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FINITE ELEMENT ANALYSIS (FEA) OF CONNECTING SHAFTS IN COLD ROLLING MILLS

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Plate and strip production is an important part of the steel industry. Cold rolled plate and strip production technology, due to its characteristics of automation, high yield, and high efficiency, has led to a sharp increase in processing demand day by day. The connecting shaft is the connecting device of the steel rolling mill, which is used to transfer the power of the electric motor or gear seat to the rolling mill. This article conducts finite element analysis on the stress state of the connecting shaft of a certain type of cold rolling mill under actual working conditions. The analysis results show that the structural design of the connecting shaft is reasonable and has a good stress distribution state. The research results have certain reference value for the development of the connecting shaft of the cold rolling mill.

Keywords: steel; cold rolling mill; connecting shaft; stress; Finite Element Analysis (FEA)

INTRODUCTION

In the development of modern industry, the production of plates and strips is an important part of the steel industry, and the production technology of cold-rolled plates and strips, due to its characteristics of automation, high yield, and high efficiency, has led to a sharp increase in processing demand day by day. Among them, cold-rolled production technology specifically refers to the rolling operation carried out when the metal temperature is lower than the recrystallization temperature, that is, rolling production at room temperature [1]. The connecting shaft is the connecting device of the steel rolling mill, which is used to transfer the power of the electric motor or gear seat to the rolling mill.

The connecting shafts of rolling mills can be divided into four categories: plum blossom connecting shafts, universal connecting shafts, curved tooth connecting shafts, and joint connecting shafts. The universal joint shaft achieves the connection of the two axis motion states by utilizing the angle between the two axes, and stably and reliably transmits torque and motion conditions [2].Universal joint shafts have the characteristics of large torque transmission, high transmission efficiency, smooth operation, and long service life, and are widely used in various steel rolling mills. When the adjustment amount of the rolling mill is large, a universal joint shaft can be used to drive the rolling mill. The maximum allowable inclination angle of the universal joint shaft is 8 ° -10 ° [3], mainly used for blooming mills, slab mills, thick plate mills, steel pipe mills, ball mills, thin plate mills, and cold and hot strip mills. The classification of universal joints can be divided into two types: slider type universal joints and cross head type universal joints. Among them, slider type universal joints can connect two intersecting shafts in spatial position, thereby transmitting motion and torque. This paper takes the slider type universal joint shaft of a certain type of cold rolling mill as the research object to analyze its mechanical properties.

THEORETICAL ANALYSIS OF STRENGTH OF CONNECTING SHAFTS IN COLD ROLLING MILLS

The slider type universal joint shaft is made according to the principle of cross joint, and its structure is shown in Figure 1. Two crescent shaped sliders are installed in the radial boring hole of the fork head through sliding fit. The position is fixed through the upper and lower necks of the small square shaft, and the flat head is inserted between the crescent shaped sliders and the small square shaft. The two ends of the joint can move along the flat head incision in the direction of the

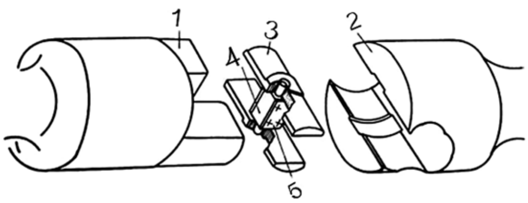

Figure 1 Structural diagram of slider type universal joint shaft: 1- flat head; 2-fork head; 3-crescent slider; 4-small square axis; 5- skateboard

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centerline of the connecting shaft. The rotation axis of the small square shaft is perpendicular to the centerline of the radial boring hole of the fork head, so that the two inclined shafts can transmit motion through the universal joint shaft.

The original parameters of this model of cold rolling mill are shown in Table 1.

Table 1 **The original parameters**

Transmitted torque	M = 1,5 MN·m
Diameter of connecting fork head	D = 1 120 mm
Radial boring diameter of fork head	d = 560 mm
Thickness of flat head	s = 280 mm
Length of flat head	l = 560 mm
Diameter of the connecting shaft body	d_0 = 120 mm
Width of cut flat head	B = 1 080 mm
Width of each fork in the flat head	b = 400 mm
Distance from hinge center to dangerous section	x = 225 mm
Inclination angle of the connecting shaft	α = 9°
Material of the connecting shaft	45# steel
Material of the flat head	40 Cr

Calculation of flat head stress

The maximum stress of the flat head isσ_1, The theoretical calculation formula is:

$$\sigma_1 = \frac{1{,}1M}{\left(B - \frac{2}{3}b\right) \cdot b \cdot s^2}\left[3x + \sqrt{9x^2 + \left(\frac{b}{6\eta}\right)^2}\right]$$

The meanings of each letter in the formula are:M – transmit torque; B – the width of the cut flat head; b – the width of each fork in the flat head; s – the thickness of the flat head; x – bending force arm of resultant force P; η – coefficient.

Calculation of fork head stress

The maximum stress of the fork head is σ_2, The theoretical calculation formula is:

$$\sigma_2 = 27{,}5\frac{M}{D^3}\left(2{,}5K + 0{,}6\right)$$

The meanings of each letter in the formula are: M – transmit torque; D – outer diameter of fork head; K – the inclination coefficient of the connecting shaft.

ESTABLISHMENT OF FINITE ELEMENT MODEL

The main components of a slider type universal joint shaft include a fork head, a flat head, a small square shaft, and a crescent slider. Due to the fact that the maximum stress on the connecting shaft occurs at the fork head during actual operation, which is often damaged, this analysis mainly focuses on three-dimensional modeling and finite element analysis of the fork head. Solid Works software has rich solid modeling functions, which can achieve part modeling and assembly, perform motion simulation finite element analysis on the assembly, and quickly convert engineering drawings, greatly improving design efficiency. It is widely used in production in various industries[4].

3D modeling of the fork head

Firstly, draw a sketch of the fork profile on the forward reference plane, apply the rotation command, and rotate the fork profile sketch around the rotation axis to generate a solid. Then sketch again on the forward reference plane, draw the outline of the arc at the fork and tiger mouth, select the stretch cut command, and cut off excess entities. Finally, draw a circle with a diameter of 560 mm on the forward reference plane, select the stretching and cutting command, symmetrical 220 mm on both sides, establish radial boring holes for the fork head, and complete the three-dimensional model of the fork head.The three-dimensional model of the fork is shown in Figure 2.

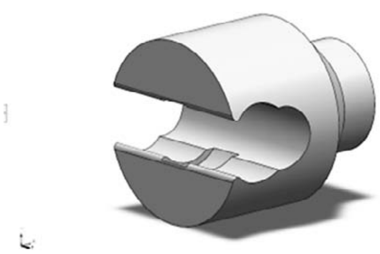

Figure 2 3D model of the fork head

3D modeling of the docking shaft body

Firstly, open the completed 3D model of the fork and use the reference geometry function to generate a reference plane at the right end of the fork. Then draw a circle with a diameter of 672 mm on the reference plane and stretch it to the right end of the fork. Finally, use the mirroring function to mirror the established model onto the right side of the reference plane, using the reference plane as the mirror surface, and complete the 3D modeling of the axis body.The 3D model of the connecting body is shown in Figure 3.

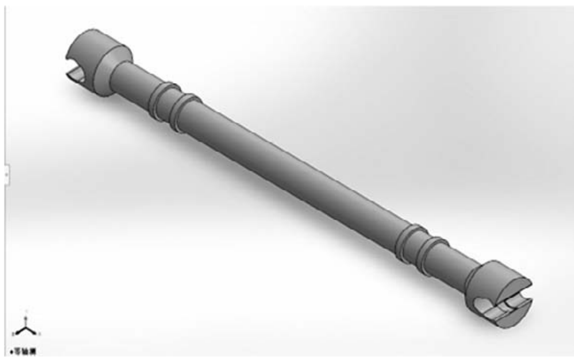

Figure 3 3D model of the connecting shaft body

FINITE ELEMENT ANALYSIS OF CONNECTING SHAFTS IN COLD ROLLING MILLS

The connecting shaft of this cold rolling mill model is made of 45# steel material, which is a high-quality medium carbon structural steel with good cold and hot processing performance and comprehensive mechanical properties, and is widely used in various fields[5]. It has the characteristics of high strength, good plasticity and toughness, and low price, and is widely used in mechanical manufacturing, vehicle components, bearings, gears, and shaft parts processing.

Add a new example of static stress analysis using a conventional model, named "Static Stress Analysis of 45# Steel Materials". After adding the new calculation example, select the 45# steel material in the application materials and define the connecting shaft material as 45# steel.

The elastic modulus of 45# steel is $2{,}05\times10^{11}$ N/m^2, Poisson's ratio is 0,29, Density is 7 850 kg/m^3.

After defining the material, apply the fixed geometry in the fixture to fix the mating surface between the right fork of the connecting shaft and the crescent slider. Apply torque to the fork of the connecting shaft, with a torque of 15 000 000 N · m. As shown in Figure 4.

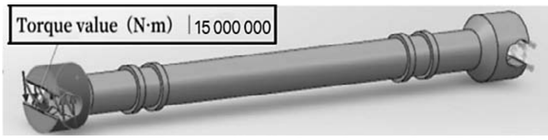

Figure 4 Applying torque to the fork head

After applying torque, select to generate a grid in the calculation example of the tab and solve it. The total number of nodes in the grid is 14 864, and the total number of units is 8 887.

ANALYSIS AND CONCLUSION

Figure 5 shows the stress cloud map of the connecting shaft of the cold rolling mill of this model. The maximum equivalent stress received by the connecting shaft after applying torque is located at the arc behind the fork on the left side of the connecting shaft, with a maximum stress value of 125,2 MPa, which is less than the yield force of 530 MPa of 45# steel. Therefore, the strength of the connecting shaft fully meets the requirements for use. The analysis results can provide good guidance for the design, manufacturing, and research and development of this type of rolling mill, and also have good reference value for the mechanical performance analysis of other rolling mill connecting shafts.

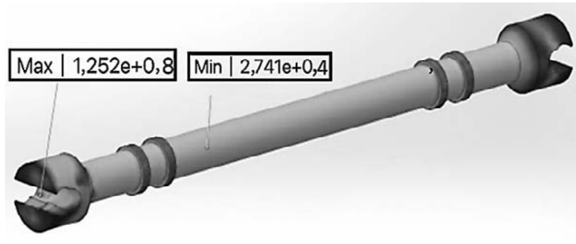

Figure 5 Stress cloud diagram of the connecting shaft

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Note: The responsible translator for English language is Y. Gao,Anshan,China