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Improvement of Temperature Drop Model Parameters for 4200mm/3500mm Rolling of Baosteel Medium and Thick Plate

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Abstract: Based on the temperature situation during the rolling process of 4200 mm/3500 mm medium and thick plates at Baosteel, this article analyzes the influencing factors of temperature changes during the rolling process from the perspective of heat transfer theory and the temperature change law during the rolling process. The temperature loss during the four rolling processes is tracked on site, and the temperature drop model parameters during the rolling process of 4200mm/3500mm medium and thick plates at Baosteel are quantitatively provided. It is applied to actual rolling production and has achieved good results.
Keywords: medium thickness plate; rolling process; temperature drop

Introduction

The steel manufacturing industry is the foundation of national industry and occupies a significant proportion in the national economy [1]. According to statistics from the World Steel Association, the global crude steel production in 2022 was 1.8785 billion tons, a year-on-year decrease of 4.2%. Among the data submitted by 64 steel producing countries, China ranked first, reaching 1.013 billion tons. As the most widely used form of steel material in steel products, steel plates have always been one of the important basic materials for industrial production and manufacturing. Medium thick plate is a general term, in which the thin plate is 0-3 mm, the medium plate is 4-25 mm, the thick plate is 26-100 mm, and ultra thick plates exceeding 100 mm.

Baosteel's medium thick plate was put into production in 2009, aiming to fill the gap in the Xinjiang medium thick plate market. In 2012, the second phase of the medium thick plate project was put into operation, with model automation as one of the main contents [2]. Temperature is a very important process parameter in model calculation, which directly affects the matching degree between model calculation and actual site, and thus affects key indicators such as dimensional accuracy, surface quality, and mechanical performance of medium and thick plate products. This article is based on this research, attempting to identify quantitative relationships between different production stages.

1 Production process and temperature drop factors of medium and thick plates at Baosteel

1.1 Production process flow of medium and thick plates at Baosteel

The rolling process of Baosteel's medium and thick plate production process is mainly divided into three stages: heating stage, widening stage, and elongation stage. After the slab passes through the heating furnace, it begins to enter the process of temperature flow reduction: (1) High pressure water is used to remove phosphorus from the surface and secondary iron oxide scale. During the rough rolling process, the rollers act on the slab to deform it to the required width size of the intermediate slab; (2) There is a roller conveyor that is transported to the finishing mill for extended rolling, achieving the target thickness and length dimensions; (3) A straightening machine corrects the shape of the steel plate, and finally reaches the shear temperature through air cooling

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on a cold bed, completing the fixed length and width contract dimensions of the steel plate.

1.2 Temperature drop factors during hot rolling process

Ginzberg summarized the calculation methods of heat transfer and temperature changes caused by hot rolling of plates and strips by foreign scholars [3], mainly divided into four aspects: (1) ignoring the radiation temperature drop of the internal temperature gradient of the steel plate, which is also known as the air-cooled temperature drop; (2) The temperature decrease caused by the action of water on the surface of the slab during high-pressure phosphorus removal process; (3) The temperature decrease caused by the temperature exchange between the hot slab and the rolling mill during the rolling process of the slab; (4) During the rolling process, the hot slab undergoes plastic deformation. During the deformation stage, the hot slab mainly receives mechanical work from the rolling rolls, which will have a positive effect on the temperature drop of the slab, i. e. temperature rise.

Hu Xianlei and others from Northeastern University mainly studied the temperature changes during the rolling process under four different conditions while studying the temperature model process [4]. They applied these research results to the actual calculations of existing models and implemented them in medium and thick plate factories. This has practical significance for the current development of automation in medium and thick plates.

Whether from the research of foreign scholars or domestic scholars, there are several aspects of temperature changes in the basic medium and thick plate rolling process: thermal radiation temperature drop; High pressure water descaling temperature drop; The thermal conduction temperature drop generated by contact with the rolling mill; Deformation temperature rise.

2 Research on rolling temperature of baosteel medium and heavy plate

On the basis of theoretical research in four aspects, the Baosteel Plate Plant has its unique characteristics and inconsistent situation, and it is not possible to directly apply the research results to the automation of the existing models of Baosteel Plate. The main reasons are as follows: (1) The medium thick plate of Baosteel is located in the Xinjiang region, far from the ocean, deep inland, and difficult to reach by ocean air currents. The climate is dry, and the air cooling temperature drop has its own unique characteristics [5]; (2) The height setting of the secondary phosphorus removal water is inconsistent with other medium and thick plate factories, and it is necessary to quantify the temperature reduction in this part; (3) During the rolling process of Baosteel medium and thick plates, due to the material of the rolling rolls, 10 Pa pressure cooling water is required to ensure a constant temperature of the rolling rolls. Therefore, the contact temperature drop of the rolling rolls during the rolling process is actually a temperature drop generated by the combined action of the rolling roll cooling water; (4) The difference in rolling process is tracked based on on-site data of Baosteel's medium and thick plates. The rolling temperature of the roughing mill is between 950 ℃ and 1150 ℃, and the rolling temperature of the finishing mill is between 750 ℃ and 920 ℃. Compared to other domestic plate mills, the rolling process used by Baosteel for plate production is low-temperature rolling, with a wide range of rolling temperatures and multiple factors affecting temperature drop.

2.1 Confirmation of thermal radiation temperature drop and blackness

During transportation or rolling gaps, steel plates may dissipate heat in the form of radiation through the surface of the rolled piece due to high temperatures [6]. According to Stefen Boltsman's theorem, the heat flux density qr and heat transfer coefficient hr generated by thermal radiation on the surface of a steel plate are:

$$qr=\varepsilon*o*(((Ts+273)/100)4-((Ts+273)/100)4) \quad 式(1)$$

$$hr=qr/(Ts-Ta) \quad 式(2)$$

Among them: ε: Steel plate blackness; o: Thermal radiation constant; Ts: surface temperature of steel plate; Ta: ambient temperature.

The accurate setting of the blackness of steel plates plays a decisive role in the temperature changes caused by thermal radiation, and the blackness of steel plates is related to the oxide scale, surface temperature, and surface roughness [7].

Based on empirical formula: $\varepsilon=((H0/H-1)*0.58+0.8)/(H0/H)$[4], It can be calculated that the blackness of the intermediate billet steel plate after rough rolling of the medium thick plate of Baosteel is 0.65.

According to on-site temperature tracking, the intermediate billets of the finishing mill are transported to the waiting area and begin to wait for temperature. The comparison relationship between time and temperature drop for different intermediate billets in the same time period is shown in Table 1.

Conclusion: Based on the data in this table, it can be concluded that the thermal radiation temperature of the intermediate billet steel plate of Baosteel after rough rolling varies by 0.7 ℃/s.

2.2 Confirmation of temperature drop for secondary high-pressure water descaling

The heating temperature of Baosteel medium and thick plates is 1250 ℃, and the rolling temperature of the roughing mill is 950 ℃ ~1150 ℃. During the rolling process, the temperature of the slab is relatively high, and during the interaction with air O_2, iron oxide (Fe_2O_3 and Fe_3O_4) will form on its surface. If this part of iron oxide is pressed into the surface of the steel plate during the rolling process and cannot adhere to the steel plate substrate, it will produce "pits" defects during the subsequent use of the steel plate. Therefore, the general practice of medium and thick plate factories is to use high-pressure water to break through the iron oxide scale, also known as high-pressure phosphorus

Table 1 Air Cooling and Waiting for Temperature of Rolling Intermediate Billet (Upper Surface)

Intermediate billet thickness/mm	Initial temperature/℃	Waiting time for heating				
		10s	30s	60s	90s	120s
91	1025	1020	1006	990	978	949
74	1000	990	980	960	945	908
79	1010	1001	983	968	947	911
77	988	970	966	946	919	883
78	1010	1000	970	955	938	916

removal. Due to the high temperature of the steel plate, a thin steam film will form on the surface of the steel plate after contact with high-pressure water. At the same time, due to the high pressure of high-pressure water (19-21 Mpa), it can be assumed that the temperature of the impacted area on the steel plate surface will drop from high temperature to the same temperature as the steam film in a short period of time [8].

The above research indicates that the temperature drop of high-pressure water descaling increases with the decrease of thickness. The basic relationship can be determined by using univariate linear regression analysis and the formula can be shown as follows: $y = 0.0041x^2 - 0.802x + 47.437$, Where x represents the thickness of the slab, and y represents the temperature decrease after one phosphorus removal process.

2.3 Heat conduction in contact with rolling mill and quantitative decrease in cooling water temperature of rolling mill

Due to the contact between the higher temperature steel plate and the lower temperature rolling mill during the rolling process, the heat from the steel plate flows towards the rolling mill, resulting in a decrease in the temperature of the steel plate. On the one hand, the contact arc length between the steel plate and the rolling mill is very small compared to the radius of the rolling mill, and the heat conduction problem between the two can be regarded as line contact conduction [9]. On the other hand, during the rolling process, the cooling water of the rolling mill also acts on the surface of the steel plate, causing a temperature drop. Due to the inability to accurately separate the contact conduction temperature drop from the cooling water temperature drop in practical on-site practice, these two temperature drop processes are considered as a whole.

According to on-site temperature tracking, the temperature drop statistics of different product specifications during the rolling process during the same time period are shown in Table 2.

The above research indicates that as the number of steel plate extension passes increases during precision rolling, the temperature drop during the rolling process is more significant, and the temperature drop during thick rolling is smaller than that during thin rolling.

2.4 Treatment of the starting temperature of the finishing mill

Due to the presence of multiple temperature gauges in front of the finishing mill, as well as after the phosphorus removal box of the roughing mill, between the roughing mill and the finishing mill, for the medium and thick plates of Baosteel. On the one hand, although it is possible to import the measured temperature values into the model through the actual values of the thermometer, the actual on-site environment is complex. When the rolling bites in, the dephosphorization water is opened at the same time. At this time, the temperature measurement covers the influence of water, so it is impossible to measure the accurate value of the rolling temperature in real time. On the other hand, during the transmission process, data packet loss and data distortion are prone to occur, and both the calculation of the precision rolling mill model data and the automation of the L1 distribution process require time, which can easily cause calculation errors in the model and ultimately lead to problems with the quality of the steel plate.

Therefore, for the treatment of the rolling temperature, the first phosphorus removal temperature measurement and the second temperature measurement after the roughing mill are used for calculation. If the first and second temperature measurements are T1 and T2, respectively, the rolling temperature is [10]:

$$Tbegin=k\cdot T1+(1-k)T2,\ 0\le k\le 1 \quad 式(3)$$

Combined with self-learning of rolling temperature, the actual rolling temperature can be calculated as:

$$T'begin(n)=\alpha\cdot Tbegin(n)+1-\alpha\cdot T'begin(n-1),\quad 0<\alpha<1 \quad 式(4)$$

Among them, T'begin (n) is the self-learning value of the opening temperature of the nth steel, T'begin (n-1) is the self-learning value of the opening temperature of the n-1st steel, and Tbegin (n) is the calculated value of the opening temperature of the nth steel, α It is the exponential smoothing coefficient.

The above calculation results parameters and corresponding processing were applied to the L2 automation model of Baosteel medium and thick plates, and the on-site final rolling temperature hit rate steadily improved compared to before.

3 Conclusion

Based on on-site research and quantitative data statistics, key parameters suitable for the medium and thick plate model of Baosteel were obtained, and the following conclu-

Table 2 Temperature drop during the finishing mill stage (upper surface)

Final rolling thickness	Rolling temperature/℃	Third pass/℃	Fifth pass/℃	Seventh pass/℃	Ninth session/℃	eleventh session/℃
30	930	885	856	830	810	754
36	910	870	860	820	790	750
25	954	907	870	850	804	760
23	938	916	880	843	798	/
20	935	880	837	793	760	/
20	960	890	860	815	762	/

sions were drawn: (1) Thermal radiation temperature drop, based on empirical formulas: ε= (H0/H-1)*0.58+0.8)/(H/H), it can be calculated that the blackness of the intermediate billet steel plate after rough rolling of Baosteel medium thick plate is 0.65. According to on-site tracking data calculation, the thermal radiation temperature of the intermediate billet steel plate after rough rolling of Baosteel medium thick plate changes by 0.7 ℃/s.; (2) The temperature drop of high-pressure water descaling increases with the decrease of thickness. The basic relationship can be shown by the formula as follows: $y=0.0041x^2-0.802x+47.437$, where x is the thickness of the slab and y is the temperature decrease after one phosphorus removal process; (3) The contact heat conduction of the rolling mill and the cooling water temperature drop of the rolling mill result in a more significant temperature drop during the precision rolling process as the number of steel plate extensions increases. Moreover, the temperature drop during thick rolling is smaller than that during thin rolling.

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