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Analysis of Center Segregation Induced by Density Changes and Shrinkage Cavities Using a Moving-Slice Model in Continuous Casting

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A simple yet effective method has been developed to simulate macro-segregation during continuous casting. The model focuses on a thin slice moving at the casting speed, incorporating temperature and solid/liquid fraction profiles derived from prior heat transfer and solidification analyses. Solidification is specifically modeled along the thickness direction of the slice.
The model incorporates micro-segregation and two key flow mechanisms: density-driven flow, governed by mass balance, and cavity-driven flow, which occurs as liquid and equiaxed crystals fill the solidification cavity forming at the center during solidification.
Density-driven flow leads to positive macro-segregation near the center in both slabs and blooms, but the effect is significantly stronger in blooms. This is attributed to their higher Flow Contribution Ratio (FCR), which quantifies the relative contribution of Y-axis flow to overall flow and is likely influenced by greater solidification shrinkage.
The cavity-driven flow model successfully explains the observed positive segregation peak at the center and the negative segregation peak at the total shrinkage location—phenomena that density-driven flow alone cannot account for.
The model's predictions closely match experimental data and exhibit expected trends when casting conditions—such as casting speed, secondary cooling intensity, and steel composition—are varied. This provides valuable insights for optimizing casting parameters to minimize center-segregation.
Additionally, the model aids in optimizing soft reduction patterns, which directly influence the velocity of the solid/liquid interface and the size of shrinkage cavities. By aligning the reduction pattern with the solidification shrinkage rate and considering the increasing liquid concentration during solidification, the model offers a precise and efficient method to reduce center-segregation.
With its fast computation speed, the model is well-suited for both offline analysis and real-time implementation, making it a valuable tool for research and industrial applications.

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