# CUSTOMIZED COPPER PLATE SHAPE OF STEEL CONTINUOUS CASTER FOR REDUCING SLAB SURFACE CRACKS

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SYNOPSIS:

During the molten steel pours into the continuous casting mold and it solidifies, various sorts of cracks present on the slab surface depending on steel grades, casting conditions and characteristics of steel casters. For instance, the most common cracks on slab surface are a longitudinal crack on the wide face and a transverse corner crack along the slab corner.

Steel grades which easily cracks such as hypo-peritectic steel are subjected to a surface machining such as a scarfing or grinding in advance of a rolling-process. However since this process may be quite costly among the steel production, great efforts are necessary to minimize the cracks. Therefore, POSCO had developed the customized copper plates including a chamfered mold of narrow face and a self-designed copper plate of wide face. These technologies are being applied to the specific caster with higher cracking rate, we verified that it works properly to achieve the reduction of the transverse corner crack and longitudinal crack, simultaneously.

In order to improve slab surface quality, we introduce activities how to analyze the causes of cracks and improve to minimize the cracks on slab.

**Keywords:** Continuous Casting, Mold, Corner Cracks, Longitudinal Cracks, Copper Plate, Chamfered Mold

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## INTRODUCTION

The chamfered mold technology is to reduce corner cracks by bending and unbending slab at the temperature ranges where crack does not occur with raising corner temperature. For this reason, many steelmakers adopt this technology [1,2]. Unfortunately, however, the longitudinal cracks occurred on the chamfered face as a side effect [3]. The corner air gap between the solidifying steel shell and copper plate which exacerbate uneven solidification, resulting in the longitudinal cracks on chamfered face.

Also, most of steelmakers are frequently facing with the longitudinal cracks on wide face of the slab during the casting of hypo-peritectic steel, and great efforts are being made to reduce them in various ways [4,5]. For example, the longitudinal cracks on wide face are reported that the crack can be reduced through the uniformity of the temperature distribution in the width direction of the copper plate. In the case of 0.14 weight percent carbon steel with adding Niobium, for example, the longitudinal crack on wide face forms over 90 percent in POSCO as shown in Table I.

Table I. The present rate of the longitudinal crack on wide face in POSCO

| Ranking | Carbon Content [wt%] | Additional Alloy | Longitudinal Crack on Wide Face Ratio |
|---|---|---|---|
| 1. | 0.14 | Niobium | 90 % |
| 2. | 0.15 | Niobium, Titanium | 75 % |
| 3. | 0.10 | - | 60 % |
| 4. | 0.16 | Niobium, Titanium | 35 % |
| 5. | 0.12 | - | 20 % |

## COMPUTATIONAL MODEL APPLICATION TO COPPER PLATE MOLD

### A. Model for Longitudinal Cracks on Chamfered Face

A symmetrical quarter of two-dimensional transient slice model was simulated in this work. All the equations of the coupled-temperature displacement model were solved using the finite-element method with commercial software ABAQUS 2017 [6]. Most of the thermal and mechanical properties are calculated by JMatPro® [7] and used in this model. In order to improve the consistency of the model, many boundary conditions are considered. The superheat flux flowing into the solidifying steel shell from the molten steel flow in the mold are calculated by Computational Fluid Dynamics method. In addition, the measured temperature distribution of whole cooper plate using optical fiber sensors and the thermal deformation of the mold based on copper temperature distribution were input to the model as boundary conditions.

The simulation result in the corner region at every 100 millimeter away from the meniscus is shown in Figure 1. Solidification proceeds as the steel shell goes downward along the mold as the casting speed. Accordance with temperature goes down, the shrinkage of the steel shell occurs rapidly in mushy zone region where the liquid phase transforms to the solid phase, especially mold upper region. Since the solidification shrinkage direction towards into the center of the wide and narrow face, a large gap is generated near corner region which is called chamfered face. A mold flux cannot be filled with in large gap, so the air gap that exacerbates uneven solidification is unavoidable. Therefore, a customized chamfered mold which can compensate the amount of solidification shrinkage at multiple regions is needed using multi-tapered shape.

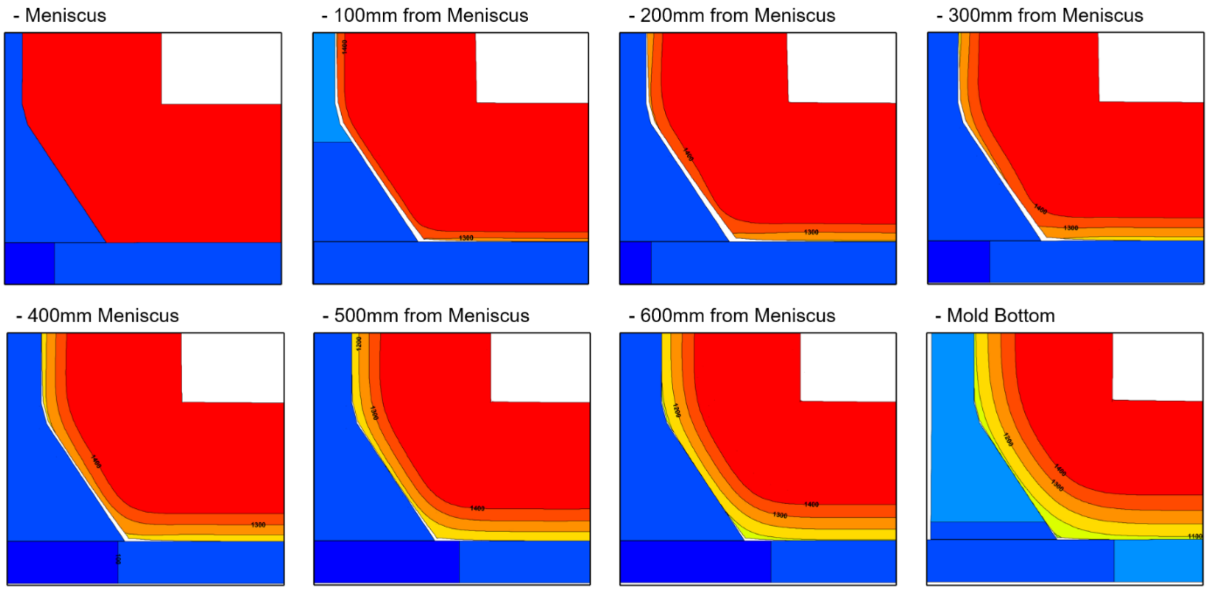


Figure I. Corner behavior of chamfered mold.

B. Model for Longitudinal Crack on Wide Face

A symmetrical quarter of three-dimensional steady-state model was also simulated in this work. All the equations of the coupled-temperature displacement model were solved using the finite-element method with commercial software ABAQUS 2017 [6]. The interfacial heat flux between solidifying steel shell and copper plate measured by optical fiber sensors was input to the model as boundary conditions. To evaluate the choice of boundary conditions, the model was validated with measured temperature distribution.

According to the simulation result shown in Figure 2, the temperature deviation between the tension bolts in the wide face is up to 15 degrees before customization of wide face. However, after the custom design is applied, the deviation is decreased to 3 degrees, also a slow cooling effect can be achieved as the average of temperature rises.

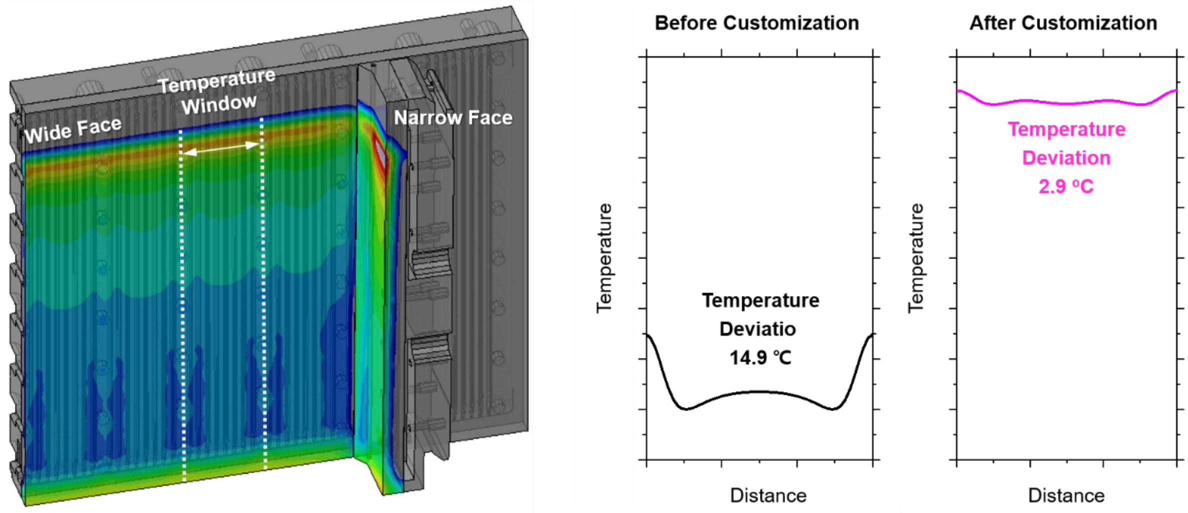


Figure 2. Temperature profiles 65mm below meniscus before and after customization of Copper Plate

# RESULTS AND DISCUSSION

## A. Multi-taper Chamfered Mold of Narrow Face

For reduction of both transverse corner cracks and longitudinal cracks on the chamfered face simultaneously, the multi-taper chamfered mold is designed using a numerical simulation and optimized with many plant trials. More than 1.3 millions of tonnes of slab were casted by multi-tapered chamfered mold in both Pohang and Gwangyang Works as shown in Table II. Since the multi-taper mold can minimize the air gap between solidifying steel shell and copper plate, it is possible to achieve zero longitudinal cracks on chamfered face.

Table II. The rate of longitudinal cracks on chamfered face after using the multi-taper chamfered mold of narrow face

| Caster | | No. of Heats | Longitudinal Cracks on Chamfered Face Rate |
|---|---|---|---|
| Pohang | A | 1,500 | 0 % |
| | B | 4,200 | 0 % |
| Gwangyang | C | 3,000 | 0 % |
| | D | 1,000 | 0 % |

## B. Uniform Cooling Mold of Wide Face

For decreasing longitudinal cracks on wide face, the copper plate was re-designed using the numerical simulation to minimize the temperature deviation along with mold width direction. By applying the uniform cooling mold to the caster that generates the longitudinal cracks the most in Pohang Works, it is possible to reduce the cracks more than 40 percent of the slabs produced more than 1.2 million tonnes as shown in Table III.

Table III. The rate of longitudinal cracks on wide face before and after using the uniform cooling mold of wide face

| Caster | | No. of Heats | Longitudinal Cracks on Wide Face Rate |
|---|---|---|---|
| Pohang | B | 8,200 | 4.1 → 2.4 % |

Both customized mold shape technologies are no operation instability such as breakout and severe mold level fluctuations, etc.

## CONCLUSIONS

The chamfered mold is effective to reduce the slab transverse corner crack, but the longitudinal cracks on chamfered face are issued. According to the simulation results, the longitudinal cracks on chamfered face is caused by larger shell shrinkage compared to the given mold taper especially in mold top corner region. The multi-taper mold which can compensates initial shell contraction is possible to utilize stably without any cracks in slab corner.

The temperature deviation distributed on copper plate in the slab width direction can initiate longitudinal cracks on wide face, especially in the hypo-peritectic steel. The longitudinal cracks on wide face can be reduced more than 40 percent with customized uniform cooling mold.

## ACKNOWLEDGMENTS

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