Study on the Vertical-Torsion Coupling Vibration of Six-high Rolling Mill

ZEFENG LI, LINGLI CUI AND LIXIN GAO

ABSTRACT

Proposes a method of constructing six-high rolling mill vertical-torsion coupling dynamics model base on the multi-freedom vibration systems theory. Finally by comparing the mean value of the vibration amplitude, quantitative analysis of the mutual influence degree of torsional vibration and vertical vibration.

INTRODUCTION

At present, many domestic and foreign scholars study the problem of the rolling mill coupling. He fined that there is a vertical torsion coupling vibration in rolling mill through theoretical research and simulation\(^1\). In this paper, the coupling coefficient is applied to the vibration of rolling mill, and the vertical torsional coupled vibration model of six roll mill is established. The natural frequency of the first 18 order of the coupling system is calculated. These provide theoretical basis for structure design of rolling mill.

VERTICAL-TORSION COUPLING VIBRATION MODEL OF SIX ROLL MILL

Establishment of dynamic model of six roller mill

Six-high rolling mill main drive system can be simplified to the symmetrical elastic branch system of 10 inertia 9 stiffness, and the vertical system can be simplified to the asymmetric eight degrees of freedom model of vertical vibration\(^2\). In the biting stage, the dynamic response of the working roll is a vertical-torsion coupling vibration due to the impact of the vertical direction of the rolling mill. At the same time, the work roll is used as the coupling interface, and the vibration is transmitted to the whole system. Six roller mill coupling vibration model is shown in Figure 1.

Determination of calculating parameters

We can see the calculation results of the parameters J, K, M of the table 1 and the table 2 in figure 2.

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Establishment of coupling vibration differential equations

According to the mechanical model of figure 2, the differential equation of the vertical-torsion coupling vibration of the six-high rolling mill is established.

\[
[M] \dddot{x} + [C] \dot{x} + [K] x = \{P\}/T
\]  

(1)

In the formula, \([M]\) is a coupling mass matrix; \([C]\) is a coupling damping matrix; \([K]\) is a coupling stiffness matrix; \(\{P\}\) is a rolling force vector; \(\{T\}\) is a rolling moment vector; \(\theta, \dot{\theta}, \ddot{\theta}\) are the element torsional displacement, angular velocity, angular acceleration, inertial array of the main drive system. \(x, \dot{x}, \ddot{x}\) are the equivalent mass displacement, velocity, acceleration array of the pressure system. \([K]\) includes \(K_{26T}\) and \(K_{16T}\), which are the vertical-torsion coupling stiffness. In this paper, we introduce the method of damping ratio for the vibration differential equation of regular coordinates. The damping term is treated by the system, and the coupling term of \([C]\) matrix is neglected \(^3\).
Determination of vertical torsional coupling stiffness

The coupling stiffness can be expressed as the product of the coupling coefficient and the corresponding stiffness, which is \( K_i \cdot K_{i/} = \delta K_i \) is the rigidity of the ith axis vertical vibration; \( \delta \) is the vertical-torsion coupling coefficient. The value is different, the vertical-torsion coupling of the mutual influence degree is not the same, so the vertical-torsion coupling coefficient is very important for the coupling vibration.

The coupling stiffness of the upper transmission system and the upper working roll is:

\[
K_{16T} = \frac{1}{K_4 + \frac{1}{K_{16}}} + \frac{1}{K_5 + \frac{1}{K_{16}}} = 6.9 \times 10^7 \ (N \cdot m/\text{rad}) \tag{2}
\]

Due to the structure symmetry, the coupling stiffness of the lower transmission system and the lower working roll is:

\[
K_{26T} = \frac{1}{K_5 + \frac{1}{K_{26}}} + \frac{1}{K_6 + \frac{1}{K_{26}}} = 6.9 \times 10^7 \ (N \cdot m/\text{rad}) \tag{3}
\]

So the coupling coefficient is:

\[
\delta = \frac{K_{16T}}{K_{16}} = \frac{K_{26T}}{K_{26}} = \frac{6.9 \times 10^7}{1.32 \times 10^8} = 0.52296 \tag{4}
\]

CHARACTERISTIC ANALYSIS OF ROLLING MILL COUPLING VIBRATION SYSTEM

Influence of vertical vibration on torsional vibration

In table 5, \( \Delta \theta_i \) represents the relative torsional displacement of each element in the main drive system. In the actual production process, effects of vertical vibration of torsional vibration may cause fracture of the steel roll shaft bite.

Table 5. Relative torsional displacement of each element in the main drive system.

<table>
<thead>
<tr>
<th>Angle</th>
<th>Without coupling</th>
<th>coupling</th>
<th>Without coupling/Without coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \theta_1 )</td>
<td>0.035</td>
<td>0.03599</td>
<td>1.03</td>
</tr>
<tr>
<td>( \Delta \theta_2 )</td>
<td>0.02699</td>
<td>0.03878</td>
<td>1.44</td>
</tr>
<tr>
<td>( \Delta \theta_3 )</td>
<td>0.02257</td>
<td>0.05726</td>
<td>2.54</td>
</tr>
<tr>
<td>( \Delta \theta_4 )</td>
<td>0.02999</td>
<td>0.06352</td>
<td>2.12</td>
</tr>
<tr>
<td>( \Delta \theta_5 )</td>
<td>0.02511</td>
<td>0.06726</td>
<td>2.67</td>
</tr>
<tr>
<td>( \Delta \theta_6 )</td>
<td>0.06523</td>
<td>0.20351</td>
<td>3.12</td>
</tr>
<tr>
<td>( \Delta \theta_7 )</td>
<td>0.01777</td>
<td>0.07815</td>
<td>4.39</td>
</tr>
<tr>
<td>( \Delta \theta_8 )</td>
<td>0.03511</td>
<td>0.08251</td>
<td>2.35</td>
</tr>
<tr>
<td>( \Delta \theta_9 )</td>
<td>0.06523</td>
<td>0.19723</td>
<td>3.02</td>
</tr>
<tr>
<td>( \Delta \theta_{10} )</td>
<td>0.01777</td>
<td>0.06731</td>
<td>3.78</td>
</tr>
</tbody>
</table>
Table 6. Influence of torsional vibration on vertical vibration.

<table>
<thead>
<tr>
<th>Displacement</th>
<th>Without coupling</th>
<th>Coupling</th>
<th>Without coupling/Without coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_1$</td>
<td>0.01215</td>
<td>0.01307</td>
<td>1.07</td>
</tr>
<tr>
<td>$x_2$</td>
<td>0.01855</td>
<td>0.02232</td>
<td>1.20</td>
</tr>
<tr>
<td>$x_3$</td>
<td>0.01804</td>
<td>0.02359</td>
<td>1.31</td>
</tr>
<tr>
<td>$x_4$</td>
<td>0.01734</td>
<td>0.02439</td>
<td>1.41</td>
</tr>
<tr>
<td>$x_5$</td>
<td>0.01772</td>
<td>0.02515</td>
<td>1.42</td>
</tr>
<tr>
<td>$x_6$</td>
<td>0.01819</td>
<td>0.02484</td>
<td>1.37</td>
</tr>
<tr>
<td>$x_7$</td>
<td>0.01832</td>
<td>0.02392</td>
<td>1.31</td>
</tr>
<tr>
<td>$x_8$</td>
<td>0.00341</td>
<td>0.00371</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Influence of torsional vibration on vertical vibration

Table 6 is the influence of torsional vibration on the vertical vibration, and is the maximum displacement of the mass block is the maximum. It can be seen that the influence of torsional vibration on the vertical vibration is mainly reflected in the upper and lower work roll. The displacement amount is 1.41 times and 1.42 times when the torsional vibration is not considered, and the influence of torsional vibration on the vertical vibration is not obvious.

CONCLUSIONS

(1) The dynamic model and the vibration differential equation of the vertical torsional coupling dynamic model of the six roll mill are established, and the vertical torsional coupling coefficient of vibration is obtained by calculation.

(2) The influence of the vertical vibration on the torsional vibration of the six roll mill is obvious, and the torsional displacement of the roller and the universal coupling is obviously increased, so the influence of the vertical vibration on the torsional vibration cannot be ignored.

(3) The torsional vibration of the six roll mill is also increasing when the torsional vibration is considered, but the influence of the torsional vibration on the vertical vibration is not obvious.

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REFERENCES


