Research of Dynamic Setting Method for Bending Force During Heavy Plate Rolling

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Abstract. Shape control of Heavy plate is one of the key technologies of heavy plate mill. Hydraulic Bending Roll System is the most common and effective way to control shape, the influence of studying bending force on the shape control has a very important significance to guarantee the proportion of steel crown and improve the level of shape control. In this paper, as the research object to heavy plate, elastic deformation of rolls was studied systematically in order to optimize shape. Based on influence function to establish rolls elastic deformation model, bending force presetting control and compensation calculation method have been developed. Applying the finite element software to simulate the established bending force model, and the model correctness was verified by experiments finally.

Introduction

In recent years, with the rapid development of industry, the demand for the heavy plate is increasing. Hydraulic bending roll is one of the most widely used methods of plate shape control. Through the hydraulic bending roll force to work roll shaft or roller roll shaft, the roll generate additional bending deformation, so as to change the shape of roll gap to achieve the purpose of controlling plate shape [1-3]. Hydraulic bending roll system is an important part of the modern heavy plate mill. It is an indispensable method in the control of the plate.

By changing the roll bending force to control the roll gap shape is the main means to adjust the shape, so the bending roll force setting is reasonable or not is not only related to the shape quality and will also affect the whole mill operation, determines the roll gap shape and cross-section shape of workpiece is good. Bending force changes constantly according to the rolling technology and equipment conditions of changing, the small bending force will produce edge wave, make steel easily deviation occurs due to the instability of the operation. Too large Bending force may generate central wave, in addition to a large bending force will increase the burden of work roll bearing. The control of plate shape is closely related to the proportion crown of rolling process, the main factor affecting the proportion crown is the plate section shape, and how to match the appropriate bending force with different rolling force is the key to control the shape of the heavy plate [4,5].

Section shape model setup

The influence function method is a discretization method to solve the deformation of roll system, which is based on the analysis of the force energy parameters of the roll system deformation. The calculation of roll system deformation includes four parts: ①the elastic flattening caused by the contact of work roll and rolled piece. ②the work roll’s deflection. ③the elastic flattening between work roll and backup roll. ④the backup roll’s deflection..

Adopt the elastic foundation beam model, we consider the backup roll as the elastic foundation and treat the elastic flattening caused by work roll and backup roll, work roll and rolled piece as the spring with elastic constant K1 and spring K2 [8].

When applying the influence function method to solve roll system deformation, it needs to divide the whole length of roller into m units with the same length and believe the pressure distribution $q(j)$ between work roll and backup roll, and $q(j)$ between work roll and rolled piece in each partition are equally distributed. The roll system equilibrium equation and compatibility equation of deformation and displacement are as followed: ①the equation of forces worked on the roller's vertical direction. ②the displacement coordinated relations of the contact place between the backup roll and work roll. ③the equilibrium equation of torque.

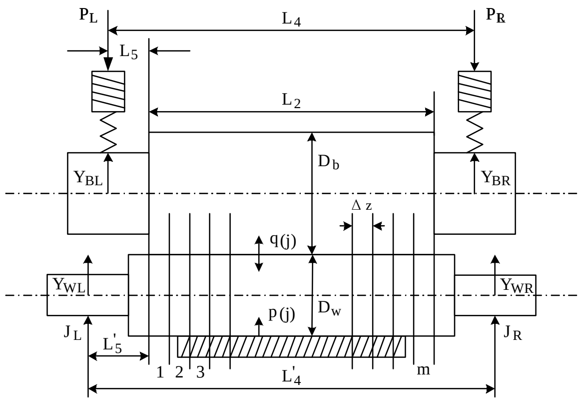

Fig.1 Diagram of roll system deformation

The roll system equilibrium include the unknown number $q(1)$, $q(2)$, …, $q(m)$, Y_{BL}, Y_{BR}, Y_{WL}, Y_{WR}, the total number of equations which have been got is $m+4$. Change the above $m+4$ equations into matrix forms and use Gaussian elimination method to solve it, and then we can get roll system deformation and the plate section shape. The section shape of the plate is the basis of the high accuracy of the calculation of the crown and the proportion crown [6].

Bending force model setup

In order to be able to ensure that the plate to meet the good shape conditions in the rolling process, two aspects are considered in the calculation of the bending force model: ①In view of the rolling schedule of pre-calculation or correct calculation generated by mill process control models, calculate the initial bending force setting matching with the rolling force of various rolling passes.②Calculate the bending compensation coefficient with the various rolling force in rolling process, and the bending force compensation process is realized by basic automation.

1) The presetting calculation of roll bending

The crown of the steel plate is influenced by the rolling force and bending force. In order to ensure the product shape, the proportion crown difference of the plate in the rolling process need to meet the good shape condition. Sometimes the plate shape is good, but the plate crown of the finished product can not meet the requirements, so the control of the crown and shape control should be considered in the rolling process. At the same time, in order to protect the equipment, on the premise of ensuring good shape to minimize the bending force is also problem to calculate the presetting bending force. In this paper, the following steps are used in the calculation of the presetting bending force: ①Obtain the initial data of the rolling schedule, including the entrance thickness, the exit thickness, and the prediction of the rolling force. ②According to the good shape condition, calculate the scope of proportion crown difference between the plate rolling. ③According to the requirements of the finished plate setting crown, calculate the bending force setting and proportion crown of the end pass. ④Using the influence function method, by the end pass in turn forward sequence pass performing calculation, under the condition of meeting good shape, in order to solve the roll bending force setting and crown of the forward sequence pass. ⑤After the calculation is finished, the bending force setting of all rolling pass is transferred to the basic automation as the presetting value of the bending force for each pass.

From the above steps, we can see that the bending force presetting calculation process not only ensures the plate shape, but also realizes the choice of the crown control and the minimum bending roll force.

2) The dynamic compensation calculation of bending force

In the rolling process, due to the uneven influence factors of the temperature and thickness on the longitudinal direction, the rolling force is constantly changing. The changing rolling force can affect the shape of the cross section, and if the bending force is not adjusted, it will also lead to the shape inconsistent phenomenon occurring at different position.

In a certain range, the relationship between the rolling force and the crown can be expressed by linear, As shown in Eq. (1).

$$\Delta C_F = K_F \cdot \Delta X_F \tag{1}$$

in it, ΔX_F is the change of rolling force, ΔC_F is the change of plate crown corresponding to rolling force change, K_F is the influence coefficient of rolling force and crown.

The change of bending force is closely related to the change of the crown, the relationship can be expressed in the follow equation.

$$\Delta C_B = K_B \cdot \Delta X_B \tag{2}$$

in the above equation, ΔX_B is the change of bending force, ΔC_B is the change of plate crown corresponding to bending force change, K_B is the influence coefficient of bending force and crown.

From the above formula, if the plate crown change ΔC_B caused by the bending force is equal to ΔC_F , the roll bending force setting can be obtained at the same time.

$$\Delta X_B = -\frac{K_F}{K_B}\Delta X_F \tag{3}$$

The ratio between the influence coefficient of the rolling force and the shape crown and the influence coefficient of the bending force and the shape crown is defined as compensation coefficient of bending force, that is, the change of the bending force adjustment is equal to the product of the rolling force and the compensation coefficient of bending force.

$$K = -\frac{K_F}{K_B} \tag{4}$$

Bending force compensation coefficient is mainly related to the deformation resistance and the plate width. After the calculation of the presetting bending force is calculated, the bending force compensation coefficient is calculated, and the bending force setting value and the compensation coefficient are transmitted to the basic automation, the dynamic bending force is calculated according to the change of the rolling force by basic automation after rolling.

Calculation and result analysis

In order to check the calculation precision of the control algorithm, a heavy plate mill is chosen to carry out the test calculation,. Table 1 is the primary initial parameter of calculation product.

Table 1 PDI data of the product

Steel grade	Slab sizes	Finished size	value
Work roll diameter	1000mm	Work roll length	4300mm
Backup roll diameter	2200mm	Backup roll length	4200mm
Mill stiffness	800t/mm	Zero force	2000t
Steel grade	Q345	Slab sizes	220*1600*2875mm
Finished sizes	10*3934mm	Target crown	0.2mm

Due to large thickness and higher temperature in the roughing stage, when the rolling slab has certain transverse flow, the shape control problem is not considered. In the finishing process, according to the good shape condition formula to calculate the critical value of proportion crown in different passes, by the crown set 0.2mm of end pass in turn forward sequence pass performing calculation, under the condition of meeting good shape, solve the crown setting and proportion crown setting meet the requirements. The influence function method is used to calculate the setting value of the bending force under the condition of the crown setting, and the calculation results are shown in table 2.

Table 2 Bending force calculations under conditions of good shape and product crown

Pass	Exit thickness (mm)	Crown (mm)	Proportion crown	Bending force (kN)	Min crown (mm)	Max crown (mm)
1	42.42	0.4401	0.010372	0.0	-0.0071	1.3155
2	31.52	0.4876	0.015469	0.0	0.3148	0.8174
3	21.93	0.5092	0.023219	749.03	0.3321	0.5122
4	15.58	0.3402	0.021838	3184.12	0.2783	0.3427
5	11.86	0.2487	0.020970	3445.21	0.2312	0.2512
6	9.70	0.1976	0.020367	3209.90	<0.2	0.2

The plate thickness of the first two pass is thicker in finishing process, , good shape condition is relatively loose, the actual plate crown meet good shape under the condition of minimum and maximum crown requirements, without the need to set the roll force. With the plate is more and thin in following four passes, the shape condition is becoming more and more strict, this bending force setting is limited by the target crown of end pass. The setting of bending force ensure the proportion crown difference within a given critical, the final crown of product plate also satisfies the setting requirement.

Conclusion

The shape control of steel plate should not only consider the initial rolling force setting, but also the change of rolling force, that is, the bending force should be compensated dynamically with the change of rolling force. Based on the influence function method, the exact plate shape is obtained, and then the crown and the proportion crown are obtained, this is the key to data of the plate shape control.

The calculation method of bending force is optimization solution to shape crown restriction, good shape condition, and minimum bending force setting in the paper, the calculation process considers the variation of rolling force, the calculation results meet the requirements of high precision control for plate shape in the heavy plate production.

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