[Article ID] 1003- 6326(2001)06- 0891- 04

Coupling solved roll contact pressure transverse distribution of HC strip mill[①]

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[Abstract] The analysis and calculation of the roll contact pressure for 900 mm HC cold rolled strip mill was carried out by using the strip element method to analyze the three-dimensional plastic deformation of strip and by using the influencing coefficient method to analyze the elastic deformation of rolls. The results indicate that the axial shift of the middle roll of HC mill and the bending of work roll have influence on the transverse distribution of the pressure between rolls.

[Key words] HC mill; cold strip rolling; roll contact pressure; coupling
[CLC number] TG 333 **[Document code]** A

1 INTRODUCTION

It is necessary to evaluate performance, to analyze and to estimate the mechanical behavior of HC mill for using it efficiently, mastering the characteristic of the pressure transverse distribution between rolls, and decreasing the rolls attrition wear. Large scale study on deformation calculation of roll system of strip mill has been made[1~3]. However, only a few reference can be found at coupling three-dimensional plastic deformation of strip model and elastic deformation of roll model, and the influence analyzing of the roll contact pressure transverse distribution about the adjusting amount of shape control. In this paper, a systematically computational simulation has been made about the influence of all shape control methods on the pressure distribution between rolls based on the theories of three-dimensional plastic deformation of strip and the influencing coefficient method.

2 THEORETICAL MODEL

The mechanical model of HC mill and rolled strip is shown in Fig. 1. The middle rolls can transverse moving. In mathematical model of shape analysis, the metal model and roll system model must be coupled. The calculation is used to determine transverse distribution of rolling pressure per unit width ($p_1(y)$), front and back tension ($\sigma_1(y)$, $\sigma_0(y)$) for three-dimensional plastic deformation of strip[4~6], It also used to determine the transverse distribution of the pressure between middle roll and work roll $q_{wm}(y)$, the pressure distribution between middle roll and back roll $q_{mb}(y)$ and the transverse distribution of the load roll gap ($h_1(y)$) for analyzing elastic deformation of roll system. In the procedure of coupling calculation, roll system deformation model is needed to supply the transverse distribution of load roll gap for metal model, and the metal model is needed to supply the transverse distribution of the rolling pressure per unit width $p_1(y)$ for roll system model. The exact result of plastic deformation of strip and elastic deformation of roll system can be obtained by iterative computation. It can obtain the transverse distribution of pressure between rolls in varying rolling conditions by shifting middle roll in δ and bending work roll F_w, then the characteristic of pressure distribution between rolls.

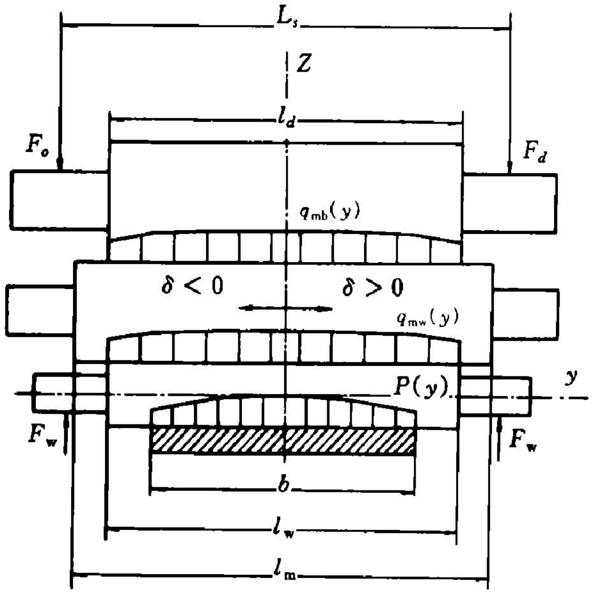

Fig. 1 Mechanical model of HC mill rolled strip

In this paper 3-D plastic deformation of rolled strip was analyzed by using the third power spline function streamline strip element method[7~9]. In this theory lateral displacement is continuous in all de-

① **[Foundation item]** Project (598275) supported by the Natural Science Foundation of Hebei Province
[Received date] 2001- 02- 15; **[Accepted date]** 2001- 06- 04

formation zones, and is satisfied with the compatibility continuous of the first-order and second-order derivative of exit lateral displacement on element nodes. The number of strip elements is largely reduced, and the computing speed is raised when this theory is employed.

The model of front and back stress σ_1, σ_0 transverse distribution in this paper is such as that created in Ref. [9]:

$$\left.\begin{aligned}\sigma_1(y) &= \frac{E}{1-v^2}[\ln h_1(y) - \ln l_0(y) - \ln h_0(y) + \ln(1+u'(y))] + c_1 \\ \sigma_0(y) &= \frac{T_0}{B\bar{h}_0} + \frac{E}{1-v^2}\left[\frac{v_0(y)}{\bar{v}_0} - \frac{l_0(y)}{\bar{l}_0}\right]\end{aligned}\right\} \quad (1)$$

$$c_1 = \frac{(T_1 - G_1)}{B\bar{h}_0} \quad (2)$$

$$G_1 = \frac{E}{1-v}\int_{-B/2}^{B/2} h_1(y)[\ln h_1(y) - \ln l_0(y) - \ln h_0(y) + \ln(1+u'(y))]\mathrm{d}y \quad (3)$$

$$\bar{h}_0 = \frac{1}{B}\int_{-B/2}^{B/2} h_0(y)\mathrm{d}y \quad (4)$$

$$\bar{h}_1 = \frac{1}{B}\int_{-B/2}^{B/2} h_1(y)\mathrm{d}y \quad (5)$$

where h_0, h_1 —The entry and exit thickness of strip; $\bar{h}_0$, $\bar{h}_1$ —The integral averages of h_0 and h_1 across the strip width B; v_0 —Longitudinal flow velocities at the entry; $\bar{v}_0$ —The integral averages of v_0 across the strip width B; l_0 —The length of initial strip; $\bar{l}_0$ —The integral averages of l_0 across the strip width B; E, v —The elastic modulus and the Poisson coefficient of strip; T_0, T_1 —The total back and front tension; u —The lateral displacement function at the deformation zone exit.

In this paper, the influence coefficient method of split mode is made to analyze the elastic deformation of rolls[1, 10, 11]

3 SIMULATION RESULTS

3.1 Modeling verification

To verify the theory model, vast scale computer simulation and experimental investigation have carried out on the cold rolled strip and crown of the 900 mm HC mill, the simulations of all tallies with the experiments. The main technical parameters of the mill are listed in Table 1[9]. The computation conditions of two cases are listed in Table 2. The comparison of experimental and simulation results are shown in Fig. 2.

Table 1 Main technical parameters of mill

Diameter of work roll body, D_w/mm	270
Length of work roll body, l_w/mm	900
Diameter of middle roll body, D_m/mm	340
Length of middle roll body, l_m/mm	920
Diameter of backing roll body, D_b/mm	850
Length of backing roll body, l_b/mm	850
Work roll bending force, F_w/kN	(− 254.5, 400)
Maximum lateral displacement of middle roll, δ/mm	200
Arc radius of middle roller end, R_m/mm	1 500
Arc length of middle roller end, l_e/mm	50
Maximum pressure, p_{max}/kN	8 000

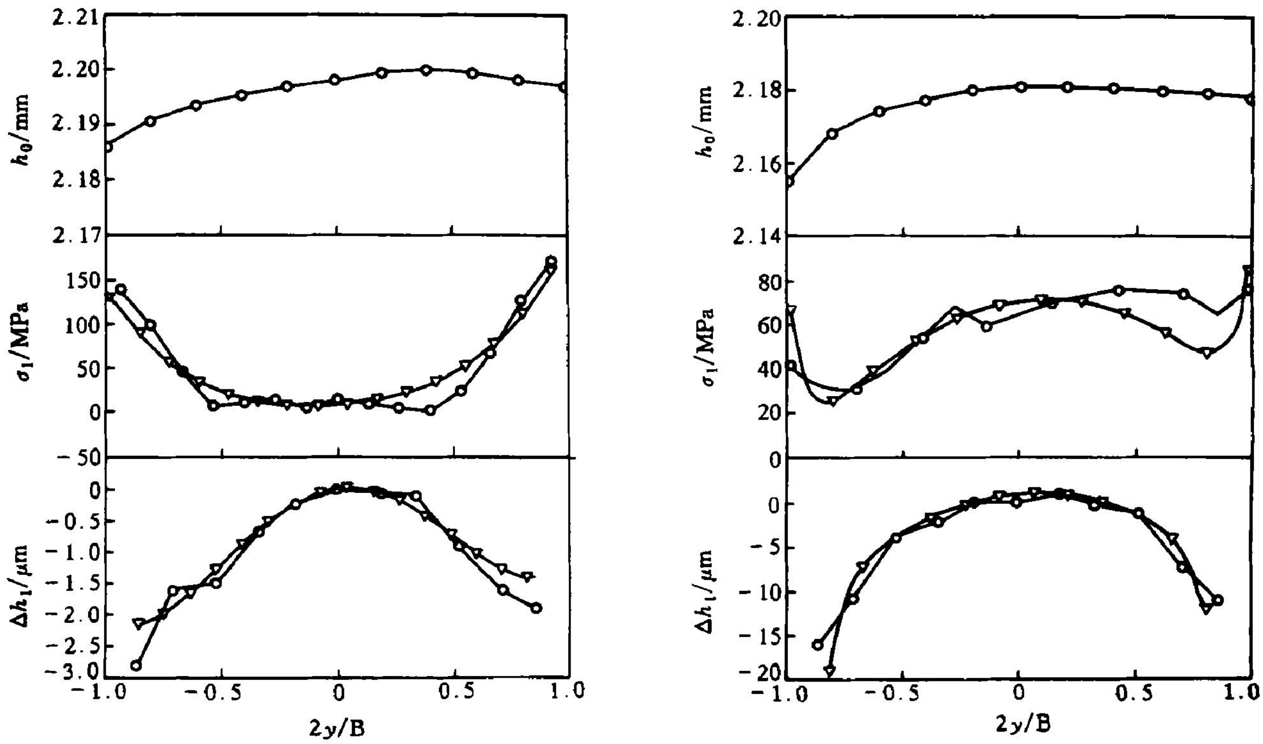

Fig. 2 Results of simulation and experiments

▽ —Theoretical; ○—Experimental; Left —Middle wave; Right —Edge wave

Table 2 Main computation conditions

Parameter	Middle wave	Edge wave
B/mm	722	662
T_0/kN	29.53	27.66
T_1/kN	47.81	41.25
Parameter	**Middle wave**	**Edge wave**
F_w/kN	153.6	147.0
δ/mm	-65.0	-70.5

3.2 Simulate results of transverse distribution pressure between rolls

The influence of the middle roll axial shift on the transverse distribution pressure between rolls are shown in Fig. 3. q_{wm} and q_{mb} of rolls bilateral are 3535.67, 4935.74 N/mm and 4610.2, 5196.53 N/mm when the axial shift of middle roll is -10 mm, and the four numerical values are 3011.53, 6818.65 N/mm and 3815.53, 6736.61 N/mm when the axial shift of middle roll is -76 mm. q_{wm} and q_{mb} variations are that the value increased at one side and decreased at the other side, the range ability is small, and the range ability of q_{mb} is more smaller than that of q_{wm}. It indicates that the influence of middle roll axial shift to q_{wm} and q_{mb} is smaller.

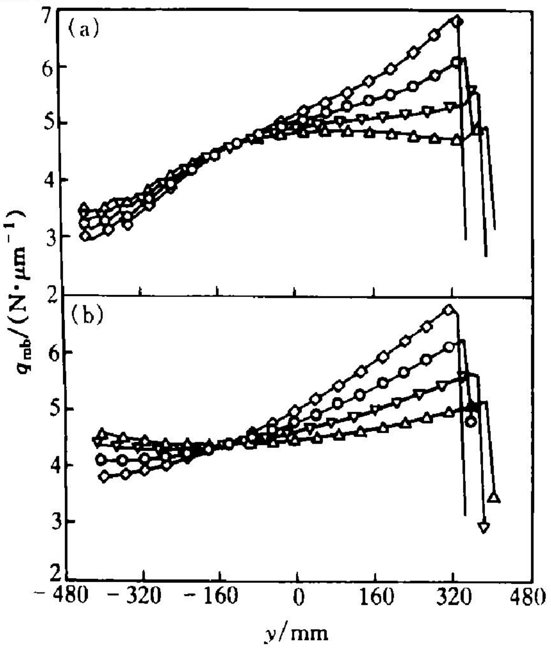

Fig. 3 Influence of middle roll axial shift on transverse distribution pressure between rolls (F_w = 80.0 kN)

△—-10 mm; ▽—-32 mm; ○—-54 mm; ◇—-76 mm

The influence of the work bending roll on the transverse distribution pressure between rolls is shown in Fig. 4. q_{wm} and q_{mb} of rolls bilateral are 2980.32, 5498.71 N/mm and 4153.31, 5764.39 N/mm when the work roll bending force is 45 kN, and the four numerical values are 4968.54, 7685.79 N/mm and 4882.21, 6626.66 N/mm when the work roll bending force is 240 kN. q_{wm} and q_{mb} variations are that the value increased at two sides, and the range ability of q_{wm} is bigger than that of q_{mb}. The influence of work bending rolls on q_{wm} and q_{mb} is big, especially on q_{wm}.

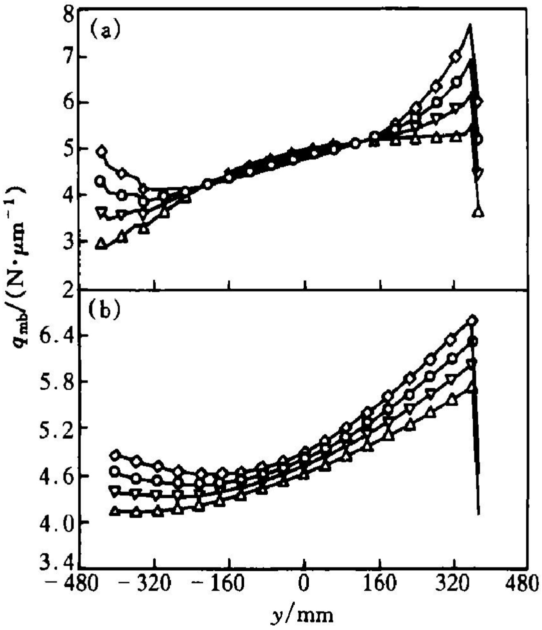

Fig. 4 Influence of work roll bending on transverse distribution pressure between rolls (F_w = -40 mm)

◇—45 kN; ○—110 kN; ▽—175 kN; △—240 kN

It is also known from Fig. 3 and Fig. 4, that the pressure between rolls dramatically decreases at the circular transition of middle roll mill body, and reduces the peak value of pressure between rolls. The condition of pressure between rolls is improved obviously because of the circular transition, and the operating life of rolls can be enlongated.

4 CONCLUSIONS

1) The simulation model is put forward and the software of HC mill deformation mechanics is compiled based on the mechanism of 3-D plastic deformation of strip and the elastic deformation of rolls. The results indicate that the accuracy of simulation can satisfy the demand of engineering. It can provide fundamental basis and be a powerfully tool for analyzing the mechanical behavior of cold strip rolling of HC mill, compiling the program of the shape control and evaluating the overall property of the mill.

2) The influence that the change of the middle roll axial shift and work roll bending force of HC mill on the transgressed distribution of pressure between work roll and middle roll is obviously, and the influ-

ence on the transverse distribution of pressure between middle roll and backing roll is obscure. The influence of work roll bending on the transverse distribution of pressure between rolls is bigger than that of middle roll axial shift.

3) The transverse distribution of pressure between rolls presents asymmetrical distribution because of middle roll axial shift. The condition of pressure between rolls is improved obviously because of the circular transition of middle roll body, and the operating life of rolls can be enlongated.

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(Edited by HUANG Jin-song)