Modeling of Macrosegregation with Liquid Core Reduction in Slab Casting

H F Shen[1],*, L Y Xu[2], Y H Dou[1], S Q Wen[1]
1. School of Materials Science and Engineering, Tsinghua University, Beijing 100084, China
2. Hunan Xiangtan Iron and Steel Co., Ltd., Xiangtan 411101, China
*Corresponding address: e-mail: shen@tsinghua.edu.cn

Abstract: During the continuous slab casting process, macrosegregation affects the product quality, and it can be improved by the liquid core reduction in which the strand thickness is reduced whilst its core is still in a liquid state. The formation of macrosegregation is a complex process related to various factors such as thermosolutal convection, mush deformation and grain sedimentation[1-2]. In this paper, a multiphase volume averaging model is developed with the liquid as the first phase and the columnar and equiaxed dendrites as the secondary and the third phases. The transportation conservation equations of each phase as well as the grain growth dynamics are coupled and solved. The results show that the model can be used to simulate the solidification process of continuous slab casting.

Keywords: continuous casting; macrosegregation, liquid core reduction; numerical simulation

1 Modeling of macrosegregation in slab casting

Figure 1 shows the numerically simulated liquid volume fraction f_l during the solidification process of continuous slab casting. It indicates that the high temperature molten steel enters the mold from the submerged entry nozzle (SEN) and a solid shell forms because of heat transfer by the water cooling.

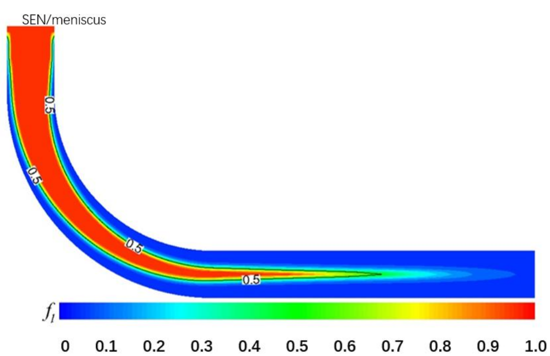

Figure 1 Solidification process of continuous casting slab

Figure 2 shows the carbon segregation index (SI=C/C_0) during the continuous slab casting. Comparing with the solidification front in Figure 1, it can be found that solute is enriched at the solid-liquid interface, and the enrichment increases with the liquid core depth. Finally, an obvious positive segregation forms at the centerline while a negative segregation forms at the surface of slab.

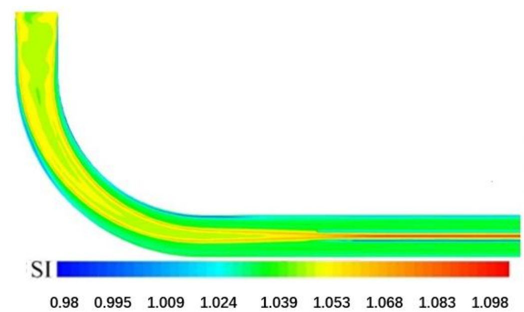

Figure 2 Macrosegregation in continuous slab casting

Figure 3 shows the evolution of liquid fraction and segregation index along the casting centerline. Segregation index is highest after fully solidification.

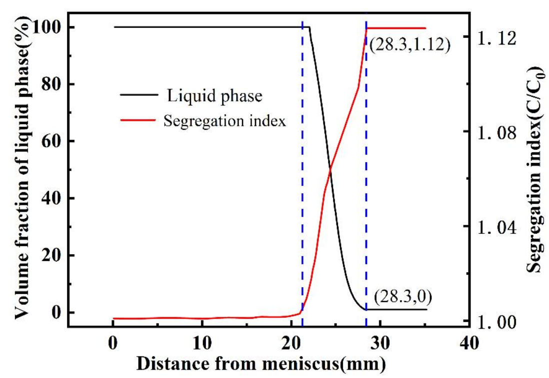

Figure 3 Evolution of liquid fraction and segregation index along casting centerline

Figure 4 shows the distribution of the carbon segregation index along the slab thickness at different distances to the meniscus *L*. Obvious solute enrichment is also found at the solid-liquid interface (referring Figure 1). When *L* is less than 20m, the concentration in the liquid pool is relatively homogenous compared to that at the solidification front and it increases with the increasing *L*. However, when *L* is larger than 20m, the concentration at the solidification front decreases first and then increases sharply. This decreased concentration at the solidification front may be lower that the melt initial concentration C_0, so the negative segregation forms near the solidification end, which can be explained later.

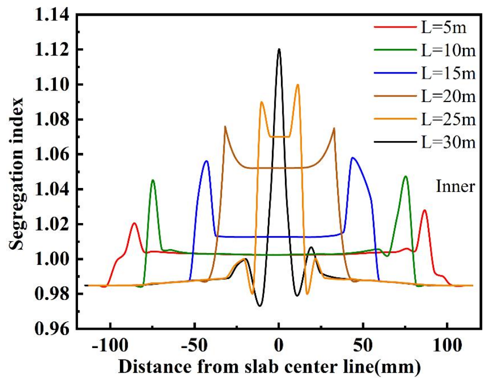

Figure 4 Segregation index at different thickness position to meniscus

Figure 5 shows the distribution of volume fraction of equiaxed phase and liquid, as well as segregation index of equiaxed along the thickness at 24m from the meniscus. Equiaxed nucleates ahead of solidification front because of decreasing temperature. Equiaxed with lower concentration sediments because of its heavier density and negative segregation may forms as shown in Figure 4.

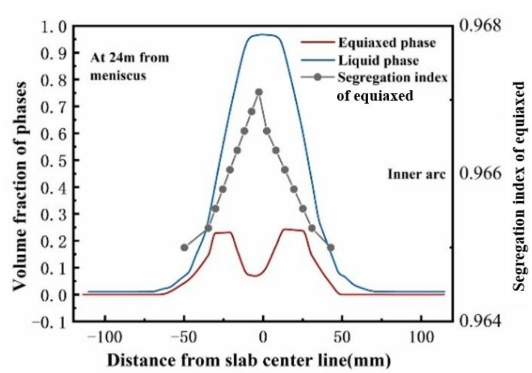

Figure 5 Liquid and equiaxed fractions as well as equiaxed segregation index along thickness

2 Effect of liquid reduction on macrosegregation

Figure 6 shows the distribution of carbon concentration along the thickness at the center of slab with different thickness reductions. It is found that the central segregation is reduced by using liquid core reduction. The segregation index C/C_0 at the center decreases from 1.11 to 1.06 when the thickness reduction is applied from 0 mm to 5 mm. Further more, negative segregation may form if the over large thickness reduction of 10 mm is applied. Concentration beyond the slab center increases because the species is pushed from the center with the reduction.

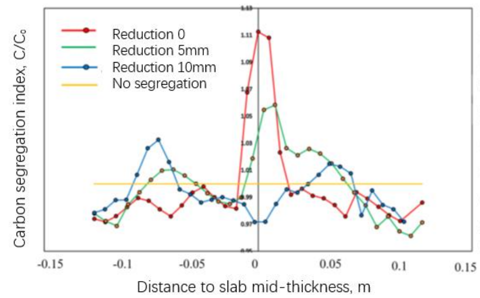

Figure 6 Effect of liquid reduction on macrosegregation

Figure 7 shows the fluid flow in the mush during the solidification of cast slab with the liquid core reduction. It is found that a backflow is pushed at the solidification end because of the enforcement of reduction. It can be explained that the center segregation is reduced because of homogenous of species caused by the backflow.

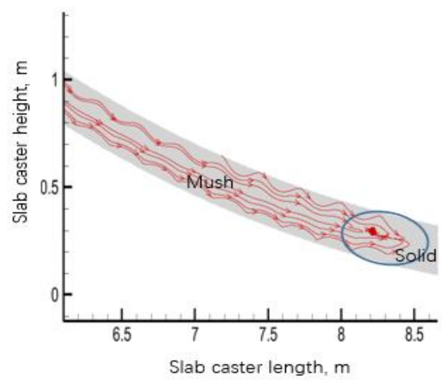

Figure 7 Backflow caused by the mush compression

3 Conclusion

The serious positive segregation is found at the center of continuous casting slab and the negative segregation is found near both sides of the thickness center, which is caused by the equiaxed sediment. The center segregation can be improved by the liquid core reduction because of the homogenous of species and the backflow induced by the mush compression.

References

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