Study on the Liquid Metal Flow Field in Narrow-Side-Patter-Mold of Slab Continuous Casting

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Abstract. The flow pattern and velocity distribution of liquid metal in the Narrow-Side-Patter-Mold (NSP-Mold) have been investigated with a mercury model as analogue to molten steel in the continuous casting. The Ultrasonic Doppler Velocimeter (UDV) has measured the velocity under various magnetic distribution and flux density. The impingement intensity of liquid metal to mold narrow wall have been calculated based on the measured data, and the influence of magnetic flux density on the liquid metal flow in the mold has been analyzed. The results show that with narrow-side-patter magnet and increase of the magnetic field, the surface of the melt gets weak and the free surface fluctuation is suppressed, the impingement intensity of liquid metal to mold narrow wall gets weak, impacting depth becomes shallow and a plug flow can be rapidly formed.

Introduction

Molten steel flow in the continuous casting mold plays an important role in the eliminating of inclusions, entrapment of mold power, uniform growth of initial solidification shell, and the surface and internal quality of slab. With casting speed increasing, the flow rate and kinetic energy of molten steel poured from the SEN greatly increases, resulting in a more complex flow pattern in the mold, and some solidification defects, such as gas bubble and inclusion entrapment and corner crack, etc. will increase. Consequently, the flow control at the mold region has become a research focus and one of key technology.

In order to control the flow and improve the quality of continuous casting, electromechanical brake (EMBr), Flow Control Mold (FC-Mold) and FC-Mold II technology has been applied widely now. By above-mentioned the way of electromagnetic brake, the impingement intensity become more strong, impacting depth becomes deeper. If using upper magnetic field, impacting depth will becomes deeper. In order to suppress the impacting depth, a new way of electromagnetic brake is considered to get better result. The magnets in NSP-Mold consist of two parts, the left electromagnet is installed at left of the mold, and the right one is installed right of the mold.

When the liquid metal flows passes the static magnetic field region, a braking force is generated. The magnet field can suppress the surface fluctuation and brake the flow below the SEN, then the flow pattern and velocity distribution in the mold are optimized, promoting the formation of a plug flow in the mold. Therefore, the solidification defects will be eliminated, and high quality production is realized.

In present study, a mercury model is used to simulate the molten steel flow in the NSP-Mold and a Ultrasonic Doppler Velocimeter is adopted to measure the velocity of the liquid metal. With the model, the influence of the magnetic field on the flow pattern, the surface fluctuation and scouring effect on the mold wall are investigated.
Experiment

The Narrow-Side-Patter of continuous caster mold of a steel mill is built, as shown in Fig.1. The experimental system, as shown Study on the Liquid Metal Flow Field in FC-Mold of Slab Continuous Casting\(^3\) in Fig. 1. The cross point of centerline of SEN and the free surface of molten steel is set as coordinate origin and direction of coordinate axis is shown in Fig. 1. The parameters of experimental apparatus and magnetic fields are listed in Table 1. The magnetic flux density in the mold is shown in Fig.2.

![Figure 1. Schematic of physical simulation experimental apparatus of flow in mold.](image)

Table 1. Magnetic field intensities.

| Case | \(B_{\text{max}}\) (T) |
|------|----------------------|
| 1    | 0                    |
| 2    | 0.2                  |
| 3    | 0.3                  |

![Figure 2. Magnetic flux density.](image)

Results and Discussion

Flow Pattern and Velocity Distribution in NSP-Mold

With magnetic field, the vertical velocity of upward stream is increased. It shows that increasing the magnetic field leads to increase in the vertical velocity near the mold narrow wall and the quantity of flow of liquid metal upward the meniscus. It is beneficial to increase the temperature of the surface of the meniscus, melt slag. It is also beneficial to improve the effect of lubrication and uniformity. But it is also shown that the fluctuation near free surface is increased with magnetic flux density increasing and the surface tends to be instable. At the same time, the flow rate near the narrow side in lower
recirculation zone is weakened. It is also shown that increasing the magnetic field leads to decrease the quantity and vertical velocity of flow of liquid metal, the impacting depth becomes shallower. So it is easy to form a plug flow in the mold.

Flow Pattern and Velocity Distribution near Free Surface in the NSP-Mold

Fig.4 shows the horizontal velocity and turbulent intensity at 30 mm below the free surface. As shown in Fig.4 (a), in the case of B=0T, the maximum horizontal velocity is -0.28 m/s (direction of flow is shown in Fig.1). With the magnetic flux density of magnet at 0.3T, compared with the one at B=0T, the horizontal velocities in most part are smaller, -0.22 m/s. From Fig.4 (b), one can learn that with the magnetic field, the turbulence intensities of the flow near the surface are weaker than that without magnetic field, indicating surface being more stable.

It is indicated that the horizontal velocity near the free surface decreased with B≠0T, which is beneficial to reduce the slag entrainment by vortex near the SEN. In Fig.4 (b), the maximum turbulence intensity generated by the horizontal velocity component at meniscus without magnetic field is 0.08 m/s; as the magnetic flux density increases from 0T to 0.2T and 0.3T, the maximum turbulence intensity at meniscus decrease from 0.08 m/s through 0.053 m/s to 0.048 m/s. Therefore, the magnetic field can decrease the maximum turbulence intensity at meniscus, and improve the stability of the surface stream.

Impacting Intensity on the Mold Narrow Wall in NSP-Mold

Fig.5 shows the distribution of impacting intensity of the stream on the mold narrow wall. Without magnetic field, the peak value of impacting intensity of the liquid metal on the mold narrow wall is 1; with the magnetic flux density increasing from 0T to 0.2T and 0.3T, the peak value of impacting
intensity is 1, 0.34 and 0.30, respectively. From above calculated data, it is shown that the condition of magnetic field presents that increasing the magnetic flux density leads to decrease of the peak value of impacting intensity. This is beneficial to the generating of initial solidification shell.

![Figure 5. Influence of magnetic flux density on mold narrow wall.](image)

Conclusions

With the narrow side patter magnets and increasing the magnetic flux density, the flow velocity near free surface is decreased, the fluctuation at meniscus zone is suppressed and the stability of the surface stream is improved. At the same time, scouring intensity in lower recirculation zones is decreased, and the impacting depth becomes shallower. So it leads to be easy to form a plug flow in the mold.

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