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Materials

Strip shape control capability of hot wide strip rolling mills

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Abstract: The elasticity deformation of rolls was analyzed by means of two-dimensional finite element method (FEM) with variable thickness. Three typical mills were used as objects for analysis. A thorough study was done on the control capabilities of these mills on the strip shape. Then the strip shape control capabilities of the three mills was compared synthetically.

Key words: hot rolling; wide strip; strip shape model; elasticity deformation; crown

1. Introduction

The proportion of strip production has become very important to assess a country's steel industry level. In that case a good strip shape is necessary for strip quality. Controlling hot wide strip shape at strip rolling is a difficult and significant problem. At present choosing the type of hot strip rolling mills and building the automatic control model of strip shape are the two main methods to control strip shape quality in hot rolling [1-4]. In this article, based on the analysis of 1500-mill, 1700-mill, and 2150-mill, which are the three typical mills in hot wide strip rolling, their strip shape control capabilities were researched. This can be a reference for building a strip shape control model and choosing the type of hot wide strip rolling mills.

2. Calculated model of elasticity deformation

Three typical mills in hot wide strip rolling are 1500-mill, 1700-mill, and 2150-mill, because 1500-mill is close to 1420-mill and 1580-mill, 1700-mill is similar to 1780-mill and 1800-mill, and 2150-mill can represent 2030-mill and 2350-mill, which are big wide strip mills. Two-dimensional finite element method (FEM) with variable thickness is used as a main tool, to analyze the strip shape control capabilities of the three mills [5-6]. The purpose is to research on the coefficients of the strip shape control model as shown in the following equation. These coefficients follow strip wide changing.

$$C_R = K_{RF}P + K_{BF}BF + K_{Cw}C_w + K_{Cb}C_b + K_{Dw}D_w + K_{Db}D_b + K_{SFT}SFT + C_{in} \quad (1)$$

where C_R is the strip crown, K_{RF} the roll force effect rate, K_{BF} the work roll bending effect rate, K_{Cw} the work roll crown effect rate, K_{Cb} the backup roll crown effect rate, K_{Dw} the work roll diameter effect rate, K_{Db} the backup roll diameter effect rate, K_{SFT} the work roll shift effect rate, and C_{in} the entry strip crown. P is the roll force, BF the work roll bending force, C_w the work roll crown, C_b the backup roll crown, D_w the work roll diameter, D_b the backup roll diameter, and SFT the work roll shifting distance.

As shown in Fig. 1, a two-dimensional FEM analysis model has been advanced by Chen [7]. The basic idea is to combine the work roll and the backup roll into one entity, so that the distributed contact pressure between the work and backup rolls is converted into the internal forces that are to be determined. The model is two-dimensional although with different thicknesses in Z direction. Each element has its own thickness according to the ordinate distance from its roll axis and radius R. This specialized finite element model can predict the roll gap profile and the contact pressure distribution. It enables the actual mill conditions to be taken into account. Its validity has been ascertained by testing.

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3. Comparison of the strip shape control capabilities of three mills

The work condition limit of a rolling mill is always considered, and the maximum, the intermediary, and the minimum conditions are chosen. The rolling force is considered to distribute evenly, that is, Q_s =1.0. First, the conventional work roll is analyzed, where the wear profile and thermal crown are not involved, because they are included in the equivalent roll profile.

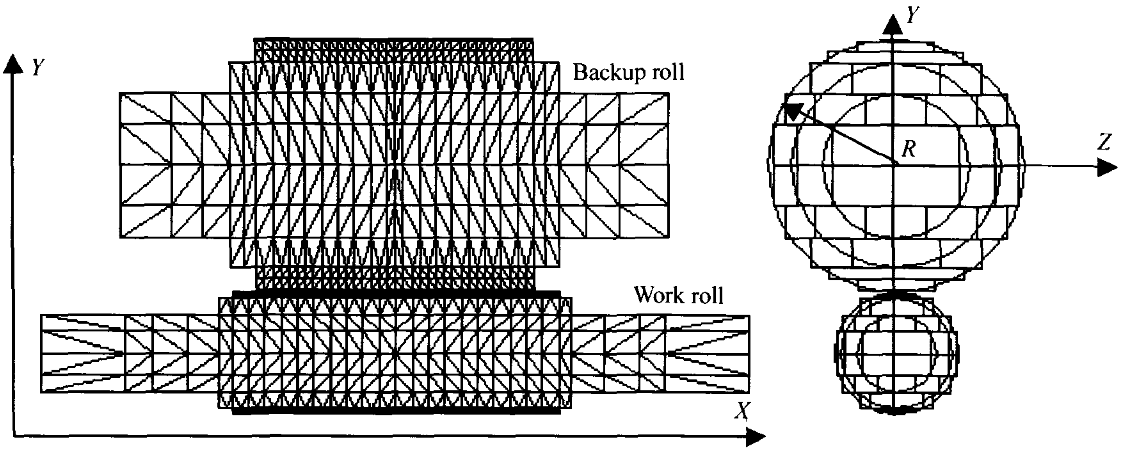

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Fig. 1. Two-dimensional FEM analysis mesh of a 4-high mill roll system.

All kinds of calculated parameters of the three mills are shown in Table 1. BW is the strip wide. The number of work conditions amount to the parameter product K_{RF}, K_{BF}, K_{Cw}, K_{Cb}, K_{Dw}, K_{Db}, and K_{SFT}, which need to be calculated in the model. At the outset C_0 can be calculated when BF=0, Q_S=1.0, C_w=0, C_b=0, and SFT=0. C_0 is the basis of calculating other parameters. Subsequently C_R is calculated. These model parameters can be readily calculated from the following equations.

$$K_M = \frac{\Delta C}{\Delta M} \quad (2)$$

$$\Delta C = C_R - C_0 \quad (3)$$

In Eq. (2), K_M is the instance of effect rate, ΔM is the instance of parameter change. In Eq. (3), ΔC is the difference between C_R and C_0. C_R and C_0 are the strip crowns corresponding to the instance ΔM.

Table 1. Calculated parameters of three mills

Mill type of	Q_S / (t·mm^{-1})	BF / kN	BW / mm	D_w / mm	D_b / mm	C_w / µm	C_b / µm	SFT / mm
1500	0.7	0	900	600	1350	−150	−100	−100
	1	550	1050	540	1250	0	0	0
	1.3	1100	1300	—	—	150	100	100
	—	—	1400	—	—	—	—	—
1700	0.7	0	900	700	1550	−150	−100	−150
	1	600	1150	630	1450	0	0	0
	1.3	1200	1350	—	—	150	100	150
	—	—	1550	—	—	—	—	—
2150	0.7	0	900	700	1600	−150	−100	−200
	1	750	1300	630	1450	0	0	0
	1.3	1500	1700	—	—	150	100	200
	—	—	2000	—	—	—	—	—

3.1. Effect of strip width on strip crown

Somers [8] predicts that roll deflection, and therefore strip crown, increases with an increase in roll force. As the roll force is proportional to the strip width, it can be expected to have a greater strip crown for the wider products that are rolled. Finite element analysis shows that the strip crown decreases with an increase in strip width reaching a certain extent. As shown in Fig. 2, this strip width inflexion approximates from about 70% to 80% of the roll barrel length. In that case this result is the same as Ginzburg's [9-10].

The maximum strip crown of 1500-mill is close to that of 1700-mill in these three mills, as shown in Fig. 2. However 2150-mill's maximum strip crown is greater than those of the other mills. It can be identified that the wider mill has the greatest strip center crown, and the strip crown also increases with increasing strip width. After a certain strip width the strip crown decreases.

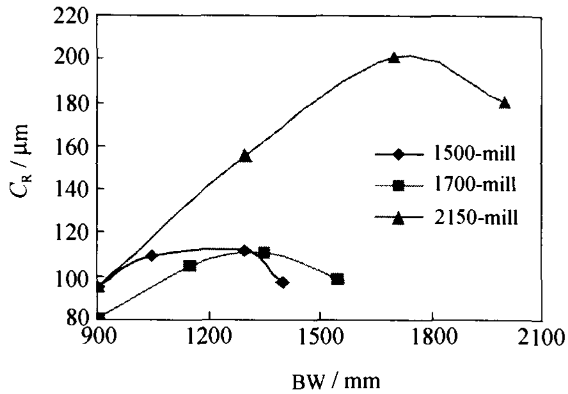

Fig. 2. Variation in strip center crown with strip width for three hot strip mills.

3.2. Effect of roll force on the strip crown

The effect of roll force on the strip center crown can be shown by the effect of the roll force parameter, K_{RF}. As stated earlier, the relationship between the roll force effect rate and the strip width is similar to the effect of strip width on the strip crown. First, it increases with an increase in strip width. Second, it decreases with an increase in strip width reaching a certain extent. As shown in Fig. 3, the roll force effect rate of 2150 mill changes rapidly and is greater than those of the other mills. The maximum roll force effect rate of 2150-mill is twice as much as those of 1500-mill and 1700-mill. It shows that the effect of the roll force on the strip crown is greater when wide strips are rolled at the wider mill. However 1500-mill's roll force effect rate is similar to that of 1700-mill's with an increase in strip width.

3.3. Effect of bending force on the strip crown

Roll bending is one of the most common methods used for continuous strip crown control during rolling. Moreover, it is the main measure of the strip control model. At present, work roll positive bending forces are applied to the work roll chocks in hot rolling. The effect of the bending force on the strip center crown is shown by bending force effect parameter, K_{BF}, and is in opposition to the effect of roll force. Positive roll bending causes the strip profile to become concave. As shown in Fig. 4 the work roll bending effect rate, K_{BF}, increases almost linearly, with an increase in the strip width, BW. Furthermore the maximum bending force effect rate of 2150-mill is greater than those of the other mills. When the same wide strips are rolled the effect of bending force of the wider mill is smaller. This indicates that the wider mill needs a great bending force to get the same strip crown.

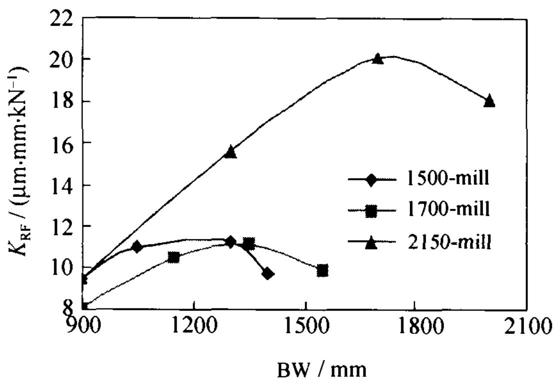

Fig. 3. Variation in roll force effect rate with strip width for three hot strip mills.

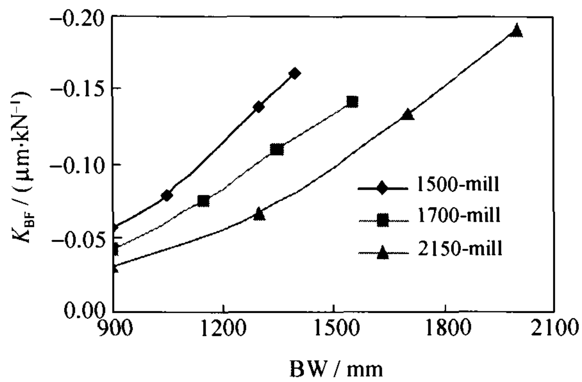

Fig. 4. Variation in roll bending effect rate with strip width for three hot strip mills.

3.4. Effect of work roll crown on the strip crown

The effect of work roll crown on the strip crown is shown by the work roll crown effect rate, K_{Cw}. Work roll crown effectively changes the no-load roll gap profile and modifies the roll contact conditions between the work rolls and backup rolls. It is one of the most common methods used for correcting a strip profile. This crown is for the whole work roll length and different from the strip crown. The effect of the work roll crowns of the three mills with an increase in strip width is shown in Fig. 5. The work roll crown is equal to −150 μm. As shown in Fig. 5, 2150-mill has the maximum work roll crown effect rate. However, at the same strip width the rate of 2150-mill is smaller than that of 1700-mill. It indicates that the work roll of a wider mill can use a big crown to reach the same crown adjusting capability.

3.5. Effect of backup crown on the strip crown

The effect of backup crown on the strip crown is shown by the backup roll crown effect rate, K_{Cb}. As shown in Figs. 5 and 6, the use of backup roll crown is much less common than that of work roll crown, as backup roll crown only modifies the interface conditions between the backup rolls and the work rolls. It has little effect on the no-load roll gap. The backup roll crown of the three mills is equal to 150 μm. 2150-mill has the maximum backup roll crown effect rate as shown in Fig. 6. However, at the same strip width the rate of 2150-mill is smaller than that of 1500-mill. This indicates that the backup roll of a wider mill can use a biger crown to reach the same crown adjusting capability. Moreover, this crown must not have a negative influence on the interface conditions between the backup rolls and the work rolls.

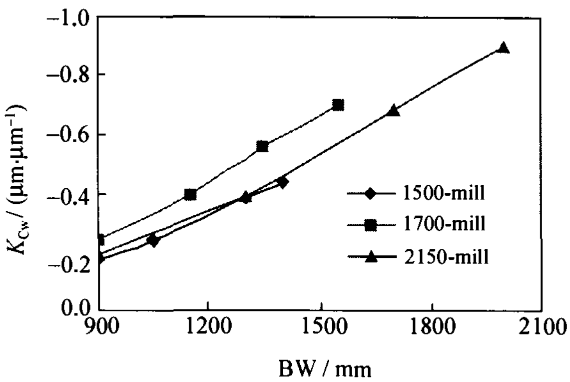

Fig. 5. Variation in work roll crown effect rate with strip width for three hot strip mills.

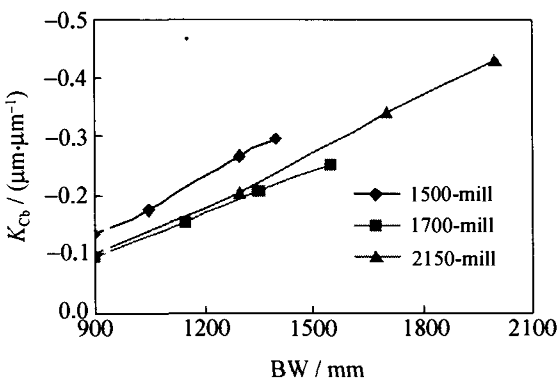

Fig. 6. Variation in backup roll crown effect rate with strip width for three hot strip mills.

3.6. Effect of work roll diameter on the strip crown

The work roll diameter effect rate, K_{Dw}, shows the effect of work roll diameter on the strip center crown. First, the effect of work roll diameter of the three mills increases with an increase in strip width. Second, it decreases with an increase in strip width reaching a certain extent. As shown in Fig. 7 this strip width inflexion approximates from about 70% to 80% of the roll barrel length. 1500-mill has the maximum work roll diameter effect rate at the same strip width, as the work roll diameter of 1500-mill is smaller than those of 1700-mill and 2150-mill. As the work roll diameter decreases, the resistance of the roll stack to deflection is lesser under a rolling load, resulting in a greater strip crown.

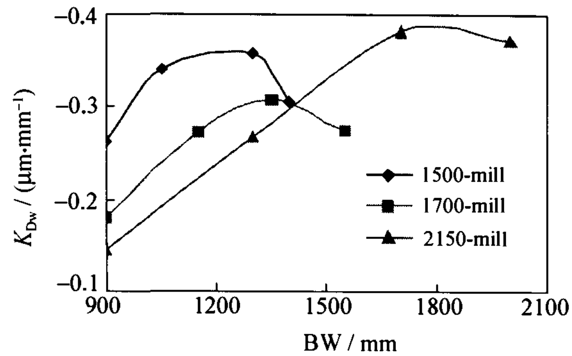

Fig. 7. Variation in work roll diameter effect rate with strip width for three hot strip mills.

3.7. Effect of backup roll diameter on the strip crown

The effect of a backup roll diameter on the strip crown can be shown by the backup roll diameter effect rate, K_{Db}, as the backup roll diameters are usually 1.5 to 2.5 times greater than the work roll diameter. With respect to the deflection, it becomes obvious that the effect of backup roll diameter on the strip crown is more sensitive than that of work roll diameter on the strip crown. The effect of backup roll diameter of three mills with an increase in strip width is shown in Fig. 8. As shown in Fig. 8, 2150-mill has the maximum backup roll diameter effect rate. However, at the same strip width the rate of 1500-mill is greater than those of 1700-mill and 2150-mill. The work roll diameter of 1500-mill is the smallest. As the backup roll diameter decreases, the resistance of roll stack to deflection is lesser under a rolling load, resulting in a greater strip crown.

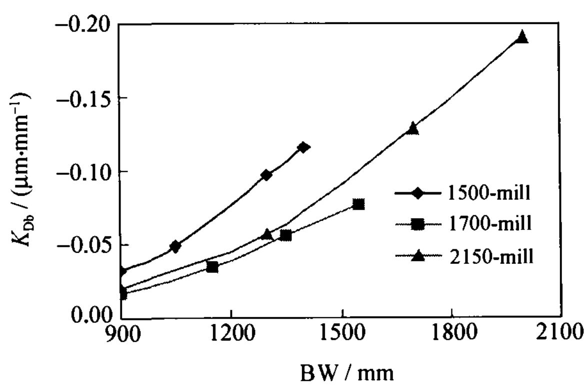

Fig. 8. Variation in backup roll diameter effect rate with strip width for three hot strip mills.

3.8. Other effect factors on the strip crown

The conventional work rolls and backup rolls are analyzed in roll deformation. By shifting work rolls there is no influence on the strip crown when the strip width changes. If continuously variable crown (CVC) rolls and linear variable crown (LVC) [11] rolls are analyzed, the shift work rolls have a great influence on the parameters of the strip control model.

4. Conclusions

(1) Two-dimensional FEM with variable thickness is an effective facility for analyzing the elasticity deformation of rolls.

(2) The common coefficients of the strip shape model are used as objects for analysis. The strip shape control capabilities of three typical mills, which follow the strip width changing, were compared. Hence, it offers a reference for building the strip shape model.

(3) The results of the strip shape control capabilities of these three mills will serve as a useful reference for choosing other types of hot wide strip rolling mills.

References

[1] R.M. Guo, Computer model simulation of strip and shape control, *Iron Steel Eng.*, 21(1986), No.11, p.35.

[2] R.M. Guo, Modeling of simulation and practical application for modern and shape control device of rolling mills, [in] *SATEC95*, USA, 1995, p.1.

[3] W. Willms, Profile and flatness control in hot strip mills, *Metall. Plant Technol.*, 18(1985), No.6, p.74.

[4] Q.H. Wu, J. Zhang, C.S. Wang, *et al.*, Effect of deformation between stands on the strip shape in hot rolling, *J. Univ. Sci. Technol. Beijing*, 7(2000), No.3, p.222.

[5] X.L. Chen and J.X. Zou, A specialized finite element model for investigating controlling factors affecting behavior of rolls and strip flatness, [in] *Proceedings 4th International Steel Rolling Conference*, Deauville, 1987, p.41.

[6] A.R. He, Q.D. Zhang, Q. Yang, *et al.*, Optimum configuration of modern tandem cold rolling mill, *Iron Steel* (in Chinese), 39(2004), No.5, p.43.

[7] X.L. Chen, Q. Yang, Y.H. Xu, *et al.*, Varing contact backup roll for improved strip flatness, [in] *Steel Technology Internation*, London, 1994/95, p.174.

[8] R.R. Somers, Verification and applications of a model for predicting hot strip profile, crown and flatness, [in] *AISE Year Book*, Pittsburgh, 1984, p.441.

[9] V.B. Ginzburg, Application of the ROLLFLEX™ computer model for analysis of the strip profile and flatness in rolling mills, [in] *The 1987 AISE Annual Convention*, Pittsburgh, 1987, p.21.

[10] V.B. Ginzburg, *High-Qulity Steel Rolling Theory and Practice*, Marcel Dekker Press, USA, 1993, p.34.

[11] R.Z. Wang, A.R. He, and Q. Yang, Research on the strip shape control capability of LVC work roll contour, *Iron Steel* (in Chinese), 41(2006), No.5, p.41.