Finite Element Analysis Elastic Deformation of Roll System for Cold Rolled Copper Belt

Weiqin Shao [1,a], Xiaobo Liu [1,b], Faqiang Feng [1,c]
[1] School of Aeronautic Manufacturing Engineering, Nanchang Hangkong University, Nanchang 330063, China
[a] email: shaoweiqin1@163.com, [b] email: liuxb2000@sina.com, [c] email: 951931285@qq.com

Key words: Cold rolled copper belt; Sendzimir twenty roll mill; Elastic deformation of roll system；Finite element

Abstract. According to the characteristics of copper belt's rolling process, the roll system's elastic deformation model of Sendzimir twenty roll mill is established, the contact normal stress between the rolls is calculated by using the ABAQUS software and the influence factors of the contact normal stress between the rolls are analyzed. Different controllable factors (such as strip width, the first intermediate roll transverse shifting, ASU adjustment) are analyzed on contact normal stress between work roll and strip copper and elastic flattening amount of work roll by using ABAQUS software to simulate finite element model in a variety of rolling.

Introduction

The scope of application is expanding for copper and copper alloy belt products, especially communications, electronics, electric power industry and technical requirements are higher development for copper belt products, so the level of production equipment and technical content are also rising [1-2].With the development of science & technology and industry, the demand of plate and strip for the high-precision, wide and thin of copper and copper alloy is growing [3-5]. Thin cold strip production must be outputted by multi-roll mill, especially more variety, low-volume and high strength of cold-rolled strip is needed. Elastic deformation analysis of roll system has the most important position on shape control theory. It has effect on the design of mill roll system structure, as well as optimizing reduction procedures and improving the quality of the shape [6-9].

In this paper, in order to obtain foundation of the plate-shaped and plate convexity, elastic deformation model of Sendzimir twenty roll mill is built and the data in rolling under different conditions are simulated, what's more, different controllable factors (such as plate width, the first intermediate roll transverse shifting, ASU adjustment, bending force and so on) and the effect of roll bending, roll flatten deformation, the shape of roll gap and the contact normal stress between rolls are analyzed.

Finite element analysis of rolls' elastic deformation

A. finite element model

According to the geometric parameters and material properties of Sendzimir twenty roll mill, three-dimensional finite element analysis model is built. As can be seen from Figure 1, due to the symmetry of the roll system, only a quarter of the model can be analyzed.

In the model, grids are divided more intensive in large deformation or stress concentration area, some are sparse, so the cells in internal of roll are divided widely; the closer to the surface of the roll, the cells are divided thinly. There are wedge (triangular prism) and hexahedral elements to analysis the three-dimensional problem, in this paper, C3D8R (eight-node linear hexahedral elements) is selected as the solid elements. Grids of rolls are divided as shown in Figure 1; there are 43764 nodes and 35896 units.

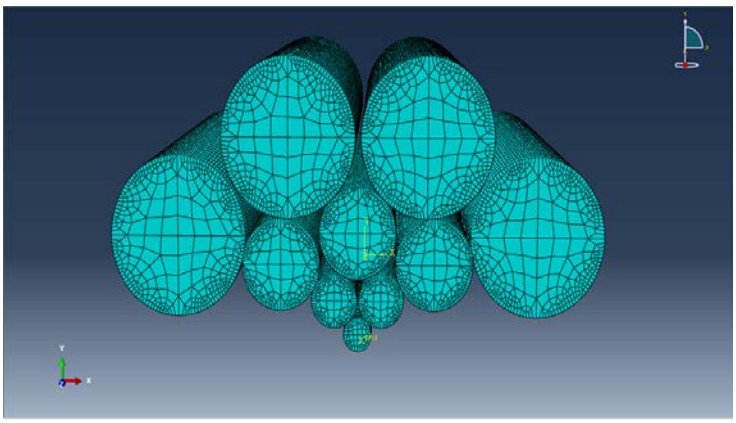


Fig. 1 Rollers' finite element mode of the sendzimir mill stand

B. Simulation of the production data

Production data can be measured by ZR33C-18 hydraulic reversible cold rolling mill which can product thin copper belt stably. Field data are shown in Table 1, Table 2 and Table 3.

Table 1 model：ZR33C-18 Copper belt width：320mm Copper belt model:C521

Number	h_0 /mm	h_1 /mm	Δh /mm	T_0 /KN	T_1 /KN	P /KN
1	0.420	0.286	0.134	4.4	10.4	183.0
2	0.286	0.200	0.086	8.8	9.3	270.4

Table 2 model：ZR33C-18 Copper belt width：400mm Copper belt model：C521

Number	h_0 /mm	h_1 /mm	Δh /mm	T_0 /KN	T_1 /KN	P /KN
1	0.700	0.455	0.245	12.2	23.9	353.0
2	0.455	0.341	0.115	19.5	20.5	405.8
3	0.341	0.256	0.085	16.0	16.9	408.3
4	0.256	0.197	0.059	13.0	13.7	377.9
5	0.197	0.160	0.037	10.8	11.4	321.9

Table 3 model：ZR33C-18　Copper belt width：480mm　Copper belt model：C521

Number	h_0 /mm	h_1 /mm	Δh /mm	T_0 /KN	T_1 /KN	P /KN
1	1.200	0.816	0.384	91	20	1166
2	0.816	0.569	0.247	152	91.1	1496
3	0.569	0.406	0163	175	151.6	1497
4	0.406	0.290	0.116	184	175	1494

Result and discussion

A. Analysis of contact normal stress between rolls

Simulation data are from Table 2 for the first pass, the second pass and the forth pass, the load roll force is 353.0, 405.8 and 377.9 respectively, then, contact normal stress between rolls is calculated as shown in Figure 2.

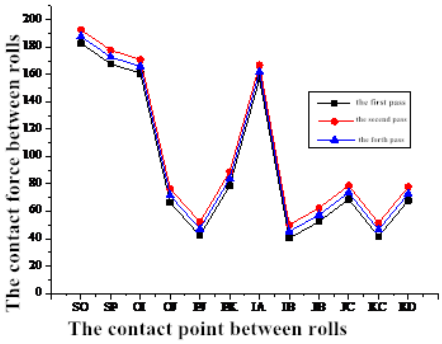


Fig. 2 The contact force between each roll in the roll system

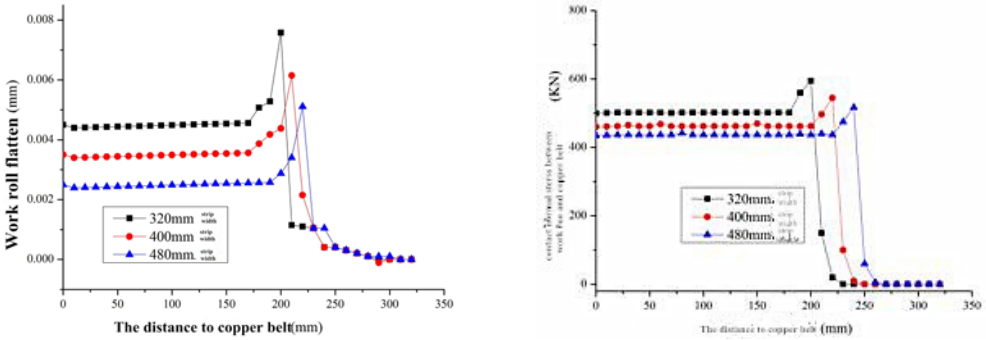
In Figure 2, the roll passes are different, the contact normal stress between each roll in the roll system also changes under the changes of roll force and strip tension.

(1) Notwithstanding the different roll passes, the changes of contact normal stress between rolls are little and the change is regularly in every rolling process. The contact normal stress is relatively large at the work roll and the first intermediate roller of the second pass; the maximum value is 192.82 *KN*. The trend of contact normal stress decreases between the first intermediate roller and the second intermediate rolls from left to right, in which the minimum contact normal stress is appeared in the first pass of the second intermediate driven roller ,and the value is 42.14 *KN*; the magnitude of the contact normal stress is certain between the second intermediate rolls and back-up roll, where the contact normal stress of left and right sides of the back-up roll is greater than the intermediate portion of the back-up roll; in addition, the minimum contact normal stress is appeared in the first pass of the second intermediate initiative roller ,the value is 40.21 *KN*;

（2）Roll force of roll system is assumed in the same position and pass reduction rate is substantially the same. As can be seen from Figure 2, roll force is proportional to the contact normal stress between rollers, and roll force has effect on the first intermediate rolls. When roll passes increase, roll force decreases after an initial increase, and the contact normal stress between rollers also changes regularly. In the rolling process, the effect of roll passes and roll force exerted on contact normal stress between rolls is relatively small, but regularly.

B. The effect of strip width

The substantially similar data are taken from the first pass of Table 1,the second pass of Table 2 and the forth pass of Table 4 and the rolled copper width is 320 mm、400 mm and 480 mm during the first intermediate roll transverse shifting is zero and ASU adjustment is zero, as shown in Figure 3(a) and Figure 3 (b). Work roll flatten and contact normal stress between rollers under various strip width are obtained by simulating.



(a) Work roll flatten (b) Contact normal stress

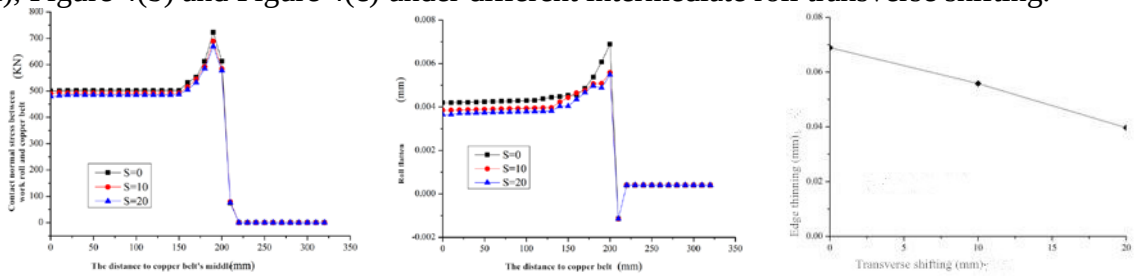
Fig.3 Under various strip width

It is seen from Figure 3(a) shown that distribution of work roll flatten deformation is substantially the same, which flatten deformation has been little change in contact area and it is plunged suddenly after reaching a peak at a contact between work roll and copper. Also, when strip width is increasing, the overall value of flatten deformation decreases and the peak declines, too. That is to say, the increasing of strip width and contact area, and the decreasing of roll force in the unit area leads to the decreasing of flatten deformation at work roll.

As can be seen from Figure 3(b), distribution of contact normal stress between work roll and strip copper is similar to flatten deformation, it has also been little change and it is declined rapidly to zero after reaching a peak at a contact area. This is also because the size of contact normal stress is directly related to the distribution of roll force; roll force reduces in the unit area with the increasing of strip width, so it leads to the overall contact normal stress reduces, but contact normal stress reaches a peak at the edge between copper and work roll.

C. The influence of the first intermediate roll transverse shifting

First, transverse shifting model of roll is established, then simulation data are calculated when the first intermediate roll transverse shifting respectively is 0, 10 and 20. Roll flatten, contact normal stress and the relation between transverse shifting and Edge thinning are shown in Figure 4(a), Figure 4(b) and Figure 4(c) under different intermediate roll transverse shifting.



(a) Roll flatten (b) Contact normal stress (c) The relation between transverse shifting and Edge thinning

Fig.4 Under different intermediate roll transverse shifting

Figure 4(a) shows that roll flatten gradually increases from left to right, the valve of roll flatten decreases rapidly after a sudden reached peak. As the first intermediate roll transverse shifting is increasing (e.g. it moves from left to right), the overall value of roll flatten slightly reduces a little, and the trend is more gentle, but roll flatten is greater impact on strip's edge.

Figure 4(b) shows that contact normal stress between copper belt and work roll has a similar trend with roll flatten during the first intermediate roll transverse shifting moves. This is to say, in rolling process, the first intermediate roll transverse shifting has effect on strip's crown; especially it has obvious effect on Edge thinning.

In Figure 4(c), original taper of the first intermediate roll is 0.2/120 (round radius/cone length); the change of edge thinning is shown when runout is set as follows: 0, 10 and 20. The first intermediate roll transverse shifting has a more significant impact on edge thinning, but transverse shifting and edge thinning is not a linear relationship.

D. The effect of ASU (as you)

Sendzimir twenty roll mill has three control strip flatness feature：(1) It has the original crown

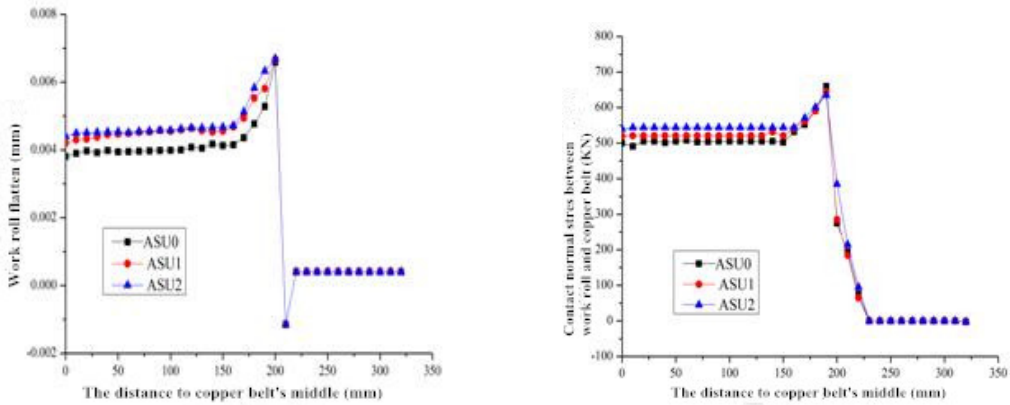
of rolls; (2) Support rollers B, C is multi-point support, this method can flexibly adjust and improve local defects in the rolling process; (3) The first intermediate roll transverse shifting with taper can be adjusted [10]. ASU has an important means to adjust plate-shaped during rolling.

Depending on the requirements of the roll shape, the form of the bearing distribution is divided into three modes: ASU0、ASU1 and ASU2.The adjustment size of each segment on ASU is shown in Table 4.

Table 4 Three kinds of adjustment mode on ASU's setpoint

ASU Adjustment/ μm					
Saddles number	1	2	3	4	Explanation
ASU0	0	0	0	0	Not adjusted
ASU1	0	-30	-30	0	ASU Intermediate depressed
ASU2	0	-60	-60	0	ASU Ends depressed

As can be seen from Figure 5(a) and Figure 5(b), work roll flatten deformation and contact normal stress between work roll and copper are obtained by the simulation under different pre-adjustment curve. When the adjustment is increasing, work roll flatten increases and the trend has been increased gradually but little impacted. At the same time, contact normal stress has the same trend as work roll flatten.



(a) Work roll flatten (b) Contact normal stress

Fig. 5 under different ASU's adjusted

Conclusion

Elastic deformation model of Sendzimir twenty roll mill is established, contact normal stress between rolls is simulated by using ABAQUS software, and the influence factors are analyzed. The results show that the influence of roll passes and roll force on contact normal stress between rolls of each roller is relatively small. Finite element model under different roll conditions is simulated by ABAQUS software and different controllable factors are analyzed, e.g. strip width, the first intermediate roll transverse shifting, the influence of ASU adjustment on work roll's elastic flattening and contact normal stress between work roll and copper belt. The results shows that as the stirp width are increasing, the overall value of flatten deformation decreases and the peak declines, too. During the first intermediate roll transverse shifting is increasing, flatten deformation of work roll in the overall value slightly reduces a little, and the trend is more gradual; the first intermediate roll transverse shifting has effect on strip's crown; especially it has obvious effect on edge thinning . What's more, work roll bending deformation also increases and the trend is gentle but has little effect on it with the increasing of adjustment.

Acknowledgement

In this paper, the research was sponsored by the External Cooperation Project of Jiangxi Province (Project No. 20122BDH80023).

Reference

[1]Lan Liya,Qin Guangwen.New technology development of copper board and copper belt [A]. Technology and applications of copper forum proceedings 2007 China [C].Beijing:China Nonferrous Metals,2007.323-333

[2]Gong Shoupeng.The status and development of copper strip products [J]. Shanghai Nonferrous Metals, 2011, 32(3)

[3] V.B.King, R Berg.Jiang Mingdong,Wang Guodong. Rolling theory and practice for hign-precision strip [M].Beijing: Metallurgical Industry Press, 2000:1-20

[4]Han Chen,Yu Jinhai,ChenJiasheng.Overview of domestic processing technology and equipment for copper strip and sheet[J]. Copper Engineering,,2012,(02):12-16

[5]Li Yaoqun. Domestic multi-roller rolling mill have been implicated in the production of thin cold rolled copper strip [J]. World Nonferrous Metals,2008,(1):18-24

[6] Zou Jiaxiang. Rolling Machinery [M]. Beijing: Metallurgical Industry Press, 2007:196-199

[7] Guanghui Yang，Jiangguo Cao,Jie Zhang,et al..The study on the backup roll contour of the SmartCrown tandem cold rolling mill [J].Journal of Science and Technology Beijing,2008,15(3):357~359

[8] Zhang Lianjun,Zhang Qingdong,Yu Meng. Analysis on shape control behavior of 20h Sendzimir mill by finite element method [J]. Metallurgical Equipment，2008，(1):40-43

[9] Zhang Qingdong,Sun Xiangming,Bai Jian. Analysis of Rolls’Elastic Deformation on CVC 6-h Mill by FEM [J]. China Mechanical Engineering，2008,18（7）：789~792