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Research on Calculation of Load Life and Strength Check of Linear Rolling Guide

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ABSTRACT. *More and more linear guide rails are used for CNC machine tool guides because of their high load carrying capacity, high guiding precision, high rigidity; good wear resistance and wide speed range. Moreover, the internal load bearing member and the motion transmission member are both useful for the ball and for the rolling guide block of the roller. This paper analyzes the selection, load carrying capacity and life calculation of linear rolling guides.*

KEYWORDS: *Linear rolling guide, Specification and model selection, Bearing capacity life calculation*

1. Introduction

Linear rolling guide is more and more used in NC machine tools. As a precise transmission component, it has large bearing capacity, high guiding precision, high stiffness, good wear resistance and wide speed range. The rolling friction coefficient is 0.002~0.003 mm, which avoids creeping and grease lubrication. The bearing elements and motion transfer elements of linear rolling guides are used not only for balls, but also for rolling guides with rollers. The rolling guide block has higher and better performance indexes. The linear rolling guide is composed of slide block and guide rail. Both can move relative, as shown in Figure 1. A row of screw mounting holes are evenly distributed on the guide rail. The guide rail is installed on the fixed datum plane in the worker's class. The length of the guide rail is calculated according to the motion stroke of the mechanical transmission. The longest is 4m/root, which can be cut and connected.

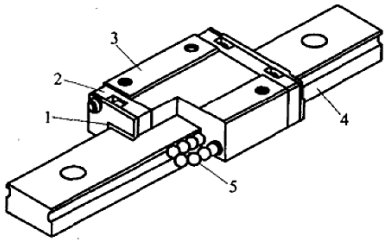

Fig.1 Structure of the Linear Rolling Guide

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2. Side End Dust Cover; 2. End Cover; 3. Slider; 4. Guide Rail; 5. Ball

The upper surface of the slider is a finished surface that is machined to mount the actuator load. Depending on the type, direction, size, point of action, presence or absence of eccentricity, the worker can select one, two or three sliders. Each slider is internally designed with two or four sets of balls. The relative movement of the slider and the guide rail is achieved by continuous cyclic rotation of the ball.

The guiding positioning accuracy of the linear rolling guide determines the motion accuracy of the actuator. The accuracy of the guide rails is divided into five grades: general grade, advanced grade, precision grade, ultra-precision grade and ultra-high precision grade. The linear rolling guide has four important planes-two mounting faces and two side positioning datums. They have all been precision ground, as shown in Figure 2. The two mounting faces refer to the C surface of the upper surface of the slider and the A surface of the lower surface of the rail. They are the assembly positioning reference of the slider and the guide rail in the height direction, which are used to install the table load and the fixed rail respectively. The two side positioning reference planes D and B are the assembly positioning references of the slider and the guide rail in the width direction. The role is to find the rail and load during assembly and work.

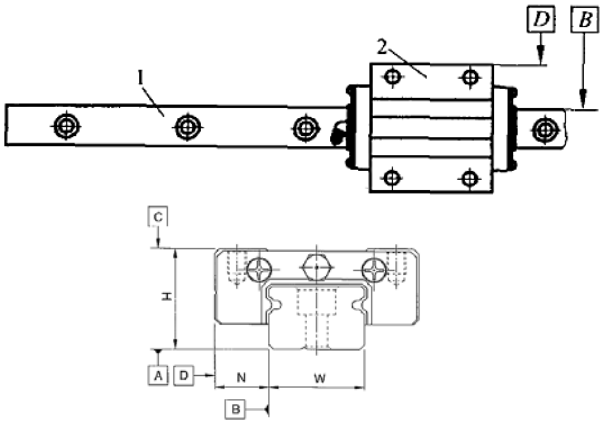

Fig.2 Mounting Surface and Positioning Surface of the Guide Rail

3. Guide Rail; 2. Slider

4. Selection of Linear Rolling Guide

The sliders of the linear rolling guides and the inside of the guide rails are all designed with circular raceways. The balls circulate in the circular raceway, transmitting motion and power, and the motion resistance is very small. With a small

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driving force, the load can be driven to achieve stable high-precision, high-speed linear motion. The arc track of the slider and the guide rail can withstand external loads from different directions such as horizontal, vertical, and tilt. After applying a certain preload, multiple directions simultaneously have high stiffness to accommodate the needs of heavy machinery. During operation, the linear rolling guide can withstand radial and reverse radial loads perpendicular to the mounting surface of the slider, as well as lateral loads parallel to the mounting surface of the slider, as shown in Figure 3. In addition, it can withstand the moment loads MA, MB, MC from three different directions, as shown in Figure 4. The force load and the moment load can be combined or combined. When the guide rail is working, the force load, the moment load or the combined load is first transmitted to the slider, the slider is transmitted to the ball, the ball is transmitted to the guide rail, and the guide rail is transmitted to the reference mounting surface.

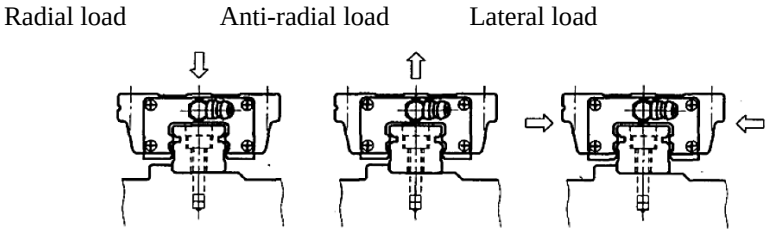

Fig.3 The Load on the Rail

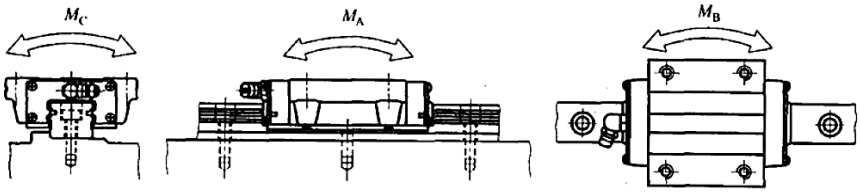

Fig.4 Torque Load on the Guide Rail

4.1 Select the Nominal Size

The nominal dimensions of linear rolling guides are mainly 15, 20, 25, 30, 35, 45, 55, 65 and other specifications. The larger the load, the larger the nominal size of the rail is. First, the worker should pre-select the nominal size of the guide rail according to the nominal diameter of the ball screw, and then calculate the rated life of the pre-selected guide rail according to the working conditions (such as stroke, acceleration, speed, load quality, etc.). If the working life of the guide rail is lower than the rated life of the guide rail, it means that the guide rail is properly selected and the load carrying capacity is sufficient.

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4.2 Select the Length of the Rail

The length of the rail is designed according to the travel of the load. The greater the load travel stroke, the longer the rail length. The length of the guide rail is calculated as shown in Figure 5: Lo = N × F + 2G. Lo. indicates the length of the guide rail mm; F indicates the center distance of the screw hole mm; N indicates the number of screw holes; G indicates the distance between the two ends of the guide rail from the first screw hole.

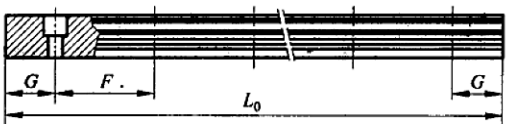

Fig.5 Rail Length Calculation

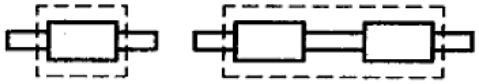

Fig.6 Single Slide and Double Slide Structure Guide

4.3 Select the Number of Sliders

When using linear rolling guide, there are three ways to assemble sliders on the guide. The structure consists of one slide (single slide), two slides (double slides) and three slides (three slides) on one guide, respectively, as shown in Figure 6.

The guide rail mainly bears radial load (worktable weight) and reverse radial load when working. When the load center is just in the center of the slider, the load is simplified as the concentrated force whose action point is in the center of the slider, and the single slider structure should be chosen. When the size of the load along the length direction of the guide rail is relatively short, as long as the bearing capacity of the guide rail is enough, the single slider structure can be adopted.

If the worktable size is much larger than the slider size and the load has a certain degree of eccentricity along the length direction of the guide rail, the slider will bear the eccentric moment load in the MA direction due to the eccentric structure in addition to the load gravity. When the moment load is transferred to the ball, some of the balls will bear large local load for a long time. This will cause abnormal wear and tear of balls and reduce the service life of sliders and guideways. In addition, the inertia force of load acceleration and deceleration also generates additional moment loads in MA or MB directions. At this time, it is necessary to increase the load support point of the guide rail. Workers can adopt double slider structure to make eccentric structure become balanced structure to reduce or eliminate the influence of

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eccentric moment load. At this time, the ability of the guideway to withstand additional moments in MB direction will also be improved. When the radial load is large but the structure space (such as height) is insufficient, the double slider structure can be used to reduce the nominal size of the guide rail.

4.4 Choosing the Number of Rails

When the linear rolling guide carries the same external load, there are single rails, double rails and three rails. In Fig. 7, (a) is a single-rail single-slider structure; (b) is a double-rail single-slider structure; (c) is a double-rail double-slider structure, and (d) is a three-rail double-slider structure. However, only one of the several rails is the reference rail, and the non-reference rail has parallelism requirements for the reference rail.

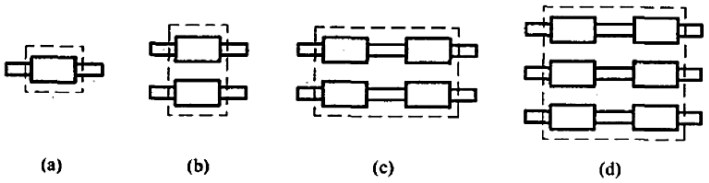

Fig.7 Combination of Rail and Slider

Select the number of rails to analyze the type, size, direction, point of action, and distribution of the external load. When the rail is mounted on a horizontal surface and the load is small in the width direction of the slider and there is no eccentric structure, a single rail structure can be employed.

If the rail is mounted on a horizontal surface, the load is eccentric in the asymmetrical direction of the slider width. This will produce a MC moment load. The MC moment load will increase part of the ball load, which will affect the working life of the rail. The ability of a single slider to withstand MC moment loads is limited. Once it exceeds its load carrying capacity, it is necessary to increase the load bearing point, using double rails. When the guide rail is installed on the horizontal surface and the load is larger in the width direction of the slider, the double guide rail should be selected to ensure the machine movement is in a stable equilibrium state.

If the load weight is very large and the load table is large in the width direction of the slider, three guide rails are needed to ensure that the mechanism motion is in a stable equilibrium state.

4.5 Choose the Installation Method of Guide Rail

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According to the transmission performance of the machine and the space structure of the working load, there are three ways to install the guide rail: horizontal plane, vertical plane and inclined plane. Most of them are mounted on the horizontal plane. Generally, the guide way is fixed and the slider moves. According to the working conditions, the slider can be fixed and the guide rail can move.

4.6 Pre-Tightening of Guide Way

There are three grades of guide rail preloading: preloading, light preloading and medium preloading. Pre-tightening is to apply internal stress on the contact parts of balls, sliders and guide ways to eliminate the gap between balls and slider arc raceways and guide rail arc raceways before they leave the factory. This can make the ball contact with slider arc raceway and guide rail arc raceway produce small elastic deformation in advance. In this way, when working, the external load on the guide rail will be absorbed and buffered by the internal stress. This can reduce the elastic deformation and improve the stiffness and bearing capacity of the guide rail. This structure is called negative gap structure. However, excessive pre-tightening force will cause excessive stress between balls, sliders and guide ways, which will shorten the service life of guide ways. Therefore, the magnitude of preload should be reasonably controlled. In principle, the preload should not exceed 1/3 of the axial load. The bigger the preload force of the guide rail, the higher the installation requirements of the guide rail.

5. Calculation of Bearing Life of Linear Rolling Guide

A machine tool feed system uses a ball screw drive mechanism (ball screw type FFZD4008-5), and a double-rail double-slider linear guide rail is selected. The guide rail was initially identified as the HG series of Shangyin Company. Because the nominal size of the ball screw is 40mm, the nominal size of the guide rail can be set to 45mm. According to the technical data of Shanghai Bank, the pre-selected rail static load C0=155930N, rated dynamic load C=77570N. The bearing and force of the preselected guide rail are shown in Fig. 8.

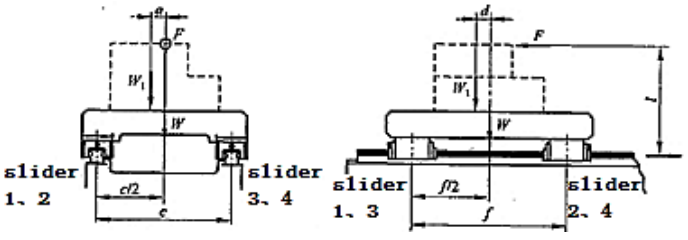

Fig.8 Double Rail Double Slide Rail Force Diagram

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Axial load F = 2274N; table weight W = 4960N. The weight of the workpiece on the table is W1=1960N; the working stroke is S=800mm. The number of reciprocating movements of the slider per minute is n1=10 times/min; the distance between the guide rails is c=300 mm, the spacing of the sliders is f=800 mm; the height of the axial load acting points is l=500 mm. Workpiece center of gravity position size: a = 140mm, d = 150mm; working life 24000 hours; work at room temperature.

5.1 Slider 1 Working Load Calculation

The slider is programmed as a slider 1, a slider 2, a slider 3, and a slider 4. The actual working load that each slider is subjected to is P1, P2, P3, and P4. Referring to the calculation formula and data of the slider working load provided by the major manufacturers, the author knows that the maximum working load occurs on the slider 1. Therefore, the rated life of the slider 1 is the rated life of the guide rail. It is only necessary to calculate and check the rated life of the slider 1.

$$P_1 = \frac{W_1 a}{c} + \frac{W_1 d}{2f} + \frac{W_1 + W}{2} + \frac{1}{2}\frac{l}{f}F$$

$$= \frac{4960 \times 140}{300} + \frac{1960 \times 150}{2 \times 800} + \frac{4960 + 1960}{2} + \frac{2274 \times 500}{2 \times 800}$$

$$= 2314.667 + 183.75 + 3460 + 710.625$$

$$= 6669N$$

The maximum working load of the slider 1 is P1=6669N

5.2 Static Safety Factor Calculation and Check

The maximum working load of the slider 1 is P1=6669N. The static safety factor is $f_s = \frac{C_0}{P} = \frac{155930}{6669} = 23.38$. Looking up the table, the static safety factor minimum value fs=1~5. The static safety factor calculation value is far greater than the static safety factor minimum value, then the static safety capability of the predetermined guide rail is sufficient.

5.3 Slider Rated Life Calculation and Check

The rated life of the slider can be expressed by the slider travel distance L1, which can be expressed by the slider operating time Lh1. The guide rail is in normal working condition, and the load factor fw=1.5. According to the hardness value of the ball, the slider and the arc track of the guide rail, the hardness coefficient fH=1. Working at room temperature, temperature coefficient fT=1. Double rail double slide,

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contact coefficient fC=1. The expected life of the slider 1 is $L_{h1} = \frac{L_1 \times 10^6}{2Sn_1 \times 60} = \frac{23287 \times 10^6}{2 \times 800 \times 10 \times 60} = 24257.3h$. It can be seen from the calculation results that the rated life of the guide rail of the predetermined nominal size 45 mm is Lh1=24257.3 hours. It is greater than the machine's working life of 24,000 hours, so its carrying capacity and life is sufficient.

5.4 Select the Accuracy Level of the Guide Rail and the Preload Level

According to the use of the guide rail and working conditions, the ordinary precision guide rail is selected. The preload rating is light preload.

In summary, the model of the linear rolling guide is determined as HGH45 CA 2 R 1200 ZA C II, the HG series guide rail of HIWIN, the square slider, the nominal size is 45mm. Double rail and double slide are adopted, and the guide rail is 1200mm in length. ZA is light preloaded, and the guide rail accuracy is normal grade C.

Acknowledgment

1). This paper is the second batch of teaching reform research project of higher education in Zhejiang Province during the 13th Five-Year Plan period, “Construction and Practice of Higher Vocational Undergraduate Specialty under the Background of New Engineering Intelligent Manufacturing -- Taking Mechanical Engineering Specialty as an example” (jg20190736), the phased research results of project construction.

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