# Multi-Factor Process Parameter Optimization of S30432 Continuous Casting Secondary Cooling Process

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**Abstract:**Niobium-containing austenitic stainless steel is widely used in ultra-supercritical thermal power units due to its excellent high temperature stability and corrosion resistance. Due to the high Nb content in S30432, the coarse primary NbC phase is produced during the solidification process of continuous casting, which can easily lead to the central crack of continuous casting billet and the perforation deformation crack of subsequent seamless pipe. In this study, high-temperature laser confocal scanning electron microscopy and macroscopic continuous casting simulation methods were used to study the solidification structure at different cooling rates and optimize the secondary cooling continuous casting process for the secondary cooling solidification process of continuous casting. The results show that the high cooling rate can greatly reduce the size of the primary NbC phase. At the same time, considering the characteristics of the solidification structure of continuous casting, the cooling intensity of the secondary cooling zone of continuous casting is designed by segmented gradient reduction, and the optimum process parameters are obtained by orthogonal process optimization of casting speed, superheat and amount of cooling water.

**Keywords:** S30432, Continuous Casting, NbC, Cooling Rate, Process Optimization

## 1 Introduction

Austenitic heat-resistant stainless steel has become an important choice material for seamless steel tubes for supercritical and ultra-supercritical utility boilers due to its excellent high temperature stability[1]. However, due to the solidification conditions of the continuous casting process and the low solute equilibrium distribution coefficient of Nb element, serious grain boundary segregation occurs in the solidification structure of S30432 with high Nb content, and large blocks of unevenly distributed niobium compounds are formed, which greatly reduces its thermal processing performance and causes pore initiation and cracks[2]. Since the bulk NbC primary phase is difficult to be removed by subsequent heat treatment methods, it can be considered to change the process parameters in the continuous casting process to realize the regulation of the solidification structure of the alloy. The main factors are superheat, casting speed and cooling water. Researchers have widely used macroscopic simulation methods to study the continuous casting process, but did not actually consider the close relationship between specific process parameters and solidification structure. Therefore, in this study, firstly, based on the influence of cooling rate on the primary phase, considering the characteristics of the actual continuous casting solidification structure, the cooling water distribution in the secondary cooling zone was designed in a targeted manner, and finally the optimized process parameters were obtained.

## 2 Experimental procedure

Firstly, a cylindrical sample with a diameter of 7mm and a height of 3mm was processed from the S30432 round billet. It was placed in a ceramic crucible with a diameter of 7.8mm and a height of 3.5mm for HT-CSLM experiment. The sample was heated from room temperature to 1500℃ for 5 minutes to ensure its complete melting. Then they were cooled to room temperature at cooling rates of 1, 10, 30, 50, 70 and 90 ℃/s, respectively. Observe and record the evolution of microstructure during solidification under high temperature conditions, and use Shimadzu EPMA-8050G to further accurately analyze and determine the element distribution in dendrites and interdendritic regions. On this basis, the Procast casting simulation software was used to simulate the continuous casting process. The casting speed was set at 0.8, 0.9, 1.0, 1.1, 1.2 m/min, the superheat was set at 10, 20, 30, 40, 50 ℃, and the specific water amount was set at 0.1, 0.2, 0.3, 0.4, 0.5 L/Kg. The orthogonal method was used to design 25 groups of process schemes to evaluate the final slab quality.

## 3 Result and discussion

### Solidification microstructure characteristics

Fig.1 shows the solidification microstructure at different cooling rates. With the increase of cooling rate, the grain structure is obviously refined, and exists in the form of fine dendrites, and the size of NbC particles is significantly reduced. However, during the solidification process of continuous casting billet, the cross-section structure of the billet presents a typical three-crystal zone morphology. According to the simulation results of continuous casting structure, the increase of secondary cooling water can directly increase the cooling rate, but at the same time, it will lead to the expansion of the columnar crystal area, which is obviously inconsistent with the ultimate goal.

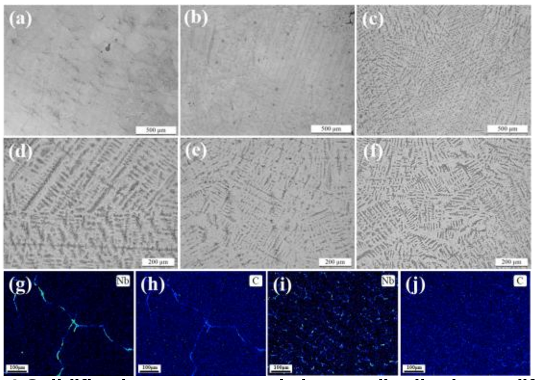


**Fig.1 Solidification structure and element distribution at different cooling rates. (a)1°C/s, (b)10°C/s, (c)30°C/s, (d) 50°C/s, (e)70°C/s, (f)90°C/s, (g)~(h)1°C/s, (i)~(j)90°C/s.**

## Secondary cooling process design

According to the characteristics of the solidification structure of continuous casting, the cooling rate can be reduced by multi-stage gradient in the secondary cooling zone, which is beneficial to the increase of the equiaxed crystal region in the core. The secondary cooling segmentation scheme adopted is shown in Table 1 :

**Table 1. Cooling area of continuous casting secondary cooling zone**

| Cooling Zone | $T_0$ | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|---|
| The actual area length $L_i$ (m) | 0.62 | 1.7 | 2 | 2.3 |
| Crystallizer liquid level to the regional center length $S_i$ (m) | 0.97 | 2.13 | 3.98 | 6.13 |

The water allocation $Q_i$ of each region is :

$$Q_0 : Q_1 : Q_2 : Q_3 = \frac{1}{\sqrt{S_0}} : \frac{1}{\sqrt{S_1}} : \frac{1}{\sqrt{S_2}} : \frac{1}{\sqrt{S_3}} \qquad (1)$$

In the formula, $Q_i$ is the amount of water in the foot roller zone, the first zone of secondary cooling, the second zone of secondary cooling and the third zone of secondary cooling, and $S_i$ is the length from the liquid level of the crystallizer to the cooling center point of each zone..

Fig.2 shows the evaluation results of 25 orthogonal process schemes. It can be seen that under the influence of multiple factor parameters, the optimal continuous casting process parameters are obtained based on the straightening point temperature above 900 ℃, lower shape factor, and lower sectional crack rate of billet. The casting speed is 0.9 m/min, the superheat is 20~30 ℃, and the amount of secondary cooling water is 0.3~0.4 L/Kg.

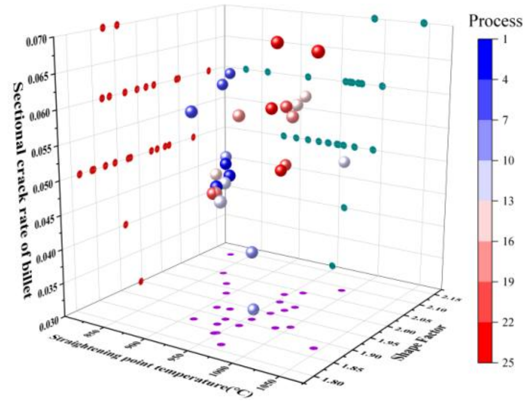


**Fig.2 Multi-factor evaluation results of 25 groups of process schemes**

## 4 Conclusion

(1) High cooling rate can greatly reduce the size of primary NbC phase.

(2) Considering the characteristics of solidification structure in continuous casting, the equiaxed grain ratio of the square billet can be improved by reducing the cooling water gradient in the secondary cooling zone of continuous casting.

(3) The optimum continuous casting process parameters were obtained by orthogonal process optimization of casting speed, superheat and cooling water. The casting speed was 0.9m/min, the superheat was20 ~ 30 °C, and the amount of secondary cooling water was0.3~0.4 L/Kg.

## Acknowledgments

This work was supported by National Natural Science Foundation of China (Nos. 52375394, 52074246, 52275390, 52201146).

## References

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