Analysis of Mechanical Parameters of 20-High Sendzimir Mill During Rolling Process

Qing-long MA¹*, Shi-qiang TIAN², Wen-long LI¹

¹College of Mechanical and Electronic Engineering, Dalian Minzu University, Dalian, Liaoning, China
²Nongfu Spring Co., LTD., Hangzhou, Zhejiang, China

*Corresponding author

Keywords: Sendzimir Mill, Mechanical Parameter, Roll system.

Abstract. Taking the 20-high Sendzimir mill as research object, the contact force and contact stress of the roll system were calculated and analyzed, and the distribution of them has been gained. What is more, the drive torque, including the rolling torque and rolling frictional torque was also analyzed, and the composing condition of the driving torque and rolling frictional torque has been obtained. The research results are significant for the design of the 20-high Sendzimir mill.

Introduction

The 20-high Sendzimir mill is one of the cold rolling mills, which has many characteristics, such as complex roll system, small diameter of the work roll, large pass reduction, and low energy consumption and so on. It is used to produce precision steel strip or high strength steel strip mainly.

About the study of 20-high Sendzimir mill, many researches were carried out from different angles, some researchers focus on the shape control of the Sendzimir mill[1-3], some focus on the stability of roll system[4], and some focus on the force analysis of the roll system[5,6].

Because of the complexity of roll system of 20-high mill, many studies have done on it, such as the roll gap pressure distribution and the acting force between contacting rolls, the contact force and resultant force of each roll in the roll system, and the roll deflection of the mill, and so on[7-9]. However, there are still not any report about the contact stress and drive torque.

In this study, the contact force and contact stress between the rolls were calculated and analyzed. What is more, the drive torque, include the rolling torque and rolling frictional torque was also analyzed. The result is important to the design of the 20-high Sendzimir mill.

Calculation Process

Roll Structure

The rolls of a 20-high Sendzimir mill are fixed symmetrically in eight plum borings with the frame of the pyramid arrangement 1-2-3-4. It consists of two work rolls S and T, four first intermediate rolls O, P, Q and R, six second intermediate rolls I, J, K, L, M and N, and eight backup rolls A, B, C, D, E, F, G and H, as shown in figure1.
Actually the backup rolls A-H are made up of a series of parts, such as backing bearing, shaft, etc. The backing assemblies, together with their bearings, transmit the roll separating force to the mill housing. Each backing assembly comprises one hardened steel shaft. All shafts are eccentrically mounted in hardened steel saddles which are located in the eight machines scallops in the housing bore. The backing bearings are mounted on the shafts between each saddle, as shown in figure 2.

The four second intermediate rolls I, K, N and L on both sides of the center line are the driven rolls driven by motors through universal spindles, the remaining 16 rolls are driven to rotate by the friction produced by each roll, and the strip is rolled between the two work rolls. The rolling force transfers from the work roll to the rack finally through the first intermediate roll, the second intermediate roll.

Three separate adjustments are provided in order to vary the work-roll gap, all three adjustments being obtained by the rotation of the eight eccentrically mounted shafts. Screw-down is controlled through the rotary positioning of the two upper central shafts "B" and "C". The position of the bottom work roll may be adjusted in relation to the mill pass-line by rotation of the two bottom shafts "F" and "G". The two outside shafts "A" and "H" and the other two outside shafts "D" and "E" are geared together and can be rotated in order to close in both the top and the bottom halves of the roll cluster simultaneously in order to compensate for reduced roll diameters.

**Calculation Model**

The forces between the rolls can be obtained through calculation according to the force analysis. Force analysis of the rolling state, in addition to the force between the rolls in the static state, the rolling friction force between the rolls and the friction force of the backing bearing should also be considered.
As to the calculation of driving torque, because of the large number of rolls in the 20-high mill, except for the torque caused by rolling process, the torque caused by the rolling friction between the rolls cannot be ignored. For the purpose of research, the rolling frictional torque was divided into four parts, namely torque 1, torque 2, torque 3, and torque 4. Torque 1 is the rolling frictional torque between the work roll and the first intermediate roll; torque 2 is the rolling frictional torque between the first intermediate roll and the second intermediate roll; torque 3 is the rolling frictional torque between the two sides of the backup rolls and the second intermediate roll, and the torque to overcome the friction in the backing bearings; torque 4 is the rolling frictional torque between the two backup rolls and the intermediate roll in the middle, and the torque to overcome the friction in the backing bearings.

The calculation model is introduced in the literature [10], so no more details here. Because of the complex relationship of the force between the roll system, especially the size and direction of each force, the iterative method is used to solve the problem, and the program has been written.

**Parameters and Rolling Plans**

In this paper, the 20-high Sendzimir mill in a stainless steel factory is selected, the parameters of the roll system are shown in Table 1. Stainless steel 304 is selected as the material for rolling process, the width of the strip is 1000 mm, entry thickness is 1.0 mm, exit thickness is 0.4 mm. Corresponding to the parameters of the rolling performance, rolling plan is made and shown in Table 2.

<table>
<thead>
<tr>
<th>Rolling pass</th>
<th>Entry thickness [mm]</th>
<th>Exit thickness [mm]</th>
<th>Entry tension [MPa]</th>
<th>Exit tension [MPa]</th>
<th>Rolling force [kN]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>0.78</td>
<td>174</td>
<td>246</td>
<td>2087</td>
</tr>
<tr>
<td>2</td>
<td>0.78</td>
<td>0.63</td>
<td>226</td>
<td>311</td>
<td>2681</td>
</tr>
<tr>
<td>3</td>
<td>0.63</td>
<td>0.53</td>
<td>265</td>
<td>353</td>
<td>2874</td>
</tr>
<tr>
<td>4</td>
<td>0.53</td>
<td>0.45</td>
<td>288</td>
<td>373</td>
<td>2854</td>
</tr>
<tr>
<td>5</td>
<td>0.45</td>
<td>0.4</td>
<td>310</td>
<td>390</td>
<td>2706</td>
</tr>
</tbody>
</table>

**Results and Discussion**

**Contact Force and Stress**

According to Table 2, the rolling force of each pass is shown in figure 3. Respectively, the contact force between the rolls of pass 1, pass 3 and pass 5 is shown in figure 4, we can see that the changing tendency of the contact force is basically the same, the value of the contact force is mainly affected by the value of the rolling force, except
for the geometric angle between the rollers. The contact force between roll S and O is the biggest, which is 1917.6 kN in pass 3. While the contact force between the roll I and B and the force between the roll P and J are relatively small, the smallest contact force in this example is 353.2 kN in pass 1 between the roll I and B.

![Figure 3. Rolling Force of each pass.](image1)
![Figure 4. Contact force between rolls.](image2)

The contact stress between rolls of pass 1, pass 3 and pass 5 is shown in figure 5, we can see that the changing tendency of the contact stress is basically the same also, the stress between the roll S and O is the biggest, which is 1105.1 MPa in pass 3, the stress between the roll I and B is the smallest, which is 334.5 MPa in pass 1. The analysis shows that the contact stress between the work roll and first intermediate roll is the biggest, which can reach more than 1000 MPa, so it should be considered during design stage.

**Driving Torque**

The total driving torque is consist of rolling torque and rolling frictional torque, the composing condition of the driving torque is shown in figure 6. There are many influencing factors of rolling torque, e.g. entry thickness, reduction, rolling force etc, so the rolling torque decreased with the thickness reduction from pass 2. In pass 1, the value of the rolling torque is 10.61 kN·m, the value of the rolling frictional torque is 2.64 kN·m, till pass 5, the corresponding values are 5.80 kN·m and 3.61 kN·m, which have become much closer.

![Figure 5. Contact stress between rolls.](image3)
![Figure 6. Composing of the driving torque.](image4)

Compared with figure 3, we can see that the variation tendency of the rolling frictional torque is similar to the variation tendency of the rolling force, the reason is that the rolling frictional torque has a lot to do with the contact force between the rolls.

The proportion of the rolling frictional torque in the total driving torque is shown in
figure 7, from pass 1 to pass 5, the proportion of the rolling frictional torque keeps raising. In pass 1, the proportion is 19.89%, while in pass 5, the proportion is 38.34%, almost double the proportion of pass 1. So the rolling frictional torque cannot be ignored during the total driving torque calculation process.

The composing condition of rolling frictional torque in each rolling pass is shown in figure 8; the change tendency of each torque with the rolling pass is basically the same. Torque 2, namely the rolling frictional torque between the first intermediate roll and the second intermediate roll is the smallest, and the smallest value is 0.515 kN·m in rolling pass 1. While torque 3, namely the rolling frictional torque between the two sides of the backup rolls and the second intermediate roll, and the torque to overcome the friction in the backing bearings is the biggest, the biggest value is 1.215 kN·m in rolling pass 3.

Conclusions

1) The contact force between roll S and O is the biggest and the contact stress between them is also the biggest, which can reach more than 1000 MPa, so it should be considered during design process.

2) The proportion of the rolling frictional torque in the total driving torque keeps raising with the decrease of the thickness of the strip. In this example, the proportion of the rolling frictional torque reaches 38.34% in pass 5, so the rolling frictional torque cannot be ignored during the total driving torque calculation process.

3) Analysis of the composing condition of rolling frictional torque in each rolling pass is done, torque 2, namely the rolling frictional torque between the first intermediate roll and the second intermediate roll is the smallest; while torque 3, namely the rolling frictional torque between the two sides of the backup rolls and the second intermediate roll, and the torque to overcome the friction in the backing bearings is the biggest.

Acknowledgement

This research was financially supported by the Fundamental Research Funds for the Central Universities.

References


