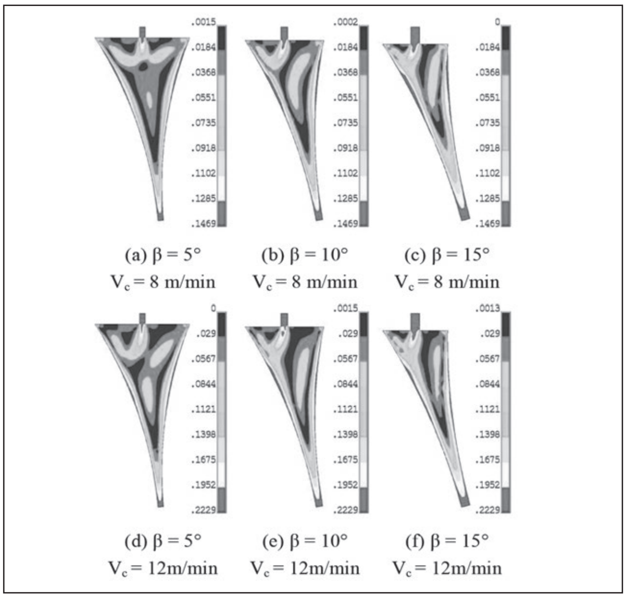

Figure 5 Flow field at different inclination angle with Hpool = 80 mm

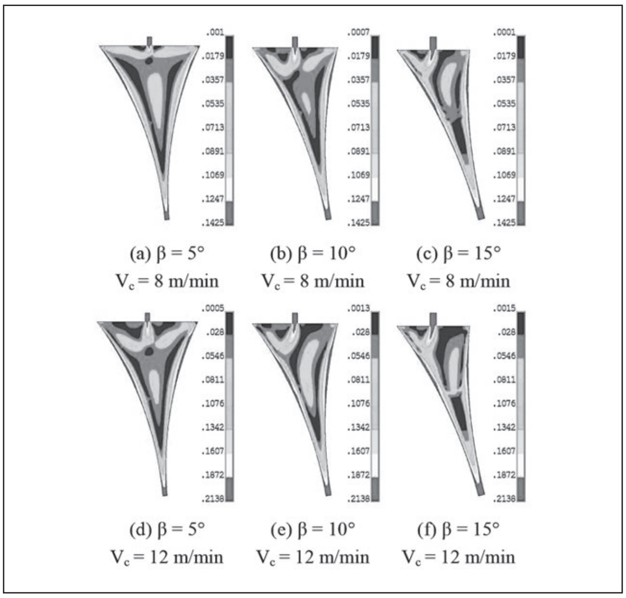

Figure 6 Flow field at different inclination angle with Hpool = 90 mm

Effect of inclination angle on flow field in molten pool

Figure 4 shows the flow field in the molten pool when the height of the molten pool is 70 mm. As the inclination angle increases, the left-right symmetry of the vortex in the molten pool gradually disappears. The flow velocity on the left side is along the direction of casting and rolling, and the melt on the right side forms a vortex with longer depth, which makes a faster heat dissipation in the right region and an increase in the thickness of the solidification shell.

Figure 5 shows flow field in the molten pool when the height of the molten pool is 80 mm, and figure 6 shows the flow field in the molten pool when the height of the molten pool is controlled at 90 mm. As the tilt angle increases, the range of the right vortex changes with the internal shape of the molten pool, but its position and asymmetry remain unchanged. From the perspective of the intensity of the flow field, the flow rate has little difference at the same casting-rolling speed, so the tilt angle only affects the shape of vortex generated by the flow field.

CONCLUSIONS

Applying the continuous fluid control equation and the finite element method, realize the fluid-thermal coupling simulation in the molten pool during the twin-roll inclined roll casting, and obtain the data of temperature field and flow field in the molten pool under different process conditions, which are the basic data for process optimization and effective control. In the twin roll inclined strip casting, the tilt angle is a very important parameter, which has a significant effect on the temperature distribution and velocity distribution in the molten pool. Under the condition that other process parameters unchanged, with the increase of inclination angle, the asymmetry of temperature field and flow field is more obvious, and the solidification point moves to the outlet of molten pool.

Acknowledgments

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Note: The responsible translators for English language is J. Wang-University of Science and Technology Liaoning, China