

Study on heating technique for high productivity, superior quality and lower consumption

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Abstract: The existing thermal characteristics of reheating furnace and heavy rail bloom heating technique was evaluated based on temperature measurement with thermal couples and energy balance. Then, the heating technique was optimized. The modified operation shows the annual production of steel for heavy rail is increased from 400 000 t to 500 000 t, the fluctuation of heating temperature is lowered from $\pm 40\text{ }^{\circ}\text{C}$ to $\pm 20\text{ }^{\circ}\text{C}$, while, temperature difference in bloom section is lessened from $65\text{ }^{\circ}\text{C}$ to less than $45\text{ }^{\circ}\text{C}$, specific fuel consumption is decreased from 2.147GJ/t to 2.014GJ/t of steel. Furthermore, metal loss due to oxidation is significantly reduced from 1.75 % to 0.72 % to 0.92 %, decarburization depth is lowered from 0.35~0.82 mm to 0.20~0.50 mm, and the rate of overburning is decreased 45 %. The purpose for realizing high productivity, superior quality and lower consumption has been achieved.

Keywords: heating technique; reheating furnace; thermal schedule; optimization

1. Introduction

Proper thermal scheme of a reheating furnace is one of the key technologies for improving heating quality and reducing fuel consumption. There are three pusher-type furnaces at Rail-beam Rolling Plant of Panzhihua Iron & Steel Corporation. These furnaces fire on mixture with blast-furnace gas and coke-oven gas, and their rated capacity is 100 tons/hour. Each furnace is comprised of three areas designated as preheat, heat and soak zone, which are each divided into two zones (top and bottom). The top heat and soak zone are equipped with radiation roof burners, and the bottom heat and soak zone are equipped with longitudinal burners, while, the blooms in the preheat zone are heated by flue gas. Since the furnaces come into operation, there have been some problems, e.g., the low heating capacity, high fuel consumption, wide fluctuation of the heating temperature, great temperature difference in bloom section, serious oxidation and decarburization. Such problems have negative impacts on improving finished rails quality and reducing furnaces energy consumption. Especially, the existing heating quality does not meet the requirement of high-speed tracks for thermal homogeneity and stability, and for minimal decarburization depth[1].

Heavy rail steel belongs to high-carbon steel, which is highly sensitive to overheating, overburning, oxidation and decarburization. Therefore, the furnaces

abroad used to heat rail steel are walking beam furnaces equipped with supervisory computer control systems[2], e.g., Yawate Works of Nippon Steel Corp., Ruhort Works of Thyssen Corp., Hayange Works of Usinor Sacilor Steel Group, and Sydney Steel Corp. While, the furnaces in major domestic rail manufactories are pusher-type furnaces. Compared to the pusher-type furnace, the benefits of the walking beam furnace include reduction in fuel consumption, minimization in decarburization depth, and improvement in thermal homogeneity of blooms heated[3]. As the furnaces in Rail-beam Rolling Plant of PZH Steel are manually controlled, the furnace temperature profile is empirically given. In order to discharge in time, there are a plenty of surplus for fuel flow rate, which causes the higher fuel consumption and heating defects, such as overheating and overburning. Therefore, it is necessary to establish a mathematical model for optimal control of the furnaces and to optimize the thermal scheme, in order to obtain required heating temperature and to minimize fuel consumption.

2. The current heating technique for rail steel

The experimental methods, e.g., temperature measurement with thermal couples, thermal balance determination, gaseous component analysis and continuous temperature measurement at the rolling process, are used to investigate the existing thermal characteristics and heating technique. The comparison

of heating quality between current and required by high-speed tracks is shown in table 1.

Table 1. Comparison of metal quality between current and required by high-speed tracks

	bloom heating temperature/°C	temperature difference in bloom section/°C	decarburization depth/mm	metal oxidation loss /%
current	1170~1250	59~65	0.35~0.82	1.75
requirement	1200~1240	≤50	≤0.5	≤1.5

Table 1 shows the thermal homogeneity should be improved, the metal oxidation loss and decarburization depth should be minimized in order to meet the need of high-speed tracks. Therefore, it is essential to optimize the furnace thermal scheme and rail steel heating technique.

3. Optimization of furnace thermal scheme

An optimum objective that is heating temperature and acceptable temperature difference in bloom section is presented, and a mathematical model for optimal control of the furnace is also developed. The calculated values are in good agreement with the measured data, which difference is less than 15°C. Then, the fuel flow to each combustion zone is supplied based on predetermining the proper furnace temperature profile along the furnace length by the mathematical model.

3.1 Optimizing objective

3.1.1 Bloom heating temperature

According to rolling technique and temperature drops during rolling process at Rail-beam Rolling Plant of PZH Steel, the bloom heating temperature is determined as follows:

(a) PD3 steel: heating temperature is (1220 ± 20) °C.

(b) U71Mn steel: heating temperature is (1200 ± 20) °C.

3.1.2 Temperature difference in bloom section

The acceptable temperature difference in bloom section for rail steel is less than 50 °C.

3.2 Optimized furnace thermal scheme

3.2.1 Heat supply schedule

The ratio of heat supply between the top and bottom combustion zones is 40 %: 60 %, and that of in the top soak zone, bottom soak zone, top heat zone, bottom heat zone is 10 %: 25 %: 30 %: 35 %.

3.2.2 Furnace temperature schedule

Temperature schedule of the furnace during normal production is shown in table 2.

Table 2. Temperature schedule of the furnace

steel grade	bloom temperature/°C		heating time/min		furnace temperature in each zone/°C			
	furnace exit	950 rougher exit	total	soak-time	top soak	bottom soak	top heat	bottom heat
PD3	1220±20	≥1120	210~270	35~45	1240~	1240~	1280~	1280~
					1290	1290	1340	1340
U71Mn	1200±20	≥1080	210~270	35~45	1220~	1220~	1260~	1260~
					1270	1270	1320	1320

3.2.3 Control of gaseous atmosphere

Gaseous atmosphere in each zone of the furnace is independently controlled. That is to say, the coefficient of excess air consumption in soak and heat zone is 0.9~1.0 and 1.15~1.25, respectively, and that of air consumption in overall furnace is from 1.05 to 1.10.

3.3 Application of the optimized thermal scheme and its effects

The optimized thermal scheme has been applied to the furnace of Rail-beam Rolling Plant of PZH Steel since 2000. The improvement in heating quality, energy saving and consumption reducing, and output of production increasing have been demonstrated.

3.3.1 Stabilizing heating temperature

Bloom temperature at the exit of reheating furnace and roughing mill 950 are continuously measured by

infrared-radiation temperature measuring system. The

typical results are shown in Fig. 1.

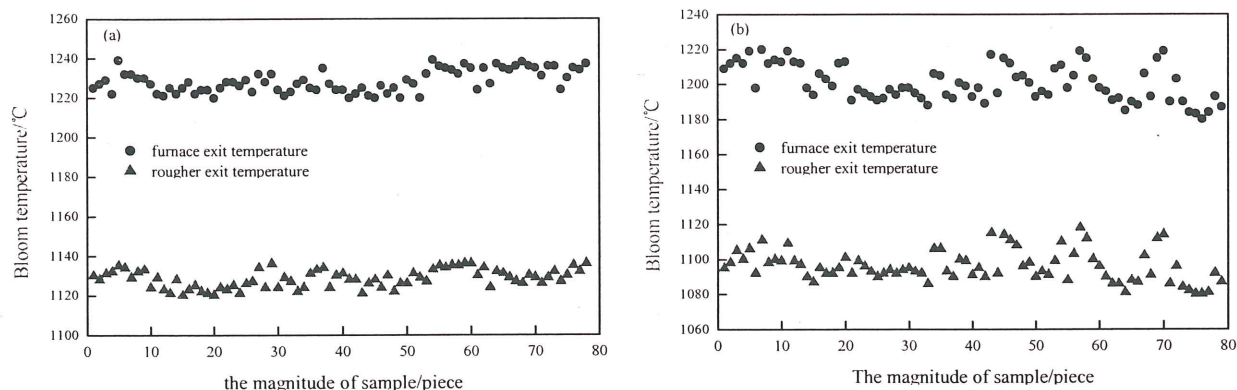


Fig. 1. Bloom temperature at the exit of furnace and roughing mill 950

(a) PD₃ steel; (b) U71Mn steel

Fig.1 shows that the furnace exit temperature for PD₃ steel ranges from 1220 °C to 1239 °C (average temperature is 1229 °C), while, 950 rougher exit temperature ranges from 1120 to 1136 °C (average temperature is 1128 °C). For U71Mn steel, the furnace exit temperature ranges from 1180 to 1220 °C (average temperature is 1201 °C), and 950 rougher exit temperature ranges from 1080 °C to 1118 °C (average temperature is 1096 °C). Furthermore, the fluctuation of the bloom heating temperature is lowered from ± 40 °C to ± 20 °C, which will have a positive impact on improving dimensional accuracy of the finished rails.

3.3.2 Increasing thermal homogeneity of blooms

After optimizing the furnace thermal scheme, temperature difference in bloom section is reduced from (59 to 65) °C to (41 to 45) °C. The significant improvement of thermal homogeneity is the result of reducing the fuel flow from 40% to 35% in soak zone and increasing the fuel flow from 60% to 65% in heating zone. Then, the furnace temperature in heating zone is increased, which will increase the heating rate in heat zone. The blooms have the required heat content before entering the soak zone, thus, the surface rate of the blooms in soak zone can be reduced to (0.3 to 0.5) °C/minute. By heat conduction, the thermal homogeneity throughout the bloom is significantly improved.

3.3.3 Reducing metal oxidation loss

The metal oxidation loss is determined based on weighing the experimental blooms before and after heat. After optimizing the furnace thermal scheme, the metal loss due to oxidation is significantly reduced from 1.75 % to (0.72 to 0.92) %. There are two reasons

for reduction in the metal oxidation loss. One is that the coefficient of air consumption in soak zone is strictly controlled within 0.9 to 1.0, which can protect blooms with high temperature from oxidizing in the final stage of heating process. The other is that the optimized furnace temperature scheme is more proper, which reduces the metal oxidation loss by shortening the heating time. The relationship between the metal loss and heating time is described in Fig. 2.

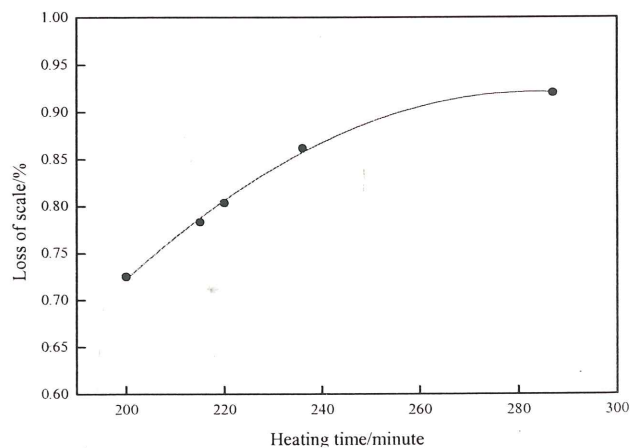


Fig. 2. Relationship between the metal oxidation loss and heating time

Fig. 2 shows that there is a parabolic relation between the metal oxidation loss and heating time.

$$y = -1.38 + 1.63 \times 10^{-2} \tau - 3 \times 10^{-5} \tau^2 \quad (r=0.998)$$

where y is the metal oxidation loss, %, τ is the heating time, minute, r is correlation coefficient.

3.3.4 Raising output of production for rail steel

The output of production for rail steel from 1999 to 2002 is illustrated in Fig. 3.

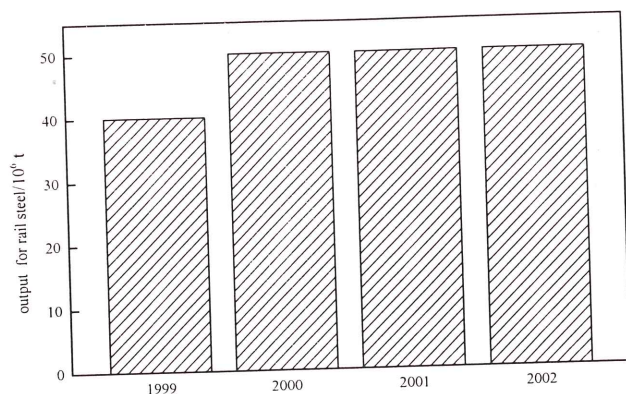


Fig. 3. The annual production of heavy rail from 1999 to 2002

Fig. 3 shows that the annual production of steel for heavy rail is raised from 400 000 t to 500 000 t. The main reason of the raise in output of production is due to higher furnace temperature in heat zone. For example, the furnace temperature for PD₃ steel is increased from (1250 to 1290) °C to (1280 to 1340) °C, which increases the heating rate in heat zone from (4.34 to 5.5) °C/min to (6.7 to 8.8) °C/min, and shortens the heating time in furnace. With the increase of heating rate, there is significant raise in output of production. for example, the daily output of production could be increased from 2693 t to 3173 t.

3.3.5 Decreasing specific fuel consumption and rate of reheating and overburning

After optimizing the thermal scheme, the specific fuel consumption is decreased from 2.147 GJ/t to 2.014 GJ/t of crude steel, and the rate of overburning is lowered from 0.00233 % to 0.00128 %.

3.3.6 Minimizing the decarburization depth

The decarburization depth of hot-rolling rails is

determined by micro-scopic examination. After optimizing the thermal scheme, the decarburization depth in running face and side face is (0.23 to 0.50) mm and (0.20 to 0.50) mm, respectively, which meets the requirement of high-speed tracks.

4. Conclusions

As mentioned above, the annual production of steel for heavy rail is increased from 400 000 t to 500 000 t, the fluctuation of bloom heating temperature is lowered from ± 40 °C to ± 20 °C, while, the temperature difference in bloom section is lessened from 65 °C to less than 45 °C, the specific fuel consumption is decreased from 2.147 GJ/ton to 2.014 GJ/ton of crude steel, furthermore, the loss of scale formation is significantly reduced from (1.75 % to 0.72 to 0.92) %, the decarburization depth is lowered from (0.35 to 0.82) mm to (0.20 to 0.50) mm, and the rate of overburning is decreased from 0.00233 % to 0.00128 %. The purpose for realizing high productivity, superior quality and lower consumption has been achieved.

References

- 1 Jia GY, Wu XD. Opportunity and challenge of rails construction at new stage for PZH Steel. Metallurgical management, 2002, (7): 39- 40 (in Chinese).
- 2 Dong ZH. Production technology for world H-section and rail. Beijing: Metallurgical industry press, 1999. 233-268 (in Chinese).
- 3 Lu ZW, Ning BL. Thermal characteristics and construction of a reheating furnace. Shenyang: Northeastern institute press, 1990. 201-215 (in Chinese).