Application of anti-eccentric open hydrostatic guideway in vertical lathe

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Abstract. This paper introduces an open hydrostatic guideway with anti-eccentric load structure for vertical lathe. This hydrostatic guide adopts swing plate feedback throttling oil supply system. The structure improves the angular stiffness of the open hydrostatic guide rail of vertical lathe, ensures the stability of the worktable in a wide range of eccentric loads, and meets the requirements of high precision machining of eccentric loaded parts.

Keyword: Open type hydrostatic guideway; Oil film stiffness; Anti-eccentric load Guide

1. Introduction
Because the hydrostatic guide is pure liquid friction, the friction coefficient is very low, and it has the characteristics of small friction coefficient, less wear of the guide, uniform movement at low speed, no crawling and so on. Because the liquid has the function of absorbing vibration, the static pressure guideway has better anti-vibration than rolling guideway, and has the advantages of large bearing capacity, high rigidity, small friction heat and small temperature rise of the guideway, so the static pressure guideway is widely used in the heavy vertical lathe.

The structure of hydrostatic guideway can be divided into open type and closed type. The structure of open hydrostatic guide is simple and easy to adjust. Because the vertical axis structure of vertical lathe spindle and the processing load range are large, the separation of worktable and base is not limited, so the open hydrostatic guide is mostly used in vertical lathe. With the different weight of the workpiece, the floating value of the worktable guide rail changes. When the workpiece shape rules are unbiased, the oil chambers of the guide rail float the same, the worktable runs smoothly, and the workpiece processed has high precision.

2. Anti-eccentric open hydrostatic guide
2.1. Structure of swing plate feedback throttling oil supply system
Because under the eccentric load, the angular stiffness of the oil film on the guide rail of the worktable is insufficient, so it can not meet the accuracy requirements. In order to improve the angular stiffness of the circular open hydrostatic guide for vertical cars, a swing plate feedback throttling fuel supply system is introduced in this paper, as shown in Figure. 1.
The swing plate feedback throttling oil supply system consists of a shell, a swing plate, a bottom plate, a throttling table and an adjusting gasket. The number and position of oil cavity holes on the bottom plate are equal to those on the throttle table. The elastic legs of the wobble plate are fixed to the casing, and the casing is sealingly coupled with the bottom plate. The oil holes are respectively connected to the oil passages of the circular rail oil chambers of the corresponding vertical lathes, thereby forming the entire static pressure system [1].

![Diagram of the swing plate feedback throttling oil supply system](image1)

**Figure 1.** Wobble plate feedback throttle open static pressure guide

2.2. Principle of swing plate feedback throttle oil supply system

The working principle is shown in Figure 1. The pressure oil from the oil pump flows into the throttle chamber through the middle inlet hole, then enters the guide rail oil chamber through the throttle clearance hc0, and finally flows back to the tank through the guide rail clearance h0.

When the vertical workbench is subjected to an unbiased load, its vertical displacement in the load direction is e, as shown on the left of Figure 2. Because the clearance and pressure of each oil chamber are equal, the pressure of all throttling platforms connected with each oil chamber is equal. The hydraulic forces on the swing plate are balanced, that is, the swing plate is not affected by the force distance, so the throttling swing plate is not affected by the moment. The throttle pendulum is in the horizontal state, and the initial throttle clearance hc0 of each throttle table is equal. [2] Obviously, the swing plate throttle is equivalent to the fixed throttle.

![Diagram of the working principle of the swing plate feedback throttle](image2)

**Figure 2.** Working Principle of Swing Plate Feedback Throttle Open Hydrostatic Guide
The table inclines under eccentric load, as shown on the right of Fig. 2. Pressure redistribution of guide rail oil chamber due to pressure regulation of throttle. The pressure $P_1$ of the oil chamber decreases with the decrease of the clearance $H_1$ of the guide rail, and the pressure $P_2$ of the oil chamber decreases with the increase of the clearance $H_2$ of the guide rail, resulting in a counter-inclined hydraulic moment balanced with the eccentric load. At the same time, the unequal pressure of the oil chamber acts on the throttle pendulum, causing the elastic leg to bend. As a result, the throttle clearance $H_1$ leading to the high-pressure oil chamber 1 becomes larger, and the pressure $P_1$ of the high-pressure oil chamber is further increased. On the contrary, the throttle clearance $H_2$ leading to low oil chamber 2 is reduced and $P_2$ is further reduced, thus forming a larger overturning hydraulic moment acting on the workbench to keep it in a horizontal state [3].

When eccentric parts are clamped on the worktable and rotated, the position of the oil chamber of the high-pressure and low-pressure rail also rotates. At this time, the throttle swing plate produces a space swing similar to the swing trajectory of the table to form a feedback voltage regulation effect. However, the swing of the table and the throttle wobble plate are exactly 180° out of phase, so this static pressure guide rail is also called “anti-phase” feedback throttle hydrostatic guide rail.

2.3. Working characteristics of feedback throttle hydrostatic guideway
The working characteristics of this hydrostatic guide are as follows.
1. When the table tilts, it uses the pressure difference between the two symmetrical oil chambers on the circular guide rail as the control signal to complete the feedback pressure regulation. Therefore, the angular stiffness of the oil film of the guide rail can be guaranteed to approach infinity within a wide range of eccentric loads.
2. The swing plate feedback throttle belongs to the centralized throttle, which can not only be compact in size, but also have good processing technology.
3. Throttle pendulum is thicker and does not need to be stabilized to eliminate internal stress, so its performance is reliable.
4. The adjustment and maintenance of the whole hydrostatic guide system is convenient.

2.4. Application of swing plate feedback throttle oil supply system
In this paper, the anti-biased open static pressure guide is tested in a 1.6-meter vertical lathe. The guide rail has a diameter of 1 m and the guide rail adopts six uniform oil chambers. The size of the oscillating disc feedback throttle is shown in Figure 3, $r_{c1} = 5\text{mm}$, $r_{c2} = 10\text{mm}$, $h_{c0} = 0.1 - 0.5\text{mm}$, the diameter of the swinging arm is $d = 5\text{mm}$, and the length of the leg is $j = 8\text{mm}$.

![Figure 3. Dimension Diagram of Swing Plate Feedback Throttle](image-url)
At no-load, the difference in oil film thickness at the midpoint of the oil chamber of the entire table rail does not exceed 0.003 to 0.004 mm, and the rail gap achieves a high consistency. Under the action of 6000 kg non-eccentric load, when the quantitative oil supply system is used, its constant flow rate is \( Q = 3 \ L/min \), and the axial oil film stiffness of the table rail can reach 3920 N/um. Under eccentric load, when the overturning moment \( M = 4900 \ Nm \), the inclination of the throttle pendulum is less than 4-5 um at the radius of 800 mm, and the inclination of the throttle pendulum is 0.04 mm.

3. Conclusion

It can be seen that the swinging plate feedback throttle type static pressure guide rail has good anti-offset effect, and it can be used in a wide range, such as vertical surface grinder, large-size vertical lathe, heavy-duty radar antenna and other open static pressure guide table [4].

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