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Research on causes and solutions of chattering in strip cold rolling mills

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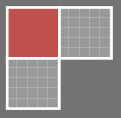
ABSTRACT

The chattering of strip cold rolling mill has various forms, and its causes and characteristics are not the same. The current studies of chattering in cold rolling mills are mainly on the torsional chattering and vertical chattering. Study on chattering in rolling mill involves rich theories including many in the fields of rolling theory, friction and lubrication theory, control theory, chattering theory, signal processing theory. And the influenced factors of chattering in rolling mill should be considered from the aspects of the mechanical, electrical, friction and lubrication, the mill itself, and production process The present study analyzes the present researches on the chattering in rolling mill, and on this basis, analyzes the causes and solutions of the torsional chattering in main drive system of rolling mill and the chattering in vertical system of rolling mill. But because chattering in rolling mills caused by multiple factors, when the mill begin to operate, it may have disturbance in many aspects, and these disturbances often influence each other. It is sometimes difficult to find out an effective solution to control. And the online monitoring system of chattering in developing engine can real-time monitor the running of the mill. Once there appears chattering, it will make a real-time alarm, so as to resolve the problems timely. Besides, it can make statistics of the parameters of chattering rolling mill which has the vital significance in the research, forecast, prevention and control of the chattering in rolling mill. What's more, the introduction of computing with high performance and real-time simulation system will have good effect on the control and monitoring of the chattering in rolling mills.

KEYWORDS

Cold rolling mills; Torsional chattering; Vertical chattering; Disturbance.



INTRODUCTION

The chattering in strip cold rolling mill is a major technical problem that plagues iron and steel enterprises, having attracted attentions by the world's production engineering areas and science and technology area. With higher the rolling speed, greater the pressure ratio, and thinner plate, the chattering phenomenon is more prone to occur[1]. Chattering in rolling mill will make light and dark lines on the surface of steel products, stripes, and change the thickness of the strip, making the strip thickness errors and reducing the quality of the products; and it will leave chattering traces on the roller and the surface of rolled piece, accelerating the abrasion of the roll surface, shortening the life of the roller, and increasing cost; besides it may cause accidents such as belt being broken or equipment being damaged, threatening the security of the staff and causing significant economic losses. So the study of the causes of chattering in the rolling mill, and putting forward the corresponding solutions is urgent researching task at present[3]. The paper makes study on strip cold rolling mill, analyzing the forms, causes and control measures of chattering in rolling mills and expecting to provide some reference for solving the chattering problems in rolling mill chattering.

ANALYSIS OF THE EXISTING RESEARCHES ON THE CHATTERING IN ROLLING MILLS

Much attention has been given to the researches on the chattering problems in rolling mill and many scholars had done in-depth researches on different types of chattering problems in rolling mills from different angles which makes great contribution to promote the development of rolling mill chattering theory and progress of rolling process. With the development of science and technology as well as the progress of computer technology, testing methods and instrumentation is continually being updates and changing. And the research of rolling mill chattering theory has entered into a new stage. Although the chattering problem has received attention of experts and scholars, there are still a lot of chattering problems in rolling mill. In order to improve the quality of strip, the chattering problems in rolling mill must be resolved. At present, the solutions put up by scholars to solve the chattering problems in rolling mill are mainly for the vertical chattering[4], and the ways to reduce the vertical chattering of the mill are: (1) reduce the rolling speed to reduce the chattering of rolling mill; (2) appropriately distribute the pressure of each machine to reduce the chattering of rolling mill; (3) reduce the inlet tension of rolled piece properly, or appropriately reduce the concentration of lubricant emulsion to restrain or delay the self-excited chattering, so that chattering in rolling mill can be reduced; (4) appropriately decrease the gap between the side of the stage supporting roller bearing and the lining plate of the frame window to reduce the chattering of rolling mill; (5) using hydraulic lining plate to reduce the chattering of rolling mill is currently popular research of reducing chattering.

ANALYSIS OF THE FORMS AND CAUSES OF CHATTERING IN STRIP COLD ROLLING MILLS

There are different forms of chattering in rolling mill and the characteristics and causes of the chattering are also different. According to the machines producing chattering, chattering in rolling mills can be divided into forced chattering and self-excited chattering. The present study for forced chattering is relatively mature, and most researches are made on the self-excited chattering in rolling mills. Figure 1 shows the system the self-excited chattering, from which it can be seen that there are two factors to form a self-excited chattering: one is a self-excited closed-loop system that absorbs the energy from outside, another is a strong enough external perturbations to undermine the stability of the system. With these two factors, e a self-excited chattering can be produced. Figure 2 shows the forming process of self-excited chattering, it indicates that when some external condition cause the rolling force, tension, and 90 degree differences between rolling motions, a self-excited chattering will be formed. According to the different relationship of the load transferring, self-excited chattering can be divided into torsional chattering in main drive system of rolling mill and chattering in vertical system of rolling mill. Now, these two modes of chattering will be\ explained simply.

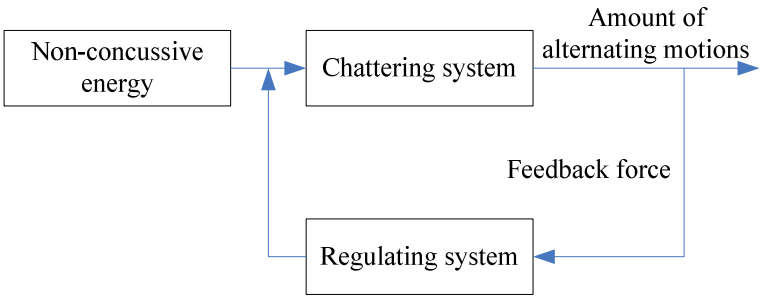


Figure 1 : The constitution of the self-excited chattering system

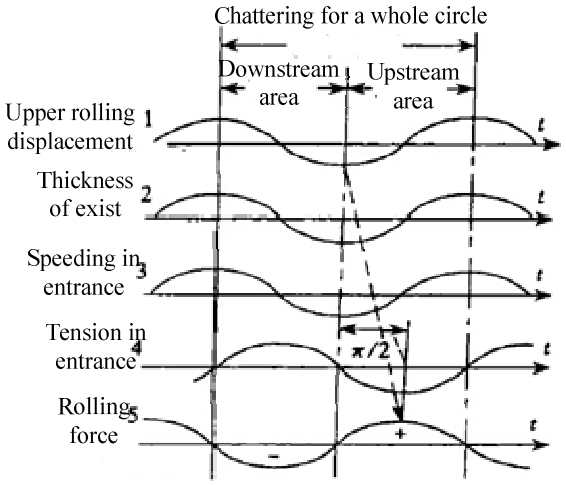


Figure 2 : The forming process of self-exited chattering

Torsional chattering in main drive system of rolling mill

In the production process of rolling mill, the transmission parts often get damages. Through the study, people gradually realize that this is result of the torsional chattering in rolling mill and the torsional chattering frequency is about between 5-20Hz. Figure 3 is a simplified model and layout of the main drive system of rolling mill, from which it can be seen that the main drive system of rolling mill is composed of several inertial and elastic links. The main drive system will not chatter in the stable loading and torque changes occurring in spindle are static and smooth, having no effect on the operation of the system. But in the running process, the sudden increase of load will result in unstable torsional chattering. And the torque in spindle will change with the changes of rotation cycle of torsional variation. The changing frequency is original torsional frequency of the system,which will make damage to the parts of the mill, effect production quality and the normal operation of plate and strip equipment, and increase the costs of supplies.

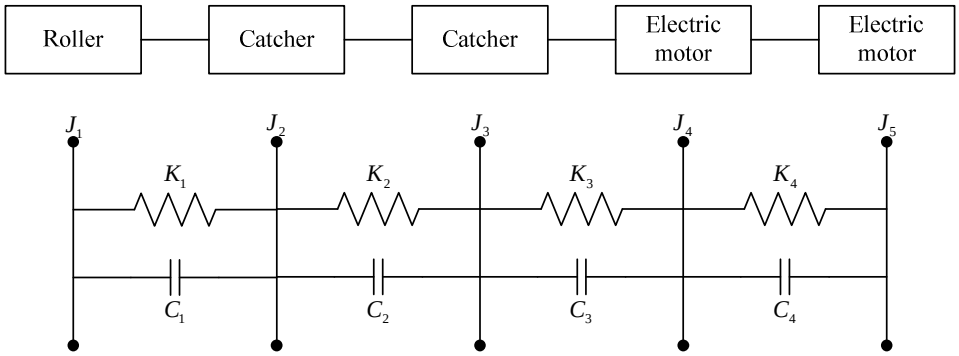


Figure 1: The layout and simplified model of the main drive system of rolling mill

The simplified model of the main drive system of rolling mill can be expressed by Formation (1):

$$J\ddot{\theta} + C\dot{\theta} + K\theta = M \quad \textbf{(1)}$$

J represents inertia matrix of the system; $\ddot{\theta}$ represents the acceleration matrix of the rotating angular; C represents the damping matrix; $\dot{\theta}$ represents the velocity matrix of rotation angular; K represents the stiffness matrix; θ represents the matrix of rotation angle; M represents the moment matrix.

The study of torsional chattering mainly refers to study of the change of toque in transmission shaft, and the factors that influence the change of toque in transmission shaft are mainly produced by mechanical, electrical, lubrication and other aspects.

(1) Influence of mechanical transmission

When cold rolling mill is in a mechanical transmission, a gap will be produced in this process. And when the rolling mill does accelerate running, the gap is closed. But when the mill undertakes some shock in operation process, rotational axis will change and the gap will open under the influence of the inertial force and gravity, space will open, which will have great

influence on the rolling amplification coefficient in the drive system and, causing torsional chattering, damaging or failing the transmission parts and resulting in the huge economic loss. The problem can be solved by reducing the rolling amplification coefficient.

(2) Influence of electrical system

In the large cold rolling mill, interface drive system of rolling mill and electrical system will be influenced by the changes of each factor in electrical system, resulting in torsional chattering in rolling mill. Factors like the periodic change of load in rolling the strip, the impact load that the mill undertakes, and the accordance between natural mechanical frequency of rolling mill and electrical frequency of driving system will all cause torsional chattering.

(3) Influence of lubrication

When the mill is in operation, lubrication of the rolling technology can reduce and control the friction in the process of rolling, and improper lubrication can also cause chattering. Then insufficient lubrication of the roller surface will intensify friction between roller and rolled pieces, thus changing the coefficient of friction, forming the negative damping feedback, and causing self-excited torsional chattering; too much lubrication of the roller surface will easily lead to roll slip, thus affecting the normal operation of the production. Australian scholars pointed out in 1967 twist rotation in rolling mill has a certain relationship with coefficient of frication in the roller gap. When the rolling speed increases, the friction coefficient will reduce which leads to the torsional chattering in rolling mill. Figure 4 shows the relationship between rolling speed and friction coefficient.

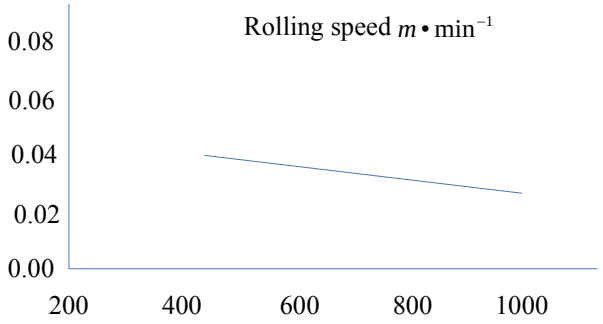


Figure 4 : The relationship between rolling speed and friction coefficient

Chattering in the vertical system of the rolling mill

Early in 1970s, scholars have began to study vertical chattering of the mill, and with the continuous change of mills, high speed and consistency have become the inevitable trend of the development of rolling mill and the vertical chattering of the mill also has aroused the concern and attention of the scholars. Vertical chattering often appears in the actual operation process of rolling mill. If classify the chattering according to frequency of chattering, one is the triple octave chattering whose frequency is between 150-250Hz, and it has the greatest harm for the high speed rolling mill at present stage. Its occurrence has no sign, and is usually a sudden one, at the same time causing a lot of noise. At this time, decreasing the speed of the mill immediately can reduce the chattering. The triple octave chattering will change the thickness of the rolled piece and may also change the tension of the rolled pieces between body frames. Sometimes it may result wasted products, broken belt, or the threat of equipment safety. Another one is the quintupling octave chattering whose frequency is between 500-700Hz. It is different from the triple octave chattering on the aspect that its happening process is a slow changing process. This chatter can make chatter mark which is perpendicular to the rolling direction on the bearing roller or on the surface of the rolled piece, influencing the quality of the product. Figure 5 shows the geometric characteristics of chattering wave generated in the production process.

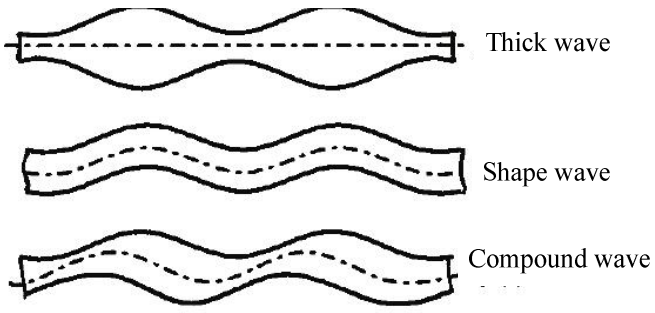


Figure 5 : The geometric characteristics of chattering wave

There are many reasons that cause the occurrence of vertical chattering of the mill. As long as the mill undertakes some impact or some changes occurs on the force, the vertical chattering can possibly happen. The causes mainly can be divided into three categories: the influence of mill system itself; the influence of fluctuating tension during the rolling process; the influence of friction and lubrication.

(1) The influence of mill system itself

In the rolling process of the mill, working roller and supporting roller may have eccentric activities which will vertical chattering in vertical system. In addition, when the control system under pressure in hydraulic system is instable, it will cause the instability of rolling mill system, thus resulting in vertical chattering, The stability of the control system under pressure in hydraulic system is related to the oil supplying pressure of servo valve in the system, compensation value of roller bending force, and the set value and actual value of rolling force. The changes of these unstable factors will cause the instability of rolling mill system, resulting in vertical chattering.

(2) The influence of fluctuating tension during the rolling process

Because the fluctuation of the rolling tension will make important influence on the chattering in rolling mill, the rolling tension in the rolling process should be strictly controlled. The change of the parameters of production process and equipment in the process will cause the balance of metal flowing amount, resulting in fluctuation of rolling tension. There are many examples of vertical chattering in mills caused by fluctuation of rolling in actual production process. Therefore, the rolling tension in the production process should be strictly controlled and supervised.

(3) The influence of friction and lubrication

In the working process of the mill, the actual diameter of upper and lower working rollers can not be exactly same. But the two working rollers are working driven by the same motor and at the same time, their speeds are the same. And subtle differences between the working rollers are likely to cause asynchronous rolling after rolling for some time, which may generate vertical chattering. This kind of asynchronous rolling phenomenon will not make the chattering in the if the roller and rolling are well lubricated and if not, the vertical chattering will appear. In a iron and steel producing factory in Chiba of Japan, vertical chattering appeared in a three stand cold rolling mill, and after research it is found that the ill performance of the using rolling oil which affects the lubricating effect cause the vertical chattering [5].

ANALYSIS OF THE STRATEGY OF CONTROLLING THE CHATTERING IN STRIP COLD ROLLING MILL

The strategy of controlling torsional chattering in main drive system

Considering from the mechanical transmission, the chattering is caused mainly by the change of friction force in roller gap and the gap at the connecting part of transmission system. So by reducing the rolling amplification coefficient, the chattering can be solved to some degree. Considering from the electrical system direction, regard the chattering generated by mechanical transmission as an external interfering in the electrical system, and control the electromechanical chattering in electrical system from the aspect of anti-disturbance. At the outset of the study, some scholars through adding a lag filter in the forward channel to control electromechanical system and avoid the resonance of natural frequencies. With the wide application of modern control theory in engineering, scholars of South Korean invented a load observer to eliminate the external disturbance and the fluctuation of speed caused by the load disturbance, controlling the chattering[6]. But adding a load observer will simplify the connection of drive system of rolling mill to rigid connection, which cannot the control chattering produced by resonance and the rolling disturbance. At the present stage, methods in electromechanical coupling, adaptive control, fuzzy neural network, variable structure control are effective for the suppression of torsional chattering caused by the instability of the electrical system. Considering from the lubrication, choosing a good lubricant and reasonable control of the degree of lubrication can control the chattering in rolling mill.

The strategy of controlling chattering in vertical system of the rolling mill

The control of chattering in vertical system of rolling mill mainly includes active control and passive control. Active control is to make control aiming at the causes of the chattering, such as reasonable choice of lubricants, strict selection of diameters of upper and lower working rollers, improving the accuracy of gear and bearing, making scientific and reasonable rules of rolling process[7]. As for the passive control, it is to make research on improving the ability of anti chattering of rolling mill, such as the use of elastic coupling, standing strip of hydraulic mill, and dynamic chattering absorber in rolling mill.

CONCLUSIONS

Chattering in cold rolling mill always concerns the engineering field. This study analyzed the existing researches on solving the chattering in rolling mill from the researching status and summarized the chattering control methods. And self-excited chattering in the cold rolling mill has been analyzed, and the fact that the self-excited chattering in the rolling mill mainly has two kinds: the torsional chattering and vertical chattering. Then the causes and solutions for these two kinds of chattering are analyzed. With the development of science and technology, study of the control of chattering in rolling mill should develop toward the simulation system with high-performance of computing and real-time quality.

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