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Multiple Setup Model for Coiling Temperature Control in Hot Strip Mill

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Abstract. The coiling temperature control method of a typical hot strip mill was investigated. Based on Time-Velocity-Distance (TVD) curve, the generation of velocity deviation between the calculated and measured was present and discussed in detail. To deal with the deviation of velocity, the main cooling zone was divided into two parts by the medium pyrometer, and the feed forward model was triggered under finishing pyrometer and medium pyrometer respectively for one strip segment. The temperature deviation of feed forward setup under finishing pyrometer could be corrected by the feed forward setup under medium pyrometer effectively. Application results indicated that the control precision of coiling temperature on different steel grades had been improved to varying degrees, and the highest point was up to nearly 4%.

1. Introduction

Coiling temperature is one of the most crucial parameter in the production of hot rolled strip[1-3]. For the purpose of obtaining the appropriate microstructure and mechanical properties of strip steel, the coiling temperature must be controlled to approach the target[4-6]. A lot of researchers focus on the development of control models or strategies to improve the control precision of coiling temperature[7-10]. However, most of the studies are conducted under the assumption of steady state to simplify the control algorithms. In the production, the strip moves at various velocity. it is inevitable to appear the velocity deviation between the calculation and the measured, which brings the negative impact on the control accuracy[11]. In this work, the cooling system arrangement was introduced firstly. Based on the basis of TVD curve, the generation of velocity deviation was present where after. To deal with the deviation of velocity, the multiple setup model was developed and discussed in detail. what's more, the application results were shown in the last part.

2. Cooling System Arrangement

In a typical hot strip rolling line, the steel slab, reheated in the furnace, goes through the rough rolling and finish rolling processes, and then turns into hundreds of meters strip before entering a cooling system (CS). In the CS section, the strip was cooled to a preset temperature before being coiled[12]. The CS consists of run-out table (ROT) and laminar cooling headers. The ROT is located between the finish rolling and coiler. The laminar cooling headers are arranged above and beneath the ROT. The laminar cooling headers can be divided into two functional parts: the main cooling zone and the fine cooling zone. The main cooling zone is grouped by 18 banks, and each bank consists of 4 top headers and 4 bottom headers. The main cooling zone is divided into two parts by medium pyrometer (MT), and called main cooling zoen-1and main cooling zone-2, respectively. The fine cooling zone is grouped by 2 banks, and each bank consists of 8 top headers and 8 bottom headers. The flow rate of top header in the main cooling zone is 120m3/h while the bottom header is 130m3/h. The flow rate of cooling headers in the fine zone is the half of the headers in the main zone. Every cooling header can be turned on or off via pneumatic switches respectively. The arrangement of cooling headers is shown in Fig.1

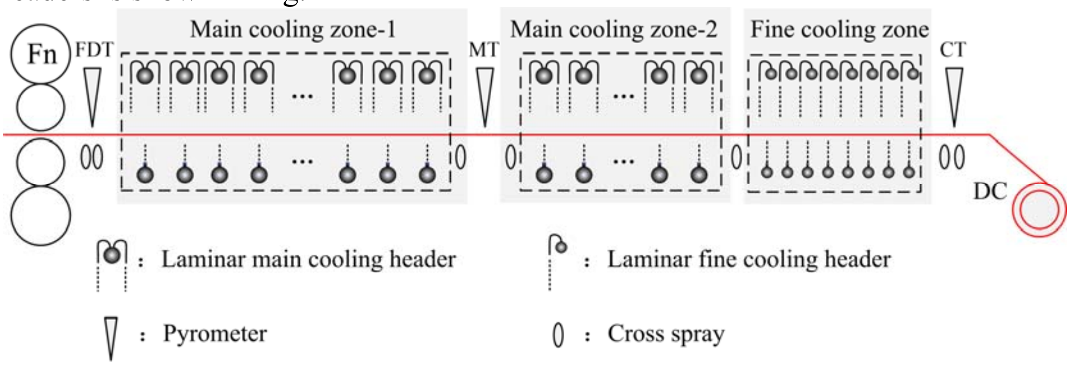

Figure 1. Arrangement of the cooling headers.

3. Generation of Velocity Deviation

The strip velocity is one of the main factors affecting the control precision of CT. In the cooling process after rolling, the Time, Velocity, Distance curve, named TVD curve, is usually employed to study the trend of velocity for strip. The typical TVD curve is shown Fig.2.

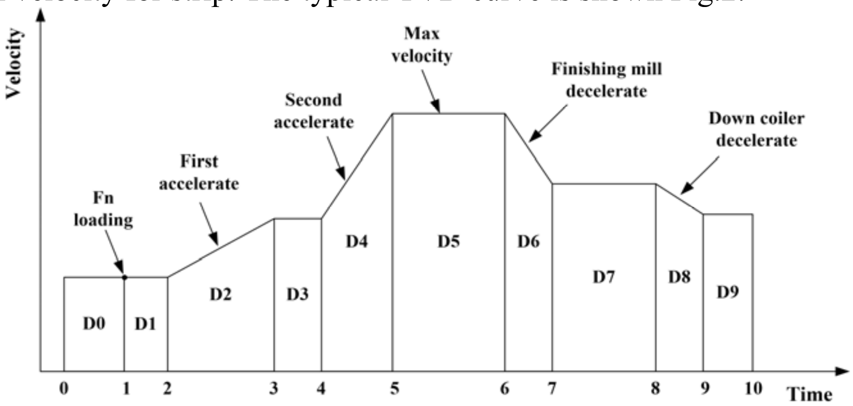

Figure 2. The typical TVD curves.

Base on the typical TVD curve, the cooling control model will predict the velocity of the strip in finishing mill and calculate the cooling pattern to make the strip temperature meet to the target[13]. However, if the cooling water between the finishing stander can't be configured, the control of finishing delivery temperature (FDT) is completely dependent on the adjustment of rolling velocity. The irregular change of strip velocity will result in the failure of the typical TVD prediction model. Fig.3 shows the strip velocity of calculation and measured, and the temperature curve, respectively. The strip grade is Q235B with the thickness of 7.75mm. For the convenience of analysis, segment 58 of strip steel is used as the analysis object. Due to the length of strip is up to hundreds of meters, which is far beyond the length of cooling line, the period of velocity of segment 58 only occupy a part of the whole strip velocity curve. As shown in Fig.3, when the measured FDT is higher than the target, the acceleration of the finishing mill begins to decrease, and the acceleration, in some area, is reduced to negative. Since the segment 58 is at the end of the first accelerate stage in the typical TVD curve, the model predicts that the segment 58 may go through the second accelerate stage after a certain length. As discussed above, there is a deviation of strip velocity between the calculation and measured.

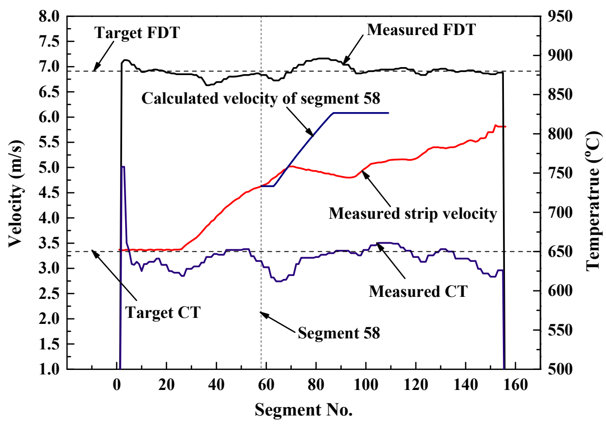

Figure 3. Illustration of the generation of velocity deviation.

4. Development of Multiple Setup Model

It is well known that the setup of cooling model by the measured parameters is an effective way to deal with the calculation deviation. The velocity, temperature, and other parameters of strip steel under FDT and MT can be obtained by the instrument and segment micro-tracking, which enable the setup of cooling model for one segment to be triggered under FDT and MT, respectively. Under the above discuss, the multiple setup model was developed. The multiple setup model is consisted of two feed forward process for one segment, under FDT and CT, which are called feed forward setup in main cooling zone-1(FF-1) and feed forward setup in main cooling zone-2(FF-2), respectively.

4.1 Feed Forward Setup in Main Cooling Zone-1

To illuminate the feed forward setup in main cooling zone-1, as shown in Fig.4, we choose the segment k as the research object. Based on the measured parameters under FDT, such as velocity, temperature, thickness, et al., the temperature drop of segment k in every cooling zone is calculated by the cooling model. The optimum cooling pattern is obtained by the iteration algorithm to make the coiling temperature calculating result of segment k meet to the target.

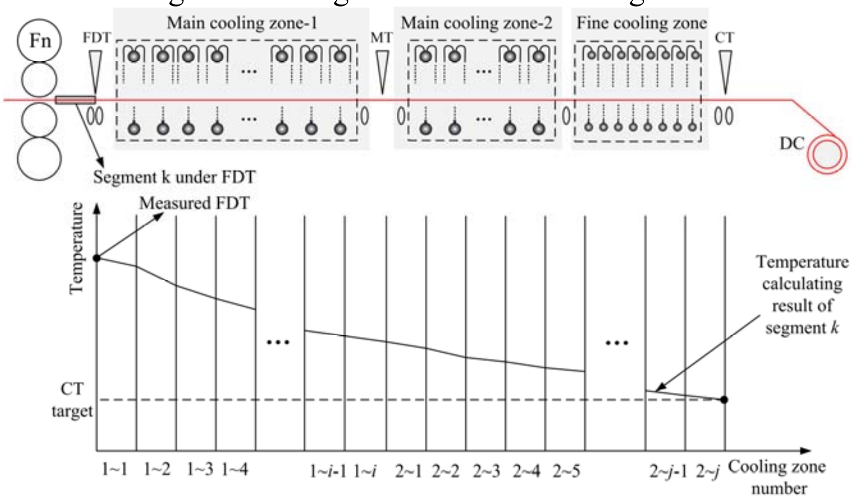

Figure 4. Feed forward setup in FF-1.

The temperature drop in every cooling zone can be obtained by the following equation:

$$\frac{dt}{d\tau}=-\frac{2\alpha_{\mathrm{a}}}{c(t)\rho\delta}(t-t_a)-\frac{2\alpha_{\mathrm{w}}}{c(t)\rho\delta}(t-t_{\mathrm{w}}) \tag{1}$$

where, t is strip surface temperature, τ is cooling time, $c(t)$ is specific heat of strip, ρ is density of strip, δ is the strip thickness, t_a is the ambient temperature, t_w is the cooling water temperature, α_a is the heat transfer coefficient of water cooling, α_w is the heat transfer coefficient of air cooling.

4.2 Feed Forward Setup in Main Cooling Zone-2

As shown in Fig.5, the strip steel moving forward to the coiler, the segment k travels to MT. The calculated MT and the measured MT are inevitably biased. According to the measured parameter, such as MT, strip velocity, the FF-2 is triggered to correct the temperature deviation and calculate the temperature drop of segment k in the main cooling zone-2 and in the fine cooling zone. Therefore, the cooling pattern calculated by FF-1 is re-corrected by FF-2, and the coiling temperature of segment k will tend to the target value further. It should be pointed out that the FF-1 and FF-2 works on the whole strip steel and the coiling temperature of strip steel along the length direction can be controlled better.

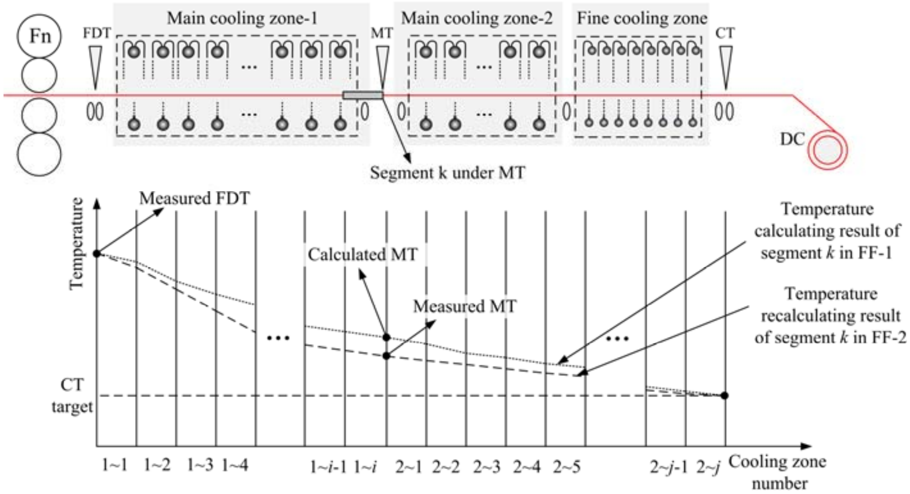

Figure 5. Feed forward setup in FF-2.

5. FIELD Application

The achievement was successfully applied to a hot strip plant. Table 1 shows the application results of the multiple setup model on the typical steel grade.

Table 1. Application results on the typical steel grade

ID	Steel Grade	Before improvement		After improvement	
		Count	CT Precision (%)	Count	CT Precision (%)
1	Q235B	50	95.5	32	96.7
2	510L	23	94.3	20	95.2
3	SPA-H	56	93.8	40	95.9
4	SPHC	50	96.6	50	98.1
5	SS400	38	95.4	30	96.3
6	X70	49	86.4	32	90.3

It can be seen that from the Table 1, the control precision of CT on different steel grades had been improved to varying degrees, and the highest point was up to nearly 4%.

6. Conclusion

Coiling temperature is one of the most crucial parameter in the production of hot rolled strip. The coiling temperature control method was investigated. On the basis of Time-Velocity-Distance (TVD) curve, the generation of velocity deviation between the calculated and measured was present and discussed in detail. To deal with the deviation of velocity, the main cooling zone was divided into two parts by the medium pyrometer, and the feed forward model was triggered under finishing pyrometer and medium pyrometer respectively for one strip segment. The temperature deviation of feed forward setup under finishing pyrometer could be corrected by the feed forward setup under medium pyrometer effectively. Application results indicated that the control precision of coiling temperature on different steel grades had been improved substantially.

References

[1]. S. X. Cheng and X. Y. Zhang, Mater. Sci. Eng. A 666, 156-164 (2016).

[2]. H. B. Xie and Z. Y. Jiang, J. Mater. Process Tech. 177, 121-125 (2006).
[3]. Q. B. Yu and Z. D. Wang, J. Iron. Steel Res. Int. 10, 75-78 (2003).
[4]. J. Q. Xu and Y. C. Jia, J. Iron Steel Res. Int. 18, 572-575 (2011).
[5]. K. Zhang and Z. D. Li, Acta Metall. Sin. 54, 31-38 (2018).
[6]. G. S. Li and W. Yu, Arch. Civ. Mech. Eng. 17, 121-131 (2017).
[7]. E. Y. Liu and D. H. Zhang, J. Iron. Steel Res. Int. 19, 39-42 (2012).
[8]. D. H. Zhang and N. Zhou, J. Iron. Steel Res. Int. 17, 18-21 (2010).
[9]. L. G. Peng and X. H. Liu, J. Cent. South Univ. 21, 43-49 (2014).
[10]. H. J. Li and Z. L. Li, J. Iron. Steel Res. Int. 20, 29-34 (2013).
[11]. H. J. Li and L. G. Li, Steel Res. Int. 86, 1225-1233 (2015).
[12]. L. Peng and Q. Li, J. Univ. Sci. Technol. B 15, 362-365 (2008).
[13]. Z. L. Li and H. J. Li, Steel Res. Int. 86, 478-488 (2015).