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Study on the Vibration of the 1700 Four Rollers Rolling Mill

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Abstract: Aimed at the vibration problem of the rolling mill, by using the large FEM software ANSYS, modal analysis of the rolling mill is did. The natural frequency and the vibration models of rolling mill model are obtained. Analysis the simulation results, the causation of the vibration is found, and the solutions are proposed, which provides references for the designing of mill and restraining mill vibration. *Copyright © 2012 IFSA.*

Keywords: Rolling mill, Vibration, Modal analysis, ANSYS.

1. Introduction

The vibration of rolling mill is a long plagued problem in mill industry. The losses are very serious cased by the vibration of rolling mill. Such as rolled strips appear chatter marks, and the quality cannot meet the production standards. Others components of rolling mill are damaged. Not only the efficiency of production is reduced, but also the safety of staffs is threatened.

As there are so many parts on mill and the assembly of those parts is complex, so there are much vibration signals when the mill is working. The transitional vibration and noise is eliminated after the researching of vibration, and then the frequency of excitation is minimized. The signal measurements are simplified, and the analysis of problem becomes efficient, by using the finite element analysis software of ANSYS. The dynamic vibration modals of rolling mill are achieved on the software platform. The performance of every parts of rolling mill is descried by the clear dynamics cloud when rolling mill is motivated [1]. The location and type of vibration source is determined by the result of modal analysis, which provides a powerful theoretical foundation for the inhibitor and avoiding of mill vibration [2].

2. The Characteristics of the Chatter Marks on Backup Rolls Surface

This is a 1700 four rollers rolling mill, its barrel length is 1700 mm, and started from 1978. The main components of rolling mill: the aches, the pressure device, the backup rolls, the balance tanks, the working rolls, the replacing roll device, the locking device and the wedge. When it is working at the stable speed of 1000 m /min, the vibration of rolling mill is significant. Chatter marks appear on backup roll surface, the chatter marks shown as Fig. 1.

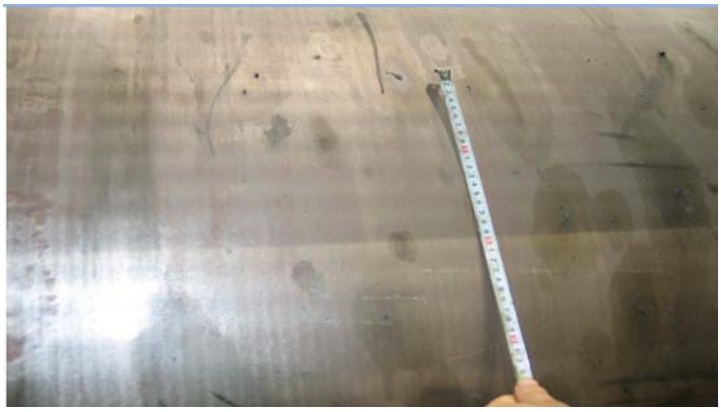


Fig. 1. The shape of chatter marks on backup rolls surface.

The Chatter marks parallel to the axis of roll. The lights and darks are alternated. The distance between light and dark is uniformity, and approximately is 138.8 mm. The intensity of chatter marks is different generally, no obvious law. The brightness of stripes can be transformed each other with the changement of the observation and illumination angle. The light stripes are changed into the dark stripes, while the dark stripes are changed into the light stripes. The locations of chatter marks on backup roll surface are not fixed. And chatter marks are shifted on the circumuferential direction of roll surface. The roughness of the light filed or the dark filed is the same.

There is a close correspondence between the distance of chatter marks, the rolling speed and the vibration frequency [3]. The stable rolling speed is 1000 m /min, while the distance of chatter marks is 138.8 mm. So the contact state between the working rolls and the backup rolls presents a certain periodicity. And the vibration frequency of backup rolls is：

$$f = \frac{v}{\lambda} = 120Hz\,, \tag{1}$$

where v is the stable rolling speed; λ is the distance of chatter marks; f is the vibration frequency.

With the mill is working, the surface of rolled strips also appear irregular chatter marks. The quality of rolled strips is reduced, and the backup rolls are damaged. There is a close association between the vibration and chatter marks. To reduce the losses cased by chatter marks, it is need to determine the location and type of vibration. To find the reason why the vibration frequency 120 Hz is caused, modal analysis of rolling mill.

3. The Theory of Modal Analysis

The classic definition of modal analysis: in order to find the modal parameters of the system, the physical coordinates in the differential equations of vibration in a linear constant system is transformed into the modal coordinates, which decouples the equations. It is an independent equation described by the modal coordinates and the modal parameters [4]. The coordinate transformation matrix is called the modal matrix that each column is the mode shape.

$$[M]\{\ddot{x}\}+[C]\{\dot{x}\}+[K]\{x\}=[Q], \tag{2}$$

where $[M]$ is the mass matrix of system; $[K]$ is the stiffness matrix of system; $[C]$ is the damping matrix of system; $\{\ddot{x}\}$ is the acceleration column vector of system; $\{\dot{x}\}$ is the velocity column vector of system; $\{x\}$ is the displacement column vector of system; $[Q]$ is the loading matrix.

The modal parameters of the system are identified, which is the ultimate goal of modal analysis. The basis for the vibration analysis of structural systems, the diagnosis and prediction of vibration fault and the properties optimization of structural dynamic are provided by modal analysis. So in order to understand and analyze the mechanism of the natural frequency characteristics, and simulate their dynamic behavior, modal analysis of rolling mill is needed [5].

4. The Modal Analysis of Rolling Mill

4.1. Establish The Model of Rolling Mill

The location of vibration source can not be got clearly, so the whole rolling mill model established. With the sheets of this mill, the components of rolling mill are drawn by the three-dimensional mapping software of PROE. And the three-dimensional solid model of rolling mill is shown as Fig. 2.

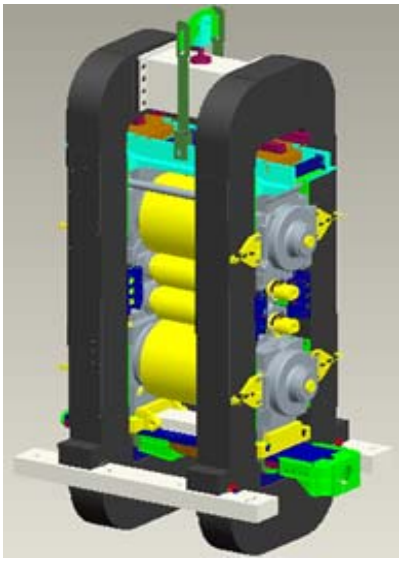


Fig. 2. The model of rolling mill in PROE.

Because the size of rolling mill is large, the structure and the assembly is complex, so it is difficult to establish the model in the pre-processor of ANSYS, otherwise the expression of the structure is

incomplete [6]. Before doing the modal analysis, the model of rolling mill can be simplified base on the three-dimensional solid model of rolling mill. Then change into the IGES format (the compatible file format of ANSYS). The main predigested parts are the pressure system of rolling mill, the oblique lease system of rolling mill, the roller device of the under roll. Expert these, the two pieces arches, the beam, the roll systems of rolling mill and the balance cylinder are remains the same with sheets of rolling mill. And the finite element model of rolling mill is shown as Fig. 3.

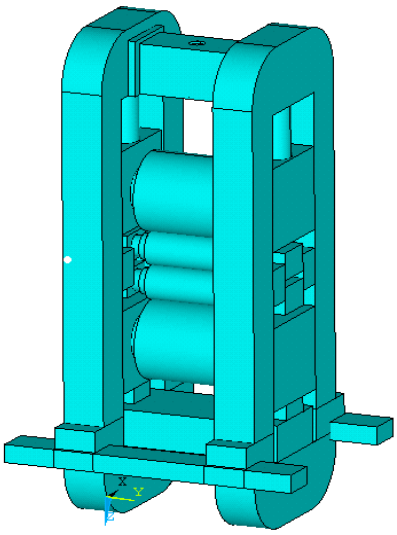


Fig. 3. The model of rolling mill in ANSYS.

4.2. Modal Analysis in ANSYS

Importing the finite element model into ANSYS, and began doing the model analysis of rolling mill. The properties of material should be defined at first. The elasticity coefficient is 2.1E5 MPa, the Poisson's ratio is 0.3, and the density is 7.8E-9 t/m^3. As the model is solid and complex, so the entire structure meshed by 8-node hexahedral element Brick 8 node 45, which is SOLID 45 element. The meshed map of rolling mill is shown as Fig. 4.

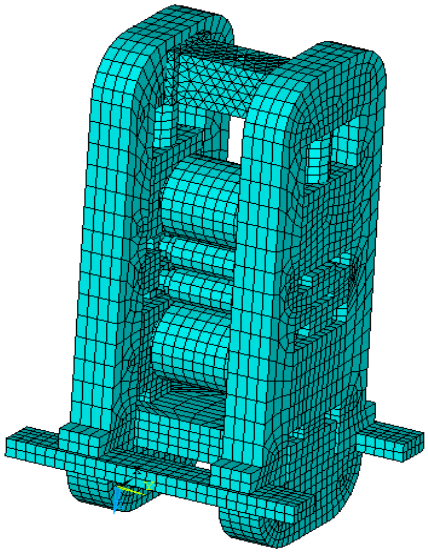


Fig. 4. The meshed map of rolling mill.

The loading of constraints are determined by the installation of rolling mill in the actual and the force in the working process. There are eight bolts used to fix rolling mill, so in this connection at the surface of the eight bolts' hole plus all constraints, the displacement of rolling mill in X, Y, Z directions is 0.

Subspace is suitable to get less vibration mode (< 40) of the models that is medium or not large. The needed memory is relatively small, if this method is used. The solid elements and the shell elements of the unit should have a better shape in Subspace. And any warning message about the shape of the unit should be attention. As a rigid body vibration mode convergence problems may occur, so it is used in the situation that there is no constraint equations [7].

Modal analysis of ANSYS is a linear analysis, any non-linear characteristics like the elastic, the plastic and the element of contact gap will be ignored, even if these are taken into the analysis. The non-linear characteristics are directly converted into linear terms, so the non-linear characteristics are not considered in the post-processing of modal analysis [8]. So the exposure in modal analysis is GLU. The 1^{st} to 10^{th} vibration modes are extracted in modal analysis of rolling mill, and the results are shown as Table 1.

Table 1. The modal results of the top 10 steps.

SET	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}
FREQ (HZ)	21.9	36.3	46.7	78.7	89.6
SET	6^{th}	7^{th}	8^{th}	9^{th}	10^{th}
FREQ (HZ)	116.3	142	176.2	240.5	469.5

The vibration patterns are be shown by the cloud model, and the DMX also can be get from the cloud model. All of these can be used to judge whether rolling mill is working properly or not. The vibration diagrams of 1st to 6th are shown as Fig. 5.

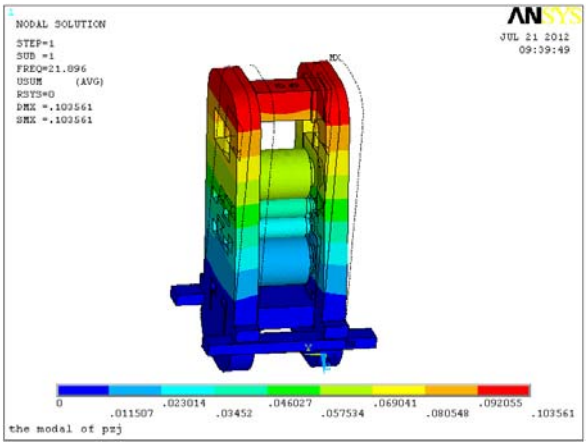
4.3. Analysis of Simulation Results

Known by the calculation results, the vibration frequency of backup rolls 120 Hz is very close to the natural frequency of 6th 116.3 Hz. And shown by the 6th vibration mode, the two working rolls of rolling mill are moved in the opposite direction. On the same side, the working roll and the backup roll are moved in the opposite direction. All of those consistent with the actual working conditions of the rolling mill. So it is considered that the natural frequency of 6th is caused by the vibration frequency of backup rolls. When the vibration frequency of backup rolls reaches 120 Hz, approaching the natural frequency of 6th, the rolling mill is occurred resonance [9]. And the surface of backup rolls appears irregular chatter marks. Then the vibration of working rolls is incentived by the chatter marks on backup rolls surface, which leads to forced vibration of working rolls. And the chatter marks become more obvious.

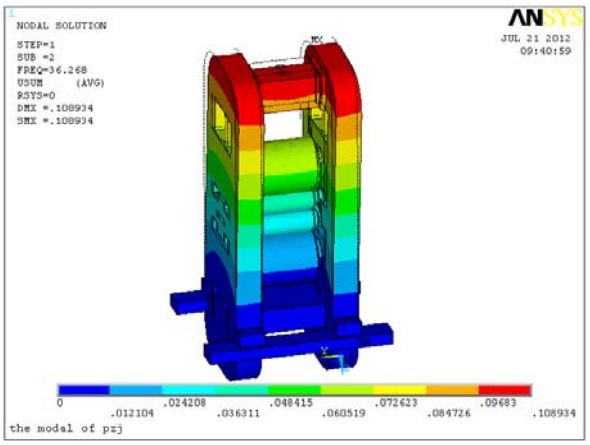
Based on the above analysis, the restraining measures of chatter marks are obtained. The countermeasures are derived as follows: adding roll to control vibration in the inlet side or changing the speed of stable rolling.

The relatively movement between the rolls system is caused by the fluctuation of entry tension, which also is the reason why chatter marks appear on the surface of rolls surface [10]. So adding roll to control vibration in the inlet side that the resonance is suppressed and eliminated, and the chatter marks are

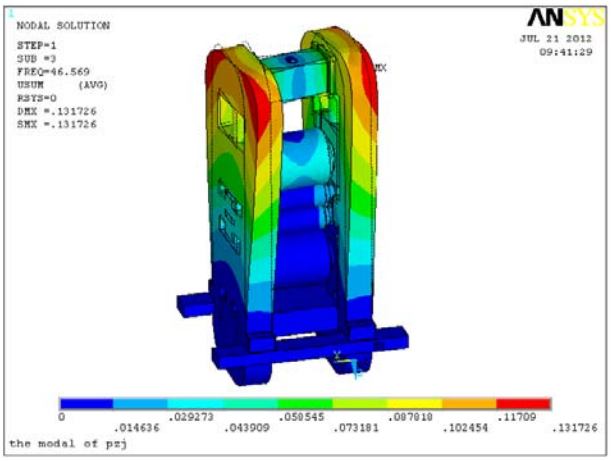
eliminated. because the chatter marks are caused in the speed of stable rolling, so changing the speed, the vibration frequency of backup rolls should not approached the natural frequency of 6th, the rolling mill is not occurred resonance. Last, the chatter marks are eliminated.



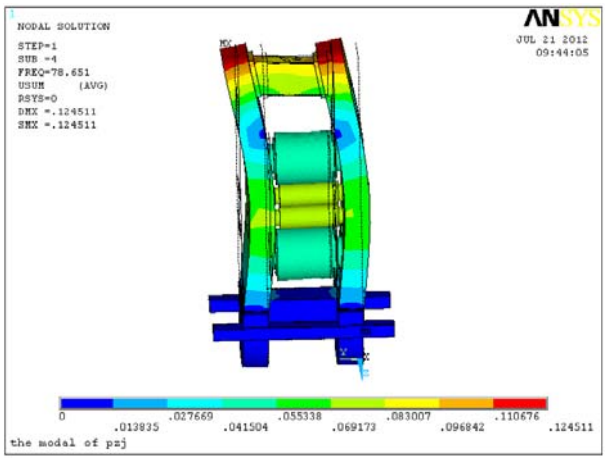
(a) The 1st vibration mode.



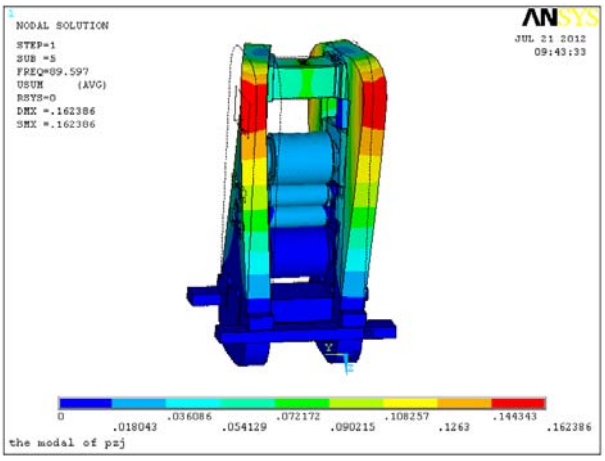
(b) The 2nd vibration mode.



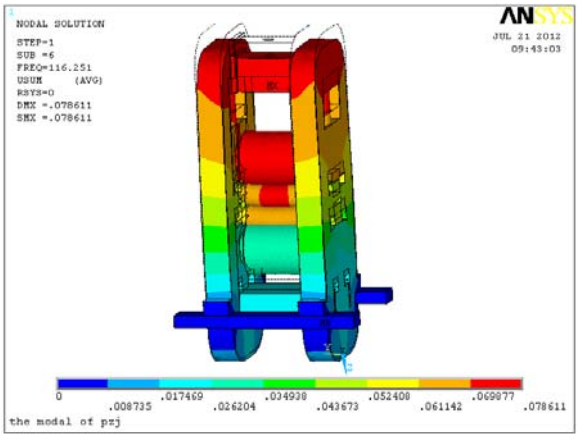
(c) The 3rd vibration mode.



(d) The 4th vibration mode.



(e) The 5th vibration mode.



(f) The 6th vibration mode.

Fig. 5. The vibration cloud modes of 1st to 6th.

5. Conclusions

In this paper, the three-dimensional solid model of a factory's four-roll rolling mill is established, which clearly expresses the structure of rolling mill. The late, the simulations of roll motion, pressure action and rolling are achieved based on this model.

The natural frequencies and the mode shapes of rolling mill are got after modal analysis, which is the foundation of the dynamic analysis of rolling mill. The results can be used to judge the capper marks are caused by the vibration of backup rolls.

The causation of the vibration is found, and the solutions are proposed, which provides references for the designing of mill and restraining mill vibration

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ADVANCES IN SENSORS: REVIEWS 1

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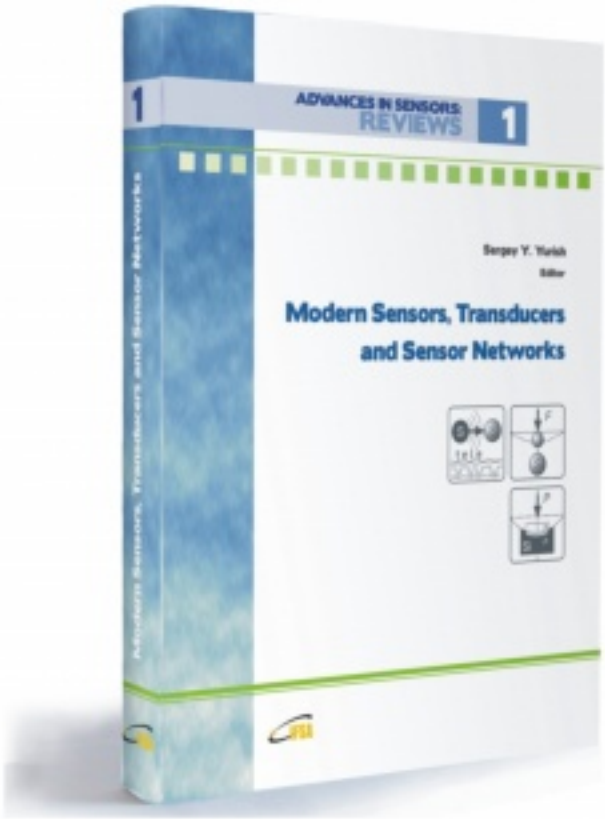

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