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High-Cleanliness Production of Crankshaft Steel through Optimization of Slag Composition

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Based on the Ion–Molecule Coexistence Theory (IMCT) and the steel–slag equilibrium theory, this study establishes a thermodynamic equilibrium calculation model for the high-cleanliness production of crankshaft steel. Systematic calculations were performed to determine the rational distribution range of SiO2 in the slag, as well as the recommended CaO/Al2O3 ratio. The variations in inclusion composition and population before and after slag optimization were then comparatively analyzed. The results indicate that, for the crankshaft steel investigated in this work, achieving a high level of cleanliness requires the aluminum content in steel to be no less than 0.008 wt%. Correspondingly, the SiO2 content in the slag should be maintained below 10 wt%, while—considering slag stability during refining—it should not fall below 5 wt%. Increasing the CaO/Al2O3 ratio effectively reduces the activity of SiO2, thereby mitigating its oxidizing effect on the molten steel. Furthermore, to ensure favorable slag formation behavior and efficient inclusion absorption, the slag composition should be adjusted as close as possible to the liquid phase region of the CaO–Al2O3–SiO2 ternary phase diagram. Through the optimization of slag composition and the coordinated design of Al and Si contents in steel, the cleanliness of crankshaft steel was significantly improved, with a pronounced reduction in both the number and the overall size of large inclusions.

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