Hydrostatic spindles,
guides and lead screws

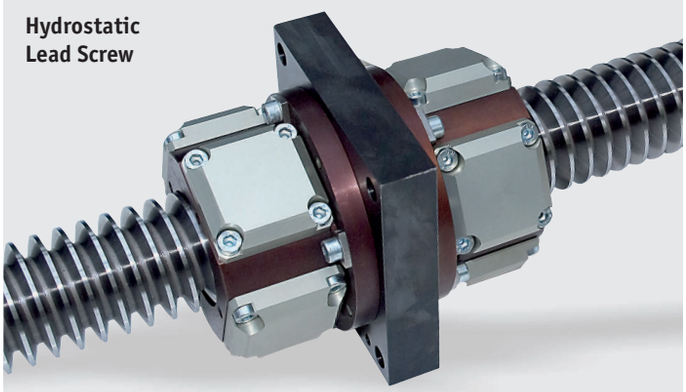
HYPROSTATIK®

Hydrostatic Lead Screws (HLS)

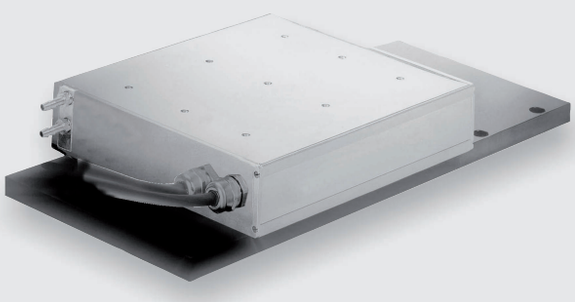
Highly durable **Highly resistant to wear and tear** **Inexpensive**

Up to 80% reduced energy use, compared with linear motion drives!

Hydrostatic
Lead Screw



Linear motion drive



The well-known disadvantages of ball screws led to the development of linear motion drives, and also to highly durable and wear and tear-free working hydrostatic lead screws.

In what follows, linear motion drives are compared with the innovative hydrostatic lead screws:

Introduction – Physical fundamentals

Electrical energy can be converted to mechanical energy at relatively low forces and high speeds, extremely effectively. For that reason, relatively fast-running motors with lead screws are used for electrical feed forces, to create slow carriage speeds and high feed forces. Using a very large lever, the electro-motor force is, in that way, transferred to the carriage. If the transference equipment is of the right quality, the carriage can be moved with a high degree of sensitivity.

Linear motion drives neglect that principle!
Extremely strong magnet fields are required to directly create large forces. Linear motion drives can only attain that with strong electrical currents and/or through coils with high inductivity. Because every coil that has current running through it is an „electrical mass“, a large electrical mass has to be sped up, alternately, when there is dynamic load change. That is also true, even if the carriage is only to be held in position. Even if extremely high voltages are used, the change of motor force is time-dependent. For linear motion drives, the result is a much higher rule-defined spread, than is the case with lead screws.

Energie requirement - thermal input - cooling

For linear motion drives:
For most processing activities that require electrical current in tools and machines, during the main work times, a low carriage speed of approximately 0.1 - 0.4 m/min and a high feed force is required.
The power loss of a linear motion drive, with for example 6600 N nominal force, amounts to approximately 5.4 kW, even for those low feed rates (based on manufacturer information). A cooling unit force of approximately 4 kW is required for cooling. In total, approximately 9 kW is consumed, in order to reach a feed force of only 6600 N!

With hydrostatic lead screws:
For a feed force of 10,000 N for higher speeds, a typical lead screw requires an oil flow of approximately 2.5 l/min, at 50 bar pump pressure. Approximately 0.5 kW is required to drive the pressure pump and oil cooling equipment, with air oil heat exchangers. For a servo motor, at 400 mm/min feed speed, 10,000 N feed force and 50% efficiency, 0.14 kW is required. That results in only approx. 0.7 kW.
Advantages with respect to the linear motion drive:
The loss reduction is 8.3 kW!

Because a linear motion drive is not continuously operated at the highest output, for example in milling machines or lathes, a saving of approximately 5 kW is realistic.
Resulting added costs, for the linear motion drive: In one-shift operation, a kW price of 0.12 EUR/kW, 5 kW consumption and 2,000 operating hours/year, there arises, per axle, 1,200,- EUR, for three-shift operation 3,600,- EUR, yearly, in additional costs. If one capitalizes those costs with 12% for interest and depreciation, that corresponds to an investment of approximately 10,000,- EUR, or 30,000,- EUR. Even if only a few machines are used with linear motion drives, the added costs for supplying electrical current, e.g. a separate transformer station, are very likely.

The hydrostatic lead screw – HLS

Just as with a ball screw, a hydrostatic lead screw converts the turning movements of a servo motor, into a linear movement. The nut of the lead screw floats on a hydrostatic oil film, on the flanks of the modified trapezoidal screw of the lead screw spindle, and for that reason, is absolutely free of wear and tear.
Using the patented **PM Flow Controller** (**P**rogressive **Q**uantity **Controller**), the oil flows are guided into the hydrostatic pockets of the nut in such a way that the oil film thickness, largely independent of the load and speed, remains almost totally constant.

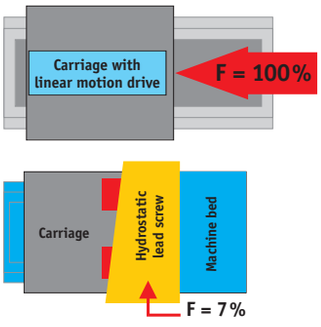
In that way, compared with ball screws, two to three times the rigidity of the nut to the spindle, and absolute freedom of movement is attained. The 8 PM Controllers are mounted in the nut, and control the oil flows, using the differential pressure between the pump pressure and pocket pressure.

The user thus only uses purified oil with the prescribed pressure for the lead screw. The frictional torque of the lead screw is very low and proportional to the speed, so that, if the movement direction is reversed, the drive torque does not „jump". Those are pre-requisites for attaining the highest positioning exactness and path accuracy, as well for ensuring the smallest travel paths, and the most precise and slow movements. The hydrostatic lead screw functions as a shock absorber and has excellent shock absorption, with respect to dynamic loads. It runs noiselessly, and without any vibrations. The lead screw can be purchased with a nominal diameter of 40,50,63, 80, 100, 125 and 160 mm, up to 5 m in length. The allowed loads range from 10 to 300 kN, the speed is up to approx. 90m/min. As with ball screws, the spindle ends of the lead screw are designed based on specific customer requirements. The lead screw can also be enhanced using hydrostatic fixed bearings and floating bearings, as well as hydrostatic guides.

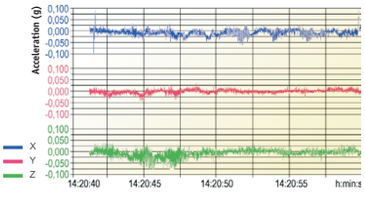
Position spread width

The linear motion drive does not just have a relatively large positional spread width with respect to oscillating or swinging loads. The comparison of measurement data on test carriages with linear motion drives makes that clear. (s. images, source: Kern)

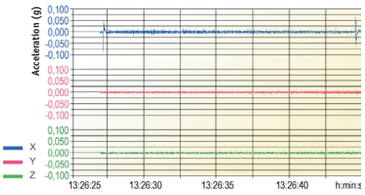
Wedge effect and force comparison



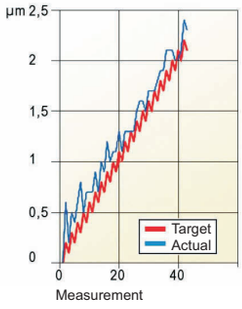
Test axis with precision guide and linear drive



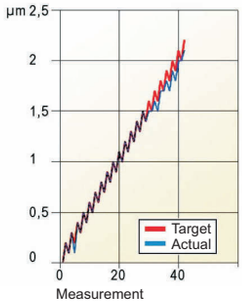
Test axle with hydrostatic guide and hydrostatic drive



Comparison pathway, smallest increment 1/10 µm: Linear drive with standard paths



Comparison path, smallest increment 1/10 µm: Hydrostatic axle with hydrostatic drive



Rigidity and absorption with respect to static and dynamic loads

The linear motion drive with: lower rigidity and deficient absorption, and due to that, the risk of resonance oscillations.
The rigidity of the linear motion drive results exclusively from the position control of the drive, in combination with the required linear dimension. Without the positional control circuit, the rigidity of the linear motion drive is zero! With respect to a static load, the rigidity of the linear motion drive is zero. But that also goes for drives that are controlled by linear dimensions.
The „dynamic" rigidity of the linear motion drive is due to the time delay due to displacement measurements, the reaction time of the control, and how the magnetic field is set up. Based on information provided by a linear motion drive manufacturer, the dynamic rigidity is between 30 n/µm (for carriage weights of 100kg) going up to 120 N/µm (for carriage weights of 600 kg), without information on frequencies. Due to the missing absorption in the movement direction with regard to swinging carriage loads, there is a risk of resonance oscillations.
HLS also has clear advantages here: The rigidity of a drive with an HLS, with a nominal diameter of 40 is considerably higher, including the suspension of the lead screw – with a 400 mm effective spindle length of 350 to 400 N/µm, when there is tension on both ends of the spindle. Together with the high absorption and the higher total mass of the lead screw, with this drive, smaller oscillation paths (by a factor of many) are attained, and smaller position divergences are attained (by a factor of many). In addition, lead screw path oscillations dissipate very quickly, due to the absorption that is registered.

Additional comparisons: Linear motion drive – HLS

Acceleration: At lower carriage weights, a linear motion drive provides higher accelerations; at higher carriage weights, from approximately 800 kg, the hydrostatic lead screw provides better performance.
Feed force: The feed forces of the hydrostatic lead screw that are possible are vastly superior to those of the linear motion drive.
The current strongest linear motion drive provides a nominal force of approximately 10 kN, a hydrostatic lead screw with a nominal diameter of 50 mm can be set up for 20 kN. Hydrostatic lead screws for 340 kN have already been shipped, and a hydrostatic lead screw with 1250 kN has already been thought out!
Carriage speed: In special cases, a hydrostatic lead screw can attain carriage speeds of 120 m/min, and realistically, speeds of 60m/min. The linear motion drive can certainly do better there, but mastering large masses at high speeds is very problematic, and not just if there is a power outage.
Vertical axles are not just hard to master if there is a power outage. On the other hand, hydrostatic screw drives can be fixed on a servo motor using a brake, very easily. In addition, hydrostatic lead screws with normal inclination have a self-inhibitor that is activated when the oil supply is shut off.
Additional disadvantages of the linear motion drive: The high exhaust heat of the linear motion drive is created in the machine, and due to that, a higher effort needed to deal with cooling and isolation is required. Due to the extreme magnetism that linear motion drives have, both when they are manufactured, and also due to their magnetic shavings, additional problems can arise. In addition, people with pacemakers and metal implants, as well as pregnant women are at risk due to the strong magnetic fields, and credit cards, digital watches, clocks, and data media can be damaged by them.
Advantages of hydrostatic lead screws: Servo motors for hydrostatic lead screws are set up outside the machine, and as a rule, air cooling is sufficient to cool them.

Price comparison: Leading tool machine manufacturers report that the use of hydrostatic lead screws, in comparison with linear motion drives, was considerably less expensive. If one takes into account the additional expense for the higher cooling required of the linear motion drive, the difference between it and the hydrostatic lead screw becomes even more pronounced. If a hydrostatic linear guide is used for the carriage, in addition, an additional hydro machine does not have to be used.

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