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Development of Variable-Width Chamfered Mold Technology for Slab Continuous Caster in CSC

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Transverse corner cracks are the main defects in the continuous casting of peritectic steels due to the δ→γ phase transformation, which induces volumetric shrinkage and weakens the solidifying shell. The presence of microalloying elements such as Nb, Al, and V further reduces ductility by promoting grain boundary precipitation above the Ar_3 temperature, leading to third-brittle-zone embrittlement. Conventional chamfered molds can mitigate overcooling at corners but are limited by their fixed width, which restricts production flexibility. This study introduces a novel variable-width chamfered mold system, which integrates a redesigned mold oscillation program, fully nickel-plated length-side mold plates, and optimized secondary cooling strategies. These innovations improve contact between mold and shell, enhance thermal performance, and maintain mold durability during frequent width changes. Industrial trials on standard, microalloyed, and Nb-added peritectic steels showed a 78.8% reduction in transverse corner crack rates. Hot-rolled coils exhibited improved edge surface quality, while cold-rolled coil quality remained stable. The new mold system demonstrated strong operational reliability, achieving over 681 heats per unit without mold damage or breakout incidents. Overall, the variable-width chamfered mold provides a flexible and effective solution for improving slab quality and process stability in peritectic steel casting.

Keywords: Peritectic steel, Chamfered mold

1. INTRODUCTION

Transversal cracks are one of the most significant defects in a continuous casting peritectic steel slab. Peritectic steels, with carbon content ranging from 0.08% to 0.16%, undergo a peritectic reaction during solidification, wherein the δ phase transforms into the γ phase accompanied by volumetric shrinkage. This shrinkage leads to the formation of gaps between the initial solidified shell and the mold wall, reducing the heat transfer efficiency at the shell-mold interface. Consequently, the shell becomes thinner and less capable of withstanding mechanical stress, increasing the susceptibility to transverse corner cracks[1].

The addition of microalloying elements such as niobium (Nb), aluminum (Al), vanadium (V), and boron (B) further complicates the issue. At elevated temperatures, these elements tend to form precipitates with carbon and nitrogen at the austenite grain boundaries. Such precipitates weaken the grain boundaries under stress and deformation, thereby reducing the ductility of the material. This phenomenon typically occurs above the Ar3 temperature range (700-900°C) and is referred to as the third brittle zone[2].

In addition to compositional factors, abnormalities in the secondary cooling zone of the continuous casting machine—such as misalignment or irregular roll gaps in the roller segments—can cause local bulging or depression of the solidifying shell. These deformations induce additional strain, particularly at the slab corners, and can trigger transverse corner cracks. This issue is more pronounced in vertical-bending-type casters, which, while promoting better inclusion flotation and higher steel cleanliness in the vertical segment, involve more bending segments compared to curved-type casters, thus imposing greater strain on the solidifying slab.

Besides the commonly reported approaches in the literature—such as controlling nitrogen content and stabilizing superheat—employing chamfered molds has proven effective in mitigating corner overcooling and reducing the risk of transverse corner cracks. Chamfered mold technology is recognized as an excellent solution to completely solve this problem. We have established chamfered mold technology in the No. 5 caster in CSC. However, conventional chamfered molds are of fixed width, limiting production to slabs of uniform dimensions and thereby constraining the variety of steel grades and casting schedules. In this study, we propose a novel variable-width chamfer mold technology that addresses the corner overcooling issue while maintaining production flexibility and downstream quality requirements [(3,4)].

2. DEVELOPMENT TECHNOLOGY OF VARIABLE-WIDTH CHAMFER MOLDS

2.1 Development of a New Mold Oscillation Program

A new mold oscillation program was developed for chamfer molds to address the issue of prolonged gaps between the mold and the solidifying shell in the previous system. A comparative schematic of the original and new oscillation curves is shown in Figure 1. The original oscillation curve (3-phase) consisted of three linear segments; however, discrepancies between the actual slab width and the preset values often led to deviations in the curve due to mechanical resistance during operation. The new oscillation curve (chamfered) ensures consistent contact between the copper plate and the solidifying shell throughout the process. The actual slab width dynamically synchronizes with the target values through real-time feedback, resulting in a more stable mold oscillation process. Moreover, the newly developed program is also applicable to right-angled molds, reducing the risk of breakout during oscillation.

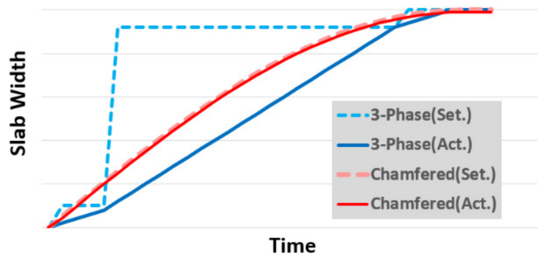

Fig.1. Schematic diagram of the mold oscillation curve.

2.2. Development of Fully Electroplated Nickel on the Length-Side of the Mold

In the design of the chamfer mold, the traditional configuration of three flat foot rolls was modified to two chamfered foot rolls and one flat foot roll. Shown in Figure 2. For conventional right-angled molds, the length-side mold plate was composed of one-third pure copper in the upper section and two-thirds nickel-plated copper in the lower section, while the width-side plate was cobalt–nickel plated. To accommodate frequent oscillations in the variable-width chamfered molds and prevent surface scratching, the length-side plate was upgraded to fully electroplated nickel. This modification improves surface hardness and enhances heat extraction performance.

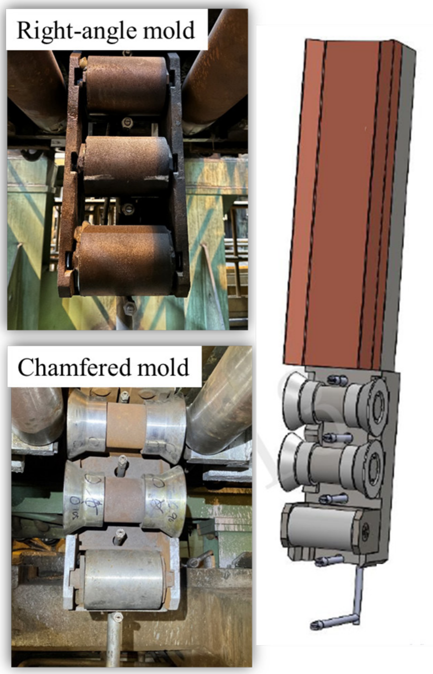

Fig.2. Schematic diagram of the foot rolls.

2.3. Optimization of Secondary Cooling, Mold Taper, and Plate Gap

To prevent breakout during the oscillation process in the variable-width chamfered mold, water flow rates were increased in both the width-side mold and the secondary cooling zone to promote shell formation. The mold taper was also optimized to enhance width-side support in chamfered slabs.

3. RESULTS AND DISCUSSION

During the initial trial production of chamfered molds, bleeding defects were observed at the chamfered corners of the slabs. After investigation, these defects were attributed to the mold gap. It was determined that the mold gap must be controlled to below 0.6 mm after each casting sequence. Subsequent monitoring confirmed that the bleeding defects were successfully mitigated by adhering to this specification.

In terms of slab quality improvement, three major peritectic steel grades were monitored—standard peritectic steel, microalloyed peritectic steel, and Nb-added peritectic steel. The implementation of chamfered molds led to a 78.8% reduction in the detection rate of transverse corner cracks. Additionally, the rejection rate of edge surface defects on hot-rolled coils was significantly lower compared to those produced with right-angle molds. The cold-rolled coil quality was found to be comparable between the mold types.

From a production perspective, the chamfered molds demonstrated an average service life exceeding 681 heats per unit. Even after undergoing several hundred mold width adjustments, no instances of mold wall scratches or breakout accidents were reported.

4. CONCLUSIONS

In the present work, technologies for variable-width chamfered molds have been studied. The major findings can be summarized as follows:

4.1 Enhanced Crack Resistance in Peritectic Steels

The usage of chamfered molds significantly reduced the occurrence of transverse corner cracks in peritectic, microalloyed peritectic, and Nb-added peritectic steels, achieving an improvement rate of 78.8%.

4.2 Improved Surface Quality in Downstream Products

Hot-rolled coils cast with chamfered molds exhibited a lower rejection rate due to edge surface defects compared to those from right-angled molds, while the cold-rolled coil quality remained comparable.

4.3 Increased Mold Durability and Operational Safety

Variable-width chamfered molds maintained an average service life of over 681 heats and withstood hundreds of width adjustments without causing mold wall scratches or breakout incidents.

4.4 Technical Advancements in Mold Design and Process Control

Innovations include a new mold oscillation program, full nickel plating on the mold length-side, and optimized secondary cooling parameters. Which contributed to improved casting stability and shell formation, thereby enhancing product quality and process reliability.

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