Study on Torsional Vibration of Six High Cold Rolling Mill

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ABSTRACT

Aiming at the quality problems caused by vibration in a cold rolling mill of a steel mill. The mechanical model and mathematical model of the main drive system of six high cold rolling mill are established based on the F4 frame which was the strongest vibration. The natural frequencies is calculated by using MATLAB. On this basis, the simulation analysis of damping, clearance and stiffness in the main drive system of rolling mill has been carried out. It is found that the relationship between damping, clearance, stiffness and torque amplification factor which provides an important theoretical reference for the structure design of the rolling mill.

INTRODUCTION

Rolling mill main drive system is mainly composed of the motor, coupling, reducer, roller and other components, its role is to the motor torque and motion to the roll. The torque of the system is stable when the load is added to the shaft, so the vibration will not happen under the condition of the system. But in the mutation load (such as biting and throwing just, brake, variable speed operation) under the action of, the rolling mill main drive system will occur unstable torsional vibration, which may in strip that leads to vertical to the rolling direction and alternating light and dark stripes, even in severe cases will cause major accidents, such as the destruction of main drive system. This situation is not explained by the theory of mechanical static strength. Therefore, it is significant to study the torsional vibration characteristics of the rolling mill main drive system, which is of great significance to solve the problem of the vibration of the rolling mill.

At present, studying on torsional vibration of rolling mill main drive system mainly focuses on two aspects: one is the research on torque amplification factor (TAF), to determine the reverse occurs when the maximum power of the main drive system of rolling mill loads; On the other hand is study on torsional vibration system of amplitude frequency characteristics, to ensure that the device has good dynamic characteristics and control performance. But these two aspects need to simplify the whole drive system, establish a reasonable mechanical model and mathematical model, and then solve the model, analysis of its inherent characteristics and dynamic response.
THE ESTABLISHMENT OF DYNAMIC MODEL AND CALCULATION OF NATURAL FREQUENCIES

Establishment of mechanical model.

A six roller cold rolling mill main transmission system structure diagram as shown in figure 1. The physical parameters of the mechanical model are the moment of inertia J and the torsional stiffness of the elastic element K and the damping C. The diagram shows the structure of the rolling mill, roll is by the same motor through a gear seat to drive the, so the mechanical model can be simplified as branching system as shown in Figure 2.

Calculation of natural frequencies.

Natural frequency is the basic characteristics of the main drive system, the natural frequency of free vibration frequency is not free, so the calculation of the natural frequency to ignore the damping. The differential equation of free vibration is:

\[
J\ddot{\theta} + K\dot{\theta} = 0
\]  

(1)

According to the structure parameters of rolling mill, the moment of inertia and torsional stiffness of each component are calculated. The natural frequency of each order is calculated as shown in Table 1.

<table>
<thead>
<tr>
<th>( f_1 )</th>
<th>( f_2 )</th>
<th>( f_3 )</th>
<th>( f_4 )</th>
<th>( f_5 )</th>
<th>( f_6 )</th>
<th>( f_7 )</th>
<th>( f_8 )</th>
<th>( f_9 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.33</td>
<td>14.82</td>
<td>34.97</td>
<td>112.86</td>
<td>114.95</td>
<td>169.49</td>
<td>178.88</td>
<td>205.61</td>
<td>286.97</td>
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</table>
According to the operation condition of the field of six roller mills, the shafting is a constant velocity motion, that is, there is no vibration before the rolling mill. So it can be assumed that the initial condition is $\{\theta\} = 0$, $\{\dot{\theta}\} = 0$, $\{\ddot{\theta}\} = 0$. Ramp loading time is 0.02s, the rolling torque of motor rotor is 135KN·m and the rolling force of the roller is 224KN·m as the initial condition. Using MATLAB programming for the following three kinds of situation of the rolling mill simulation analysis. Because of the complete symmetry of the upper and lower system branches, only the upper support system is analyzed and studied.

**Influence of damping on transmission system.**

Large amount of measured data show that the mill to bite into the workpiece, transient response is attenuated, of which the damping plays a big role, damping and not in any condition can ignore, otherwise, the calculation results will have a certain bias. In fact, because of the friction between the bearing and the drive system, the damping of the air resistance is not small, so the effect of the damping on the main drive system of the rolling mill cannot be completely ignored. For the damping of the system has been tested in the main drive system of rolling mill about damping ratio in the range of 0.025~0.05.

The damping ratio of $\xi$ is 0, 0.025, 0.030, 0.035 and 0.040 respectively, and the results are shown in Figure 3.

By the above analysis shows that the main drive system of the rolling mill, the greater the damping, the smaller the torque amplification factor, the smaller the damage to the system. Therefore, in the design of the main drive system of rolling mill, to consider appropriate increase damping.

![Figure 3. The TAF value under different damping ratio.](image-url)
Effect of clearance at the joint of the universal joint on the torque amplification factor.

Generally speaking, the torque amplification factor is not more than 2, then the vibration will not cause damage to the equipment. However, due to the existence of the main driving parts of the mill processing errors and running wear, it will inevitably produce a gap. In the rolling mill main drive system, the most prone to failure is the universal joint shaft, so the study of the universal joint shaft at both ends of the gap between the situations. Using MATLAB programming and Taking the gap between 0rad, 0.05rad, 0.1rad, 0.15rad, 0.2rad, 0.25rad, 0.3rad for research and analysis. The results shown in Figure 4.

From the above analysis, we can know that when the gap between the two ends of the universal joint, the size of the gap directly affects the size of the torque amplification factor. It can be found that the gap size is proportional to the size of the torque amplification factor. So when the main drive system in the gap, it should be the first from the elimination of clearance.
The influence of the stiffness of universal joint on the torque amplification factor.

Because the natural frequency of the rolling mill main drive system is closely related to the torsional rigidity, the torsional rigidity of the main drive system of the rolling mill cannot be ignored. In this paper, the change of the torque amplification factor is analyzed by studying the torsional stiffness of the universal joint. The torsional rigidity is 0.5K, K, 1.5K, 2K, 2.5K, and the results are shown in Figure 5.

Through the analysis of Figure 5 shows that: the torque amplification factor TAF value of the universal joint will decrease with the increase of the K5 of the stiffness. According to this Law in the design of the rolling mill can be appropriately increased to reduce the torsional rigidity TAF. By material mechanics, it can be known that by adjusting the diameter D and length L of the universal joint, the torsional rigidity of the universal joint is changed, so that the TAF can be reduced.

SUMMARY

(1) By setting up the mechanical model and mathematical model of the main drive system of six roller mill, the natural frequencies is calculated.

(2) Considering the influence of damping on the main drive system of rolling mill, the simulation calculation of different damping ratio was carried out, and the TAF value of each shaft section under different damping ratio was obtained, and the higher the damping ratio, the lower the TAF value was found.

(3) Based on the analysis of the gap between two ends of the universal joint shaft of the rolling mill main drive system: the greater the gap, the greater the value of TAF, the more likely to cause damage to the system.

(4) For the stiffness of the system, it can be known that increasing the torsional stiffness can reduce the TAF value, thereby reducing the vibration of the main rotation system of the mill.

ACKNOWLEDGEMENTS

Project funds: Early Fault Features and Extraction Method Research of Cold Rolling Mill System Based on Flexible Multi body and Coupling Dynamics Research Foundation Project: 51375019.

REFERENCE