IMPROVEMENT OF CORNER CRACKS IN SLAB CONTINUOUS CASTING FOR PERITECTIC STEEL BY CHAMFERED MOLD TECHNOLOGY

BY

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SYNOPSIS:

To improve the transverse corner cracks of peritectic steel slabs, the chamfered mold technology had been developed in CSC. However, the complex geometry of the chamfered mold resulted in bleeding defect and longitudinal depressions. By adapting the design of chamfering slab supporting foot roll system, increasing the slope of the narrow side for the mold, using nickel-cobalt alloy coatings for mold coppers, increasing the frequency of slag cleaning, the transverse corner crack rate lowered down 33%, and the bleeding rate was also decreased. Eventually, through the successful application of the chamfered mold technology, the quality of the peritectic steel slabs had been improved and the recondition cost of slabs was greatly reduced.

Keywords: transverse corner crack, peritectic steel, chamfered mold, slab continuous casting

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1. INTRODUCTION

Mostly high-grade products which are peritectic steel such as tinplate and high-strength automotive steel are often rejected due to sliver defects, as shown in Fig. 1. Figure 2 shows an example of a defect revealed by OM for cross section, the sliver gap fills with scale which grows at high temperature and sufficient time, decarbonization and internal oxidation only exist above area of gap. Besides, part of slabs were found of transverse cracks at the corner, as shown in Fig. 3. Obviously, the sliver defects on the hot-rolled coil were caused by transverse corner cracks from the slab. Cold inspection and recondition is required to ensure the slab quality, and additionally, the cost and carbon emission after reheating of cold slab were enormous.

Fig. 1 Sliver defect on hot-rolled coil of peritectic steel.

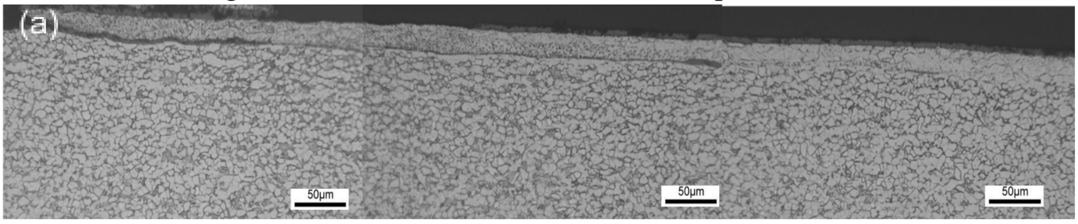

Fig. 2 Sliver defect revealed by OM.

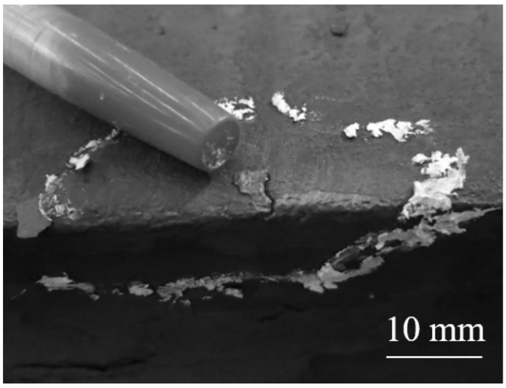

Fig. 3 An example of transverse corner crack of peritectic steel.

The mechanism of transverse corner crack is complex. The hot ductility performance of steel slab is affected by chemical compound and 2nd cooling design. For example, the crack risk is relatively high of peritectic steel and HSLA steel because of low hot ductility which is related to the austenite grain size, the grain boundary precipitation and the peritectic effect[1]. Considering the source force of crack applied on the slab, such as unbending stress and the abnormal mechanical stress, which came from mold mismatch or strand misalignment. The quality of alignment and mold oscillation were very important and useful to keep good quality of slab, but not easy to keep stable for long time and hard to exam online. Besides, the crack appeared at slab corner easily, related with conventional mold design, the rectangle slab corner slab corner getting 2-Dimension cooling, which was different from slab face, only 1-Dimension cooling. In this case, the hot ductility and surface temperature when unbending were lower than slab face. Additionally, the strain concentration effect also occurred at corner, which made peritetic steel corner more crack-risky [2].

The concept and study about chamfered mold technology were developed during this three decades, the idea eager to reduce the 2-Dimension cooling and strain concentration of slab corner, to increase surface temperature therefore the hot ductility would increase when unbending, to separate the stress and strain so that reducing the possibility of frack [3, 4].

2. MATERIALS AND METHODS

From the research, enhancing higher surface temperature by chamfered mold might resulted in steel shell was too thin and weak therefore bleeding defect and longitudinal depressions appeared. In addition, the complex geometry brought other producing bottlenecks, such as the difficulty of mold-width change when casting, and the short life time of mold comparing with conventional mold [5, 6].

To reduce transverse corner crack and to solve above problems, an integrated chamfered mold technology which developed and applied in the mill consisted of (a) large chamfered face, to solve transverse corner crack problem, (b) enhanced mold cooling, multi-face design, and modified foot roller, to ensure the support of chamfered slab shell [6]. Besides, the strategy to make mold life-time close to conventional mold were (c) extending the mold repair equipment and changing coating material from nickel alloy to nickel-cobalt alloy for better wearing ability, (d) adjusting the production schedule, and (e) improvement of mold and foot roller alignment skill (f) increase of slag clean frequency.

The first applied caster was a vertical-bending which provided low carbon steel, peritectic tin plate steel and low alloy steel for hot rolling. Fig. 4 shows the slab appearance produced by chamfered mold.

Fig. 4 slab produced by chamfered mold

3. RESULTS AND DISCUSSION

3.1 Slab defects

Fig.5 Shows transverse corner crack rate of chamfered slab was reduced by 33% compared with conventional slab, quality improved significantly.

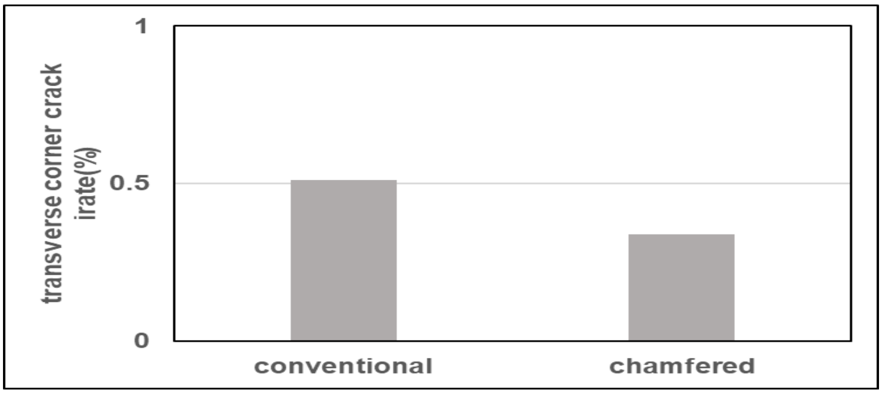

Fig.5 the transverse corner crack rate between conventional and chamfered slab

The bleeding defect was found at slab narrow face from few batches, as Fig.6 (a) shown. Bleeding was parallel with oscillation mark, and the defect size was short. These slabs didn’t get breakout while out of mold, which meant there were small transversal cracks appearing in the mold and liquid steel leaking out, then repaired in short time. According to the appearance of shell and oscillation mark, shell was without messy sticking un-melting casting powder or sticking point. The oscillation marks lined well, parallel and straight, didn’t tilt as sticking breakout occur. Which indicated that lubrication in the mold was well and no potentially sticking-type breakout. Besides, face and corner of mold didn’t have fatal damage or deformed, the seam between broad face mold and narrow face mold didn’t filled with large slag or steel, which told the mold quality was well. From these phenomena, the cause of bleeding were unrelated with ill lubrication or bad mold quality. Another mechanism was considered, the slope of chamfered mold and theoretical multi-face design was not sufficient to compensate the shell shrinkage at partial area of mold. The weight of liquid steel and demolding process gave the shell a tear force so the crack appeared. The bleeding rate between different taper ratios is shown at Fig. 6(b). By increasing 0.01% taper ratio, the bleeding ratio was decreased 81%, compared with initial design.

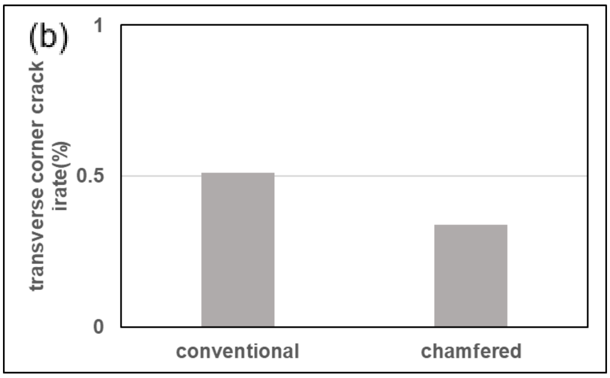

Fig.6 (a) bleeding at chamfered slab narrow face (b) the bleeding rate of narrow face between deferent taper ratio(taper ratio: (top-bottom)/bottom*100%)

3.2 Hot rolled coil defects

Fig.7 shows the defect rate of peritectic steel after hot rolling, coils produced by chamfered mold was 57% lower than those produced by conventional mold. Rejected rate of peritectic tin plate produced by chamfered mold decreased 78% comparing with coil produced by conventional mold. Taking more than one year observation, the chamfered slab and hot rolled coil quality was very stable, therefore, slabs could run hot-charge process directly, free from recondition, which earned quality and cost gratefully.

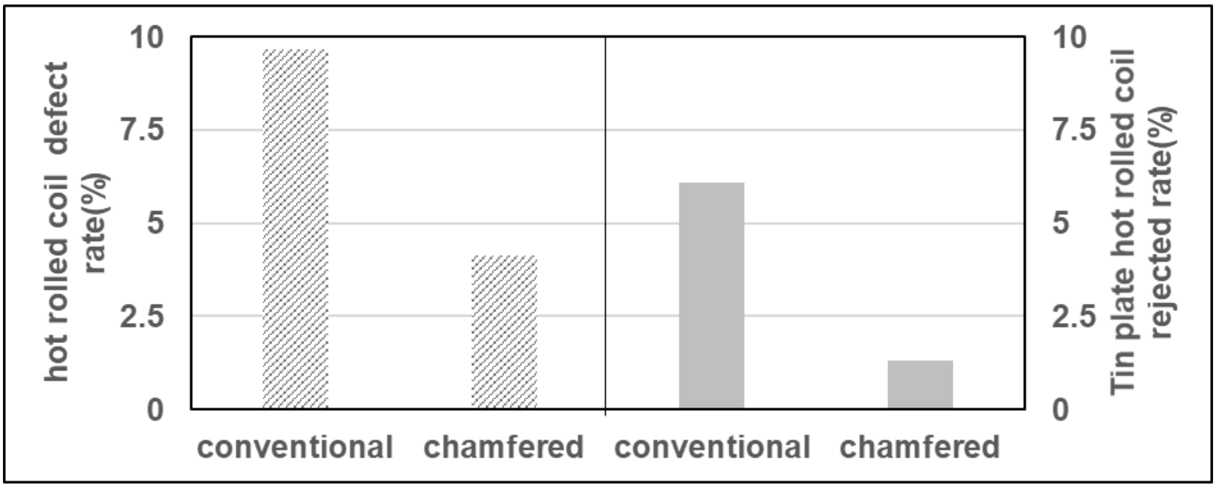

Fig. 7 the defect rate of peritectic steel and the rejeted rate of peritectic tin plate between conventional and chamfered slab after hot rolling.

4. SUMMARY

With the application of chamfered mold, changing coating material from nickel alloy to nickel-cobalt alloy for mold coppers, and increasing slag clean frequency, slab transverse corner crack lowered down 33%, compared with slab produced by conventional mold. Through increasing 0.01% taper ratio, the bleeding defect at slab narrow face decreased 81%. Eventually, the hot rolled coil defect rate reduced by 57%, which indicated peritectic steel quality control is long-term well via introducing chamfered mold technology and saved the cost of recondition of slab gratefully.

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