Analysis of Roll Equivalent Crown of CVC-6h Mill

YANG Guang-hui[1, a], ZHANG Jie[1], CAO Jian-guo[1], XIE Zhen-ning[1]

[1]School of Mechanical Engineering, University of Science and Technology Beijing, Beijing 100083, China.

[a]yanggh@ustb.edu.cn

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Abstract. The 2180 mm tandem cold rolling mill is one of the widest cold mills in the world, and it improves the output and production efficiency largely, but some problems puzzle the production such as shape problems of strip, especially the limit width specification. In order to solve the problems, it is necessary to redesign the intermediate roll contour. However, the 2180 mm mill is a six-roll mill, and the intermediate roll adopts CVC contours, and the strip does not contact the CVC contour directly. The roll equivalent crown of the CVC contour can not be used after calculation. It is necessary to study the corresponding relationship between roll equivalent crown and strip crown of the ultra-wide mill. The finite element simulation model (FEM) is built with the MSC.Marc software. Through using the model, the corresponding relationship between roll equivalent crown and strip crown is analyzed, the result shows that the needed crown of work roll is the minimum, however, the needed crown of backup roll is the maximum in order to roll the strip which is same strip crown and approximate same cross section shape, and the effect of roll crown used in different rolls exists a relationship between each other.

Introduction

Since China has introduced the first set mill-the 1700 mm cold rolling mill on the seventy's of last century, the shape technologies such as rapid roll bending, CVC(Continuously Variable Crown), HC(High Crown), PC(Pair Cross), laminar cooling and so on have been widely used in wide-strip-steel tandem cold rolling mill. The common product width of cold rolling is generally below 1800 mm, the ratio of width to thickness is not more than 3800. In recent years, the number of ultra-wide rolling mill increases day by day, and the rolling width is greater than the 1800mm, and the ratio of width to thickness already reaches 4000, which brings a lot of difficulties to the shape control of strip[1-10].

The rolling width and roll length of the ultra-wide rolling mill are increased significantly, but the rolling thickness of strip and roll diameter do not change much. The increase of the width to thickness ratio of steel strip is easier to buckle, particularly prone to complex wave, and the large length to diameter ratio of the roll is easier to bend, this undoubtedly increases the difficulty of shape control of super wide strip mill. The 2180 mm rolling mill can roll the maximum width of 2080 mm, and it is equipped with many shape control means such as work roll and intermediate roll bending force, intermediate roll shifting and laminar cooling.

The work roll of a CVC four-roll mill adopts CVC contours, the strip contacts the CVC contour directly, and its roll equivalent crown is easier to calculate. However, the 2180 mm mill is a six-roll mill, and the intermediate roll adopts CVC contours, and the strip does not contact the CVC contour directly. The roll equivalent crown of the CVC contour cannot be used after calculation. It is necessary to study the corresponding relationship between roll equivalent crown and strip crown of the ultra-wide mill.

Establishment of finite element model

The Finite element model including roll and strip is built with the MSC.Marc software, and its modelling parameters are shown in Table 1 and Table 2, and its model is shown in Figure 1(a)[11-15]. Because the CVC mill has dissymmetry contour of intermediate roll, it needs to establish the section model of the upper and lower roll system. The model adopts the integration form including elastic deformation of roll and plastic deformation of strip, and its advantage is that it avoids the distribution assumption of deformation resistance of strip, meanwhile, it can apply the rear tension on the strip, so it is more suitable for the actual rolling process.

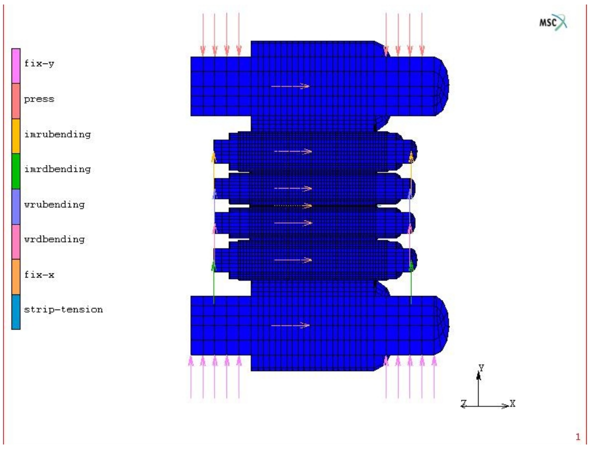
Table 1. Geometrical parameters of finite element simulation model

Roll	Roll barrel(diameter×length)	Roll neck(diameter×length)
Work roll/(mm×mm)	520×2180	317.5×250+465×360
Intermediate roll/(mm×mm)	610×2580	355.6×266+565×164
Backup roll/(mm×mm)	1380×2140	900×1051
Strip/(mm×mm)	1000~2000×0.5~5 (width×thickness) σ_s=270MPa, σ_b=320MPa	

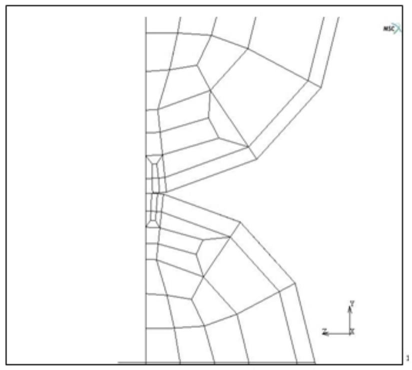
Table 2. Rolling parameters of finite element simulation model

Parameter	Value
Unit rolling force/(kN·mm^{-1})	10
Bending force of work roll/kN	-350~500
Shifting stroke/mm	-200~200
Tension/kN	0
Bending force of intermediate roll/kN	-450~650

The model unit selects 8 node tetrahedral element, and it has a total of 16258 units, 22626 nodes. The contact units are refined in the regions between rolls and between roll and strip as shown in Figure 1(b). The CVC contour of intermediate roll as shown in Figure 2 can be input by the coordinate value.



(a)



(b)

Figure 1. Finite element model including roll and strip

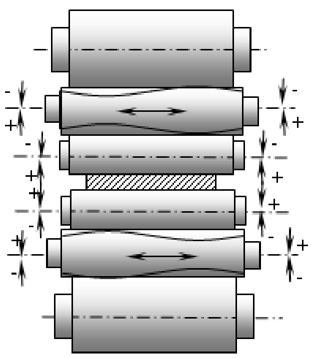


Figure 2. Sketch map of six-roll mill

Corresponding relationship between roll equivalent crown and strip crown

Due to the increase of the number of roll of six-roll mill, makes the mill, especially the optimization of roll shape have more choices, however, whether the impacts that the same crown (or equivalent crown) is used in different roll on the rolled strip are the same or not, in order to solve this problem, need the application analysis on the equivalent degree problem of roll shape.

On the assumption that the work roll, intermediate roll and backup roll are all conventional crown rolls, the strip crown and cross section are calculated and analyzed in different roll crown. The roll crowns are respectively 0, 0.02, 0.04, 0.06 and 0.08 mm as shown in Table 3. Except for the considered roll, the roll contours of the rest are flat.

Table 3. Corresponding relationship between strip crown and roll crown

Roll crown /mm	0	0.02	0.04	0.06	0.08
Srtip crown of different work roll crown /mm	0.16993	0.160921	0.151518	0.142674	0.13431
Srtip crown of different intermediate roll crown /mm	0.16993	0.164409	0.159057	0.15299	0.147508
Srtip crown of different backup roll crown /mm	0.16993	0.167701	0.165726	0.163616	0.161571

The variation corresponding relationship between roll crown and strip crown is described in curve as shown in Figure 3, strip crown changes with roll crown in a linear change, and the change rate of backup roll is the minimum, and the change rate of work roll is the maximum. The change rates of work roll, intermediate roll and backup roll are respectively 0.045, 0.028 and 0.0104. It can be seen from the Figure 3, although the rolling effects that the same roll contour is used for the different rolls are not completely equivalent, but there are certain relationships.

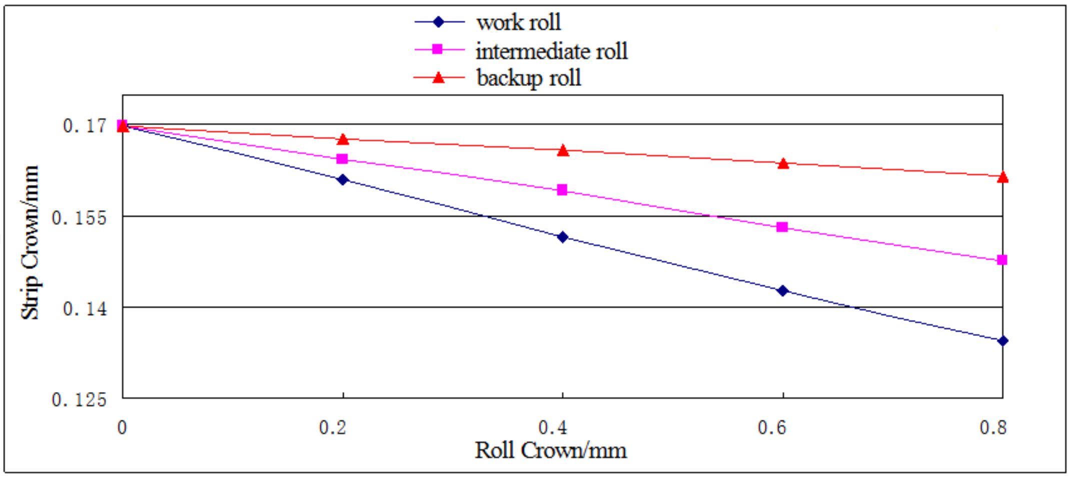


Figure 3. Corresponding relationship between roll equivalent crown and strip crown

Comparison of strip cross section shape

Select No.1 group and No.2 group of work roll, intermediate roll and backup roll with which the crowns of the rolled strip are the same, wherein, the crown of work roll of the No.1 group is 0.08 mm, and the crowns of intermediate roll and backup roll are flat. The crown of backup roll of the No.2 group is 0.02 mm, and the crowns of work roll and intermediate roll are flat. Their difference of cross sections is shown in Figure 4.

Select No.3 group and No.4 group of work roll, intermediate roll and backup roll with which the crowns of the rolled strip are the same, wherein, the crown of intermediate roll of the No.3 group is 0.06 mm, and the crowns of work roll and backup roll are flat. The crown of backup roll of the No.4 group is 0.02 mm, and the crowns of work roll and intermediate roll are flat. Their difference of cross sections is shown in Figure 5.

Select No.5 group and No.6 group of work roll, intermediate roll and backup roll with which the crowns of the rolled strip are the same, wherein, the crown of work roll of the No.5 group is 0.04 mm, and the crowns of intermediate roll and backup roll are flat. The crown of intermediate roll of the No.6 group is 0.02 mm, and the crowns of work roll and backup roll are flat. Their difference of cross sections is shown in Figure 6.

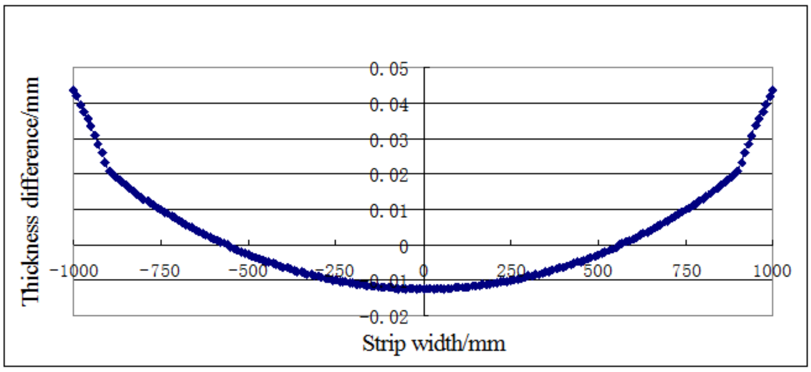


Figure 4. Difference of cross sections of No.1 group and No.2 group

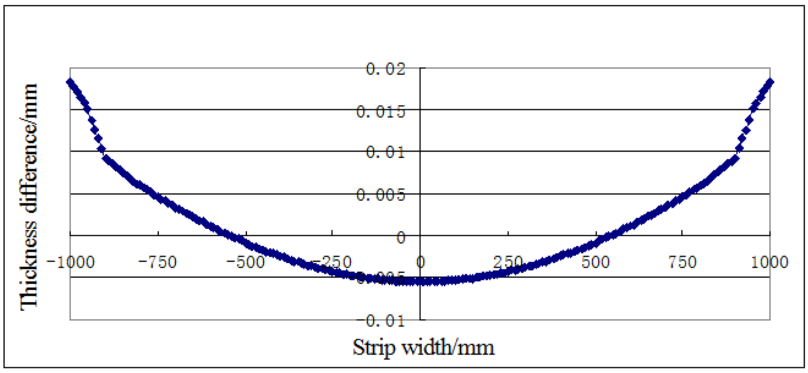


Figure 5. Difference of cross sections of No.3 group and No.4 group

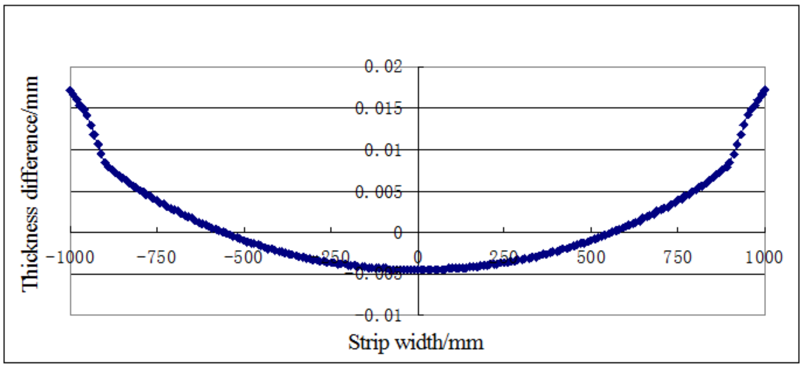


Figure 6. Difference of cross sections of No.5 group and No.6 group

It is seen from that Figure 4~ Figure 6 that differences of all cross section shape of strips are within 0.06 mm, taking the rolled strip thickness 5mm into account, so it can be thought that the cross section shapes of all rolled strips are almost the same corresponding to these roll crowns.

Summary

To sum up, if using different crown rolls to roll the strip respectively, in order to roll the strip which is the same strip crown and approximate same cross section shape, the needed crown of work roll is the minimum, however, the needed crown of backup roll is the maximum, and the effect of roll crown used in different rolls exists a relationship between each other. So the crown roll contour can be selected to use on work roll, intermediate roll or backup roll according to the actual produciton. For example, the CVC mill can use the roll crown contour on the intermediate roll, and the HC mill can be use the roll crown contour on the work roll.

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