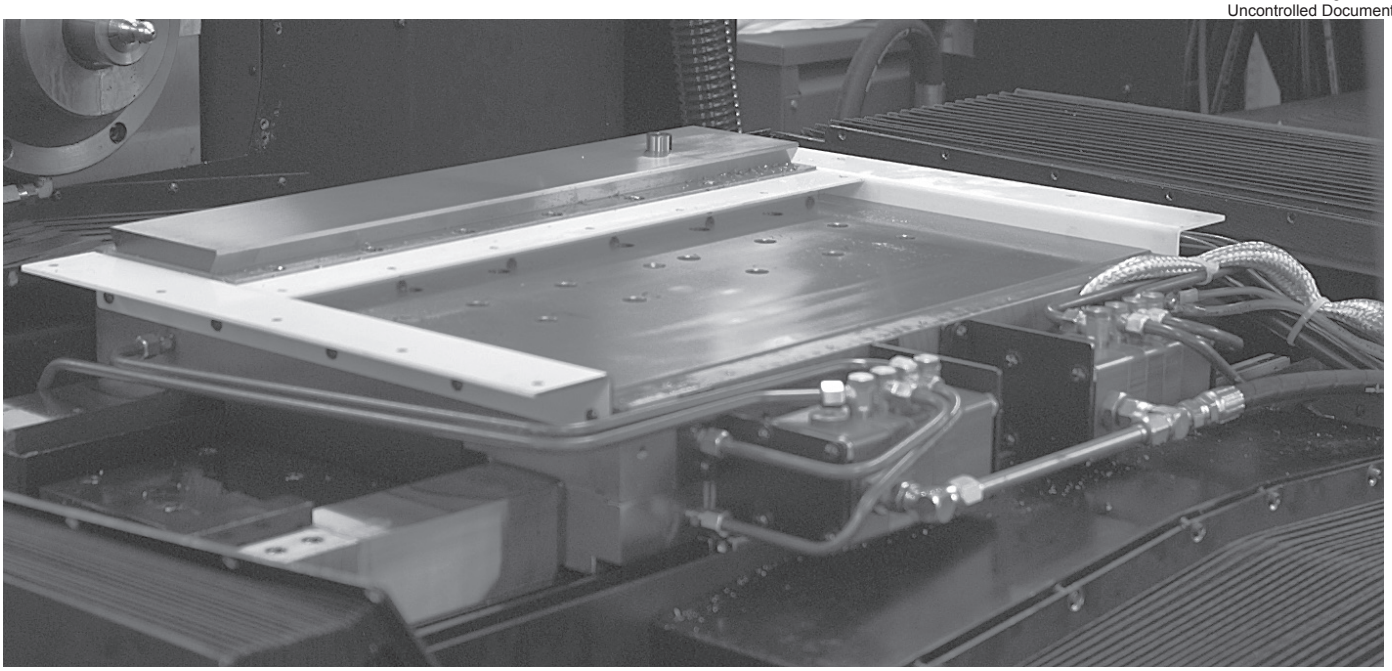


Picture by Hardinge, Inc., Elmira NY

New hydrostatic guideway for linear motors

Linear motors are used on high-speed machine tools with high acceleration and slide speeds. For slides with linear motors, HYPROSTATIK has developed hydrostatic guideways that have no wear, excellent damping characteristics, high stiffness and much lower friction when compared with ball or roller rails.

The secondary part of a synchronous linear motor is the permanent magnet field, which results in enormous attraction forces. The high attraction forces, combined with high acceleration and speed, mean conventional ball- or roller guideways are not always a design option. High speed, high acceleration and oscillation movements lead to increased wear of the balls or rollers, sealing lips and backlash. Dirt or chips which get past the sealing lips are coined in the rail surface. The permanent existing attraction force of 26000 N to 30000 N at a drive force of 10000 N places an additional load on the guide system and leads to short life in ball- or roller systems. The wear results in reduced stiffness in the guideway and, in extreme cases, to clearance, poor guide quality, and inaccurate positioning.

HYPROSTATIK has developed a hydrostatic guideway designed for the support of linear motors. The guideway does not wear, has excellent damping characteristics, is dynamically stiff, and has much lower friction when compared with ball or roller rails.

Function

On hydrostatic guideways, the hydrostatic pockets perform the load carrying instead of balls or rollers. Before starting, the slide rests on the guideways (red – see schematic). When the machine is turned on, the hydraulic pump supplies filtered oil to the PM-flow controller (pink), which then distributes it to the pockets (yellow). The pressure in the vertical pockets increases until the load of the slide weight and the magnetic force is equalized. The slide is then suspended about 0.001 inch from the guideway. The oil exits the pocket through this clearance and flows back to the hydraulic tank. A continuous supply of oil keeps the pressure in the pocket constant. When the pocket is additionally loaded by machining, acceleration, or weight forces, the PM-flow controller increases the pocket pressure and flow to keep the gap virtually constant. In an optimized design, the hydrostatic guideway is not influenced by hydrodynamic effects and viscosity changes, so the high stiffness and load capacity is basically independent of the speed of the slide and the temperature of the oil.

Wear features

In a working hydrostatic guideway, the slide is always suspended on the oil pad of the hydrostatic pockets, independent of speed, load and temperature. This means that the guide surfaces are never in contact while in use and wear is not possible. Machine features such as stiffness, load capacity, guide precision, positioning precision, and damping remain constant over years of operation.

Design

The hydrostatic guideway for linear motors shown in the graphic has no retainers. The attraction force of the linear motor magnet replaces the prestress of the retainers used on standard guideways. This open guideway can also be used at an angle or vertically if the tilt- or lifting forces allow this, and the guideway is not lifted. If lifting forces are high, the guideway can be designed with additional hydrostatic pads.

Some linear motor designs use two linear motors in opposite directions so the magnetic forces cancel each other out. Disadvantages of this design are a very tall slide design, and stress from bending forces on the guideway or slide. Additionally, there are added costs for the second linear motor. With a hydrostatic system, the design height of the guideway and the linear motor between the slide plate and the guide plate is small - only about 2 inches.

The load capacity of hydrostatic pockets can be modified by changing the pocket size and

the pump pressure. The stiffness of the pocket depends on the load and the flow control. Depending on magnetic force and slide weight, the stiffness of a hydrostatic pocket at the edge of the slide is between 600 lbs/0.0001 inch and 6000 lbs/0.0001 inch (»1000 N/µm and 10000 N/µm).

Friction and Positioning

The friction of hydrostatic guideways is proportional to the speed. At low speeds, friction is almost non existent. A light tap with a finger can move a 200kg slide.

The reverse-direction play and friction increase found with ball and roller guideways does not exist on hydrostatic guideways. The friction force of hydrostatic guideways can be tailored to nearly any requirement by changing the pad surface area, oil viscosity and gap size. Using a PM-flow controller from HYPROSTATIK, the friction is almost independent of the load, especially at low speeds — 100 to 1000 times lower than on ball guideways. The precision of positioning, the smallest movement and the slowest movement of the hydrostatic supported slide are only limited by the linear motor's resolution and the CNC control.

Damping

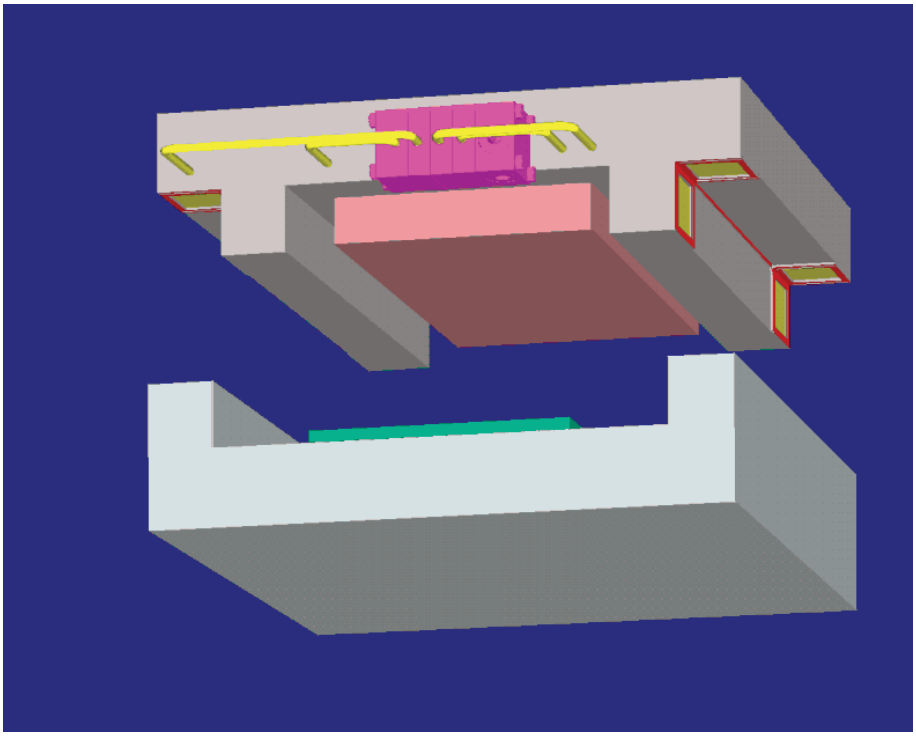
The hydrostatic pocket design can be optimized by working with HYPROSTATIK. A correct design allows excellent absorption of the excitation frequency, which is especially beneficial in machine tools. Chattering from standing waves is suppressed, the cutting power is increased, the tool life is prolonged, and workpiece finish is improved when compared to ball or roller guideways.

Production Costs

The hydrostatic pockets (yellow/red) are machined into the slide at nominal additional cost. No additional space for the roller pad and rail is necessary. The surface around the pockets in the slide (red) and the mating areas are the functional surface of the guideway. These surfaces are responsible for the guideway precision and can be produced by precision milling, grinding or forming. The function of the hydrostatic system is independent of the material and the surface hardness of the guideway. The choice of the surface and the material depends only on the required material stiffness, emergency features, and stability during transport.

Assembly and Testing

On ball guideways, deformation by improper mounting of roller pads or railways can lead to premature wear and malfunction. By measuring the pocket pressure during the stroke, proper assembly and function of the hydrostatic guideway can be monitored easily and inexpensively. With a pressure sensor connected to the CNC controller, it is possible to measure and monitor static and dynamic forces caused by weight, acceleration or machining during production.



Example design of a hydrostatic guideway for a linear motor

Only filter and oil changes are needed to maintain the hydrostatic system. Dirt on the guideway is pushed away by the pocket or washed away by the constant oil flow. With a proper design, hydrostatic guideways have no problems if chips or coolant should enter the protective covers. For special applications, hydrostatic guideways without covers can be designed, where a seal around the pocket prevents mixing and entering of coolant.

Example: CNC Lathe

At the exhibition IMTS '98 in Chicago, Hardinge Inc. Elmira, New York introduced their Concept 2000 machine with a hydrostatic cross slide and linear motor drive. The maximum speed demonstrated was 3000 inch/min (76 m/min) with an acceleration of 3 g (30 m/s²). Vertical stiffness at the edge of the table is over 2000 N/µm. Required oil volume of the hydrostatic guide is only about 0.5 l/min at 32 bar. Hardinge reports a precision of one axis 1 micro-inch (0.025µm) and contour precision 2 micro-inch (0.05µm). This results in an axis acceleration increase of up to 15 times, and up to 3 times faster cycle times.

Example: CNC Grinder

Ingersoll-Naxos in Langen in Germany makes grinders for cam- and crank shaft grinding with a hydrostatic supported cross slide with a V-flat design. Both axes are driven by linear motors. The precision and damping characteristics of the hydrostatic system produce excellent grinding results.

Example: Ultra-Precision Milling Machine

Kugler in Salem Germany successfully uses hydrostatic guideways with linear motors in their 3 to 5 axis Micro-Machining center for ultra-precision machining.

The calculation and optimization engineering services, the PM-flow controller, and the support with all necessary information to install hydrostatic guideways, are supplied by HYPROSTATIK.

Hydrostatic guideways with the PM-flow controller have been used for over 13 years and are installed in over 4000 guideways in machine tools, including hydrostatic leadscrews and hydrostatic spindles.