Technical
Information

HYPROSTATIK®

Hydrostatic Spindles

Hydrostatik by Hyprostatik®

Innovative Spindle Concepts

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1. Advantages and disadvantages of hydrostatic spindles

1.1 Advantages of hydrostatic spindles:

- free of wear;
- excellent damping;
- high runout quality, not affected by wear;
- minimal bearing heating with corresponding high-quality cooling of the oil outside of the bearing by conducting the heat from the spindle with the oil;
- minimal introduction of heat into the machine through the bearing, where thermally-caused displacements are minimal;
- supervision of the spindle by control of the pocket pressures.

These advantages are achieved primarily also through hydrostatic spindles using capillaries.

With our HYPROSTATIK® system using our patented PM-flow controllers (progressive flow controllers), the following benefits are achieved compared to solutions with capillaries:

- multiple greater stiffness of the hydrostatic bearing;
- multiple reduced friction- and total loss energy through the use of the lowest viscous oils possible and water or emulsions;
- higher, up to doubled load capability through potential extension use of the pump pressure;
- practically cold, very temperature-stable spindle, based on the reduced friction. With a high-quality cooling of the oil outside of the spindle friction heat carry-off from the bearing with the oil;
- no introduction of heat to the machine through the spindle where thermally-caused dislocations can be prevented;
- higher damping values by several times in the lower and middle frequency range through computer optimization with sophisticated calculation programs;
- unrestricted (continuous) loading capacity even at the highest speeds;
- speed-independent bearing properties due to minimal oil heating.

1.2 Consequences of using spindles with hydrostatic bearings:

- Considerably higher procurement costs with fast-running spindles through an additional required hydro unit with an oil re-cooling system;
- difficult optimal configuration;
- only for spindles with capillaries or comparable control systems but not with PM-flow controllers, at higher speeds, total risk of destruction even at average speeds.

2. Advantages of hydrostatic spindles with the „Hyprostatik®“ system

(with PM-flow controller)

2.1 Higher function security by several times compared to capillary tube systems.

When using capillaries to control the oil flow to supply hydrostatic pockets, the flow of oil through the capillaries is proportional to the differential pressure over these capillaries. The oil stream drops with constant pump pressure with a drop in pressure in the hydrostatic pocket. Here, compared to supply of the pockets with a constant oil stream when changing a load, a greater change in the gap height is required in order to achieve the required change in pocket pressure to receive the load.

However, when you use our PM-flow controllers, a higher oil flow is fed to the hydrostatic pockets when pocket pressure increase. Here a smaller change of the gap height is required for same change of pocket pressure than with a constant stream of oil and much smaller compared to use of capillaries. With adaption of our PM-flow controller, theoretically a virtually unlimited stiffness can be achieved.

By using our PM-flow controller instead of capillaries, a higher stiffness is achieved by several times and as a result, a dislocation is several times less than with capillaries. Realistically, it is possible to increase the stiffness by the approximately the factor of four.

2.1.1 Minimal gap size in the radial bearing with load on the spindle.

Due to the bent shape of the circular hydrostatic gap of radial bearings, the gap for the dislocation of the spindles in the bearing bore hole only directly „under” the load is minimized according to the spindle displacement. With an increasing angle to the load direction, the gap height reduction becomes smaller according to the cosine function. When a load is placed on a four-pocket radial bearing in the direction of the pocket land between two hydrostatic pockets, the gap between these pockets remains unchanged at the angle 90° to the load direction through spindle displacement. Compared to hydrostatic pockets on even surfaces, with this bent shape of the hydrostatic gap a considerably higher displacement is required to achieve a comparable increase in the flow resistance.

When supplying the pockets with hydrostatic radial bearings via capillaries, large displacements of the spindle are required due to the bent gap shape and the decreasing oil flow described in section 2. A load cannot be received several times due to the pump pressure and pocket surfaces because the spindle get contact before a sufficient increase of the flow resistance of the hydrostatic gap on the bearing bushing. This problem is compounded by the heating of oil during spindle rotation.

When the loaded hydrostatic pockets are supplied via PM-flow controllers, a considerably lower displacement occurs by increased oil flow. Thus, the effect of the comma-shaped hydrostatic gap is reduced. With the PM-flow controller, it is always possible as a result, to achieve a great increase in pressure in the pockets under load, with a sufficient minimal distance between the spindle and the bearing bush.

2.1.2 Reduction of the minimal gap size in the bearing under load through oil heating.

The friction is, reverse, proportional to the gap size and increases with the square of the spindle speed. For hydrostatic pockets supplied via capillaries, as explained above, when under load the gap height of the pockets under load is greatly reduced, while the friction in these pockets greatly increases. The greatly increased friction warms the reduced volume of oil flowing through these pockets, while the oil temperature in the gaps of the pockets under load greatly increases and the viscosity is decreased considerably. The reduced oil viscosity must be compensated for by a greater displacement of the spindle when the load is unchanged. With increasing speed, i.e. declining viscosity of the oil in the pockets under load, the spindle displacement becomes greater and greater. With a sufficiently large load and spindle speed, the spindle displacement finally becomes so great that the result is contact between the spindle and bearing bore hole and the bearing becomes damaged or destroyed. This relationship, which was often not recognized in the past, is responsible for the failure of many hydrostatic spindles.

If the hydrostatic pockets are supplied by a PM-flow controller, an increased volume of oil is fed into the pocket under load. The displacement of the spindles and thereby the friction increases under load considerably less than with pockets supplied by capillaries. Thus, the oil quantity which is also increased also heats up due to the friction of the reduced gap sizes of the hydrostatic pockets under load. When properly proportioned, the PM-flow controller can make the increase of the oil volume in the pockets under load equal to or greater than the increase in the friction in these pockets. The oil temperature in the pocket under load is not increased in relation to the bearing not under load even with high loads and the oil viscosity is not reduced, at times it is even increased. Thus, the risk of destruction does not occur when using our PM-flow controller as is known to occur with capillaries.

2.2 Considerably higher load when using PM-flow controllers.

The PM-flow controller requires a lower differential pressure of maximum 10% of the pump pressure. Without a reserve, a maximum pocket pressure of 90% of the pump pressure is possible. Here the oil flow through the pockets under load is very great - e.g. double that as a bearing not under load, but a sufficiently large gap size results despite the high pocket pressure. For conventional configurations with our PM-flow controller, the pocket pressure in the pockets free of load as less than 10% of the pump pressure. Thus, with the PM-flow controller without reserve, 80% of the pump pressure can be used as a differential pressure between the pockets. Thus, a higher load is possible.

If the bearing is under load up to a pocket pressure of 90% with capillaries, for conventional configurations, the oil flow into the pockets under load is reduced to 20% (!) of the oil stream for bearings free of load. Here the spindle would already contact the bearing bushing in general. With capillaries, therefore only an extreme pocket pressure of approx. 75% of the pump pressure is possible.

At conventional configurations, the pocket pressure drops in the unloaded pockets to only 35% of the pump pressure. Thus, when using capillaries, only a differential pressure between the pockets of approx. 40% of the pump pressure can be used.

When a radial bearing is under load, by using our PM flow-controller instead of capillaries, the increase of loadability is doubled with an unchanged pump pressure by approx. 100%! At high speeds, with hydrostatic bearings controlled by capillaries, the load can also be reduced based on the relationship shown in chapter 2.1.2, the load of the bearing can also be reduced so that, at high speeds, the load via bearings which are supplied by PM-flow controllers can be three times greater than those with capillaries.

2.3 Almost unlimited load capacity by using PM-flow controllers.

As explained in section 2.1.2., the HYPROSTATIK® hydrostatic spindle system can be loaded at least to the permissible maximum speed virtually without restrictions with the prescribed maximum load. For bearings supplied by capillaries, on the other hand, a considerable reduction of the maximum load is required. This also applies to spindles on roller bearing.

2.4 Energy dissipation loss reduced several times and/or highly increased speeds.

A security criteria for a hydrostatic bearing is certainly the minimum size of the hydrostatic gap under maximum load. Comparable bearings will show same minimal gap sizes at a maximum load. Because in pockets under maximum load with supply via capillaries is greatly reduced but with supply via PM-flow controllers a greatly increased oil flow is supplied, it is generally possible to use a lower viscous oil with PM-flow controllers like with capillaries. There can be a reduction of friction power or a higher spindle speed is possible than with capillaries based on the PM-flow controller. A reduction of the friction to one third (!) or a higher maximum speed of the spindle by approx. 70% by using the PM-flow regulators are realistic.

2.5 Heating based on friction at high speeds, cooling the oil.

Due to the reduced friction with PM-flow controllers - see section 2.4 - there is considerably reduced oil warming with comparable spindles then when supply is via capillaries. Because considerably lower pump pressure suffices than when using capillaries with a comparable load capacity with PM-flow regulators - see section 2.2. on this issue - the heating of oil is considerably lower with our PM-flow controller is considerably lower than with capillaries due to the capillaries.

Particularly low oil heating is achieved if the spindles are designed with an increased oil flow. In particular at high speeds, a higher total loss power (= friction + pump capacity loss) must be expected than would be minimally possible with an optimal design.

Another possibility to reduce the temperature change of the bearing parts due to the speed has to do with heating insulation of the spindles and the bearing parts.

If, forexample, the bearing area on the spindle is ceramic-coated areas in the bearing which come in contact with oil escaping from bearings, have a plastic coating or are heat insulated through inserted plastic parts, heating of the bearing parts can be considerably reduced. The friction heat resulting in the oil is then almost completely transported out of the spindle.

A prerequisite for minimal heating of the spindle is cooling of the oil to a temperature a few degrees under room temperature if at all possible. Furthermore, minimal heating of the oil should be attempted with a run of the spindle. Typical heating, each with a maximum speed, is between 6 and 12 °. The difference with this oil heating at different speeds is even smaller. With the aforementioned measures, the deviation in the temperature of the bearing parts can be limited from room temperature to approx. 3 to 1 °C.

Thus, an extremely cool bearing it is possible to achieve a minimal heat cycle and an extremely small amount is introduced to the machine.

3. Hydrostatic spindles

3.1 Motor spindles of conventional design.

For motor spindles of a conventional design, the drive motor is arranged between both radial bearings. The result is that a relatively short motor spindle and no additional bearings are required as a bearing for the motor roller.

The disadvantages of this concept are also extremely high:

- The considerable heat volume can only be carried out with a cooling system under certain conditions for high-performance motors in the motor rotor. This heat also migrates into the spindle and also results in thermally-dictated position changes of the tool even if the motor stator has cooled as much as possible.
- The temperature increase in the spindle can be 60 to 100 °C.
- In addition, this introduction of heat to the spindle results in various thermally-dictated changes of the bearing diameter of the spindles and the bearing boring. This is also a problem for roller bearings but completely unacceptable with the very stiff HYPROSTATIK® System hydrostatic spindles.
- Due to the overall length of the motor, the distance of the radial bearing centres most generally be selected to be considerably greater than what is optimal and
- due to the prescribed bore diameter of the motor rotor, the spindle generally must be designed to fit thinly between both radial bearings, it is also relatively flexible,
- as a result of which the stiffness of the spindle is relatively small on the processing side and the dynamic stiffness is greatly reduced.
- The electromagnetic radial and axial vibrations are directed without restriction to the spindle bearing, which impedes the running quality of the spindles. This has a particularly negative effect on the hydrostatic bearing because the highest run quality is expected from this bearing and it is also achieved without the effect of the aforementioned motor forces.
- The motor data such as power, speed, dynamic properties etc. and also the motor supplier can only vary under some conditions. Another motor mostly requires another spindle.
- In the spindle with hydrostatic base, have not two but four sealing points (each bearing must be sealed by both sides). ■

3.2 Hydrostatic, directly actuated grinding spindle.

In order to avoid the aforementioned disadvantages, HYPROSTATIK® has developed the following alternative concept:

Instead of a “motor spindle”, a directly actuated spindle is used. The motor is arranged behind the spindle. In order to avoid the transfer of the motor hear to the spindle, a “heat insulation wall” is inserted between the motor and spindle. With this concept, virtually all of the disadvantages mentioned in section 3.1 are avoided. In some circumstances, higher motor temperatures, i.e. higher motor power can be permitted.
A relatively short construction is also achieved with this concept using the following measures:

- The motor rotor and the spindle are two different parts.
- Two alternatives are possible in terms of coupling the motor rotor with the spindle:
- The motor rotor is ”floating”, i.e. attached at the end of the spindle without a third radial bearing. A very heat-resistant plastic insulation is built in between the motor rotor and the spindle, which extensively prevents the transfer of heat from the motor rotor to the spindle. A relatively short motor can be realized with this concept even with high output if motors with a larger diameter are possible. Under some circumstances, additional devices such as clamping devices can be placed in the motor rotor boring. The disadvantage of this solution is that the electromagnetic vibrations of the motor have an unrestricted effect on the spindle and thereby negatively impact the concentricity. One benefit is that no third bearing is required and the transfer of force of the clamp cylinders to the spindle is not a problem.
- Alternatively, the motor rotor is arranged on bearings on the back of the end plate using service-free angular ball bearings. Rolling bearings with ceramic bearings are provided for high speeds. The front bearing of the motor rotor

is not required for this concept. The motor rotor is supported above a plastic bushing (for heat insulation) without a clearance at the end of the spindle. The turning torque is transferred via a clearance-free claw coupling (for heat insulation with plastic intermediate elements) directly from the motor rotor. The electro-magnetic vibrations of the motor are primarily transferred to the back bearing of the spindle only to a small degree. A disadvantage is the need for the third bearing, the larger structural length, additional efforts for an axially coupling capable of bearing between the motor shaft and the spindle to transfer the tension forces and the higher costs.

- Through an alternative bearing concept with two conical or spherical bearings, not only a thermally advantageous bearing can be achieved according to the concept above, but also the distance of the "effective bearing centres" with a set housing length can be considerably increased.

With these concepts, not only the disadvantages described under item 3.1 are avoided, but also the following benefits are achieved:

- Without an effect on the spindle, drive motors with various outputs, speeds and by different manufacturers can be added on, if the interface for the spindle is taken into account.
- With the corresponding design of the interface, in some cases the motor can be replaced without disassembling the bearing or in some cases the spindle can be replaced and the motor remains in the machine. ■

3.3 Braking the grinding spindles in the event of power loss.

- In the event of a power loss, the pump pressure to maintain the spindle must be maintained as long as possible until the spindle stops. In order to limit the effort by the hydro unit, the spindle must be braked to a stop as soon as possible. Alternatively, this can be achieved using additional brakes or by brakes using the possibilities of the drive motor.
- Here we prefer the following solution:

For modern tool machines, the spindle drive is generally controlled via a frequency transformer. With the low-viscous oils required for the high speed for spindles, specially constructed pressure limit valves are problematic from the perspective of dynamics. That is why we use very low-pulsation internal gear pumps and adjust the pump pressure using a pressure sensor in the pump pressure line and a frequency transformer by adjusting the speed of the pump motor. With a comparably small accumulator, the control circuit becomes sufficiently sluggish so that the pump pressure is kept constant in sufficiently narrow limits. A pressure limit valve with an opening pressure considerably above the prescribed pump pressure is only used as a safety valve, i.e. it is only active for faults or when starting. Through a suitable coupling of the frequency transformer in the intermediate circuit, the drive motor of the spindle can be used as a generator in the event of power loss as it supplies the energy to the pump motor drive. A suitable electrical control concept proven many times is offered by several companys. A small hydro-accumulator is sufficient here.

- Alternatively, the oil supply can also be maintained by an accumulator or an IPS (independent power source). ■

4. Physical requirements when designing hydrostatic spindles

4.1 Optimization possibilities for minimal energy dissipation.

As is correctly indicated in the literature, minimal energy dissipation is achieved when the gap size and the oil viscosity are equal to zero. Then both the pump output as well as the friction and therefore also the total energy dissipation is equal to zero.

Now we know, however, that both of these prerequisites cannot be maintained. Minimal heat dissipation is, however, achieved is the smallest possible oil viscosity and smallest gap size are chosen.

If the gap size is fixed, then minimal total energy dissipation from the pump and friction result with the oil viscosity (to be selected), with which the pump energy dissipation and the friction must be equal. If the oil viscosity is fixed, the minimal energy loss is determined with the gap size (to be selected), with which the friction will be three times the pump loss energy.

For a very fast-running spindle, the optimal configuration according to the criteria mentioned above will generally not be possible because then the oil would be too heated and due to this fact, different thermally-dictated disadvantages could not be avoided. In such cases, the heating of the oil would be limited through an increased oil throughput with unchanged friction, the oil would be guided from the spindle housing in the quickest way and the parts which are oil-moistened would be heat-insulated to the best extent possible.

4.2 Optimization for minimal energy dissipation and best possible vibration reduction.

Minimal friction at fixed gap size requires a small value for the product from the perspective of oil viscosity and gap width of pockets (approx. x h). High damping values at average and high exciter frequencies, on the other hand, require a high value for the product from the perspective of oil viscosity, multiplied by the third potency of the gap width (η x b^3). Both requirements can only be fulfilled, if, with a given size of the product (η x b), the oil viscosity (η) is kept as low as possible and the gap width b is selected to be as large as possible. The smallest possible friction and best possible damping are only achieved with the lowest viscous oils and, as a result, the widest possible gaps.

The radial flexibility of the spindles at the machining point results in part from the spindle bending and partially due to the flexibility of the radial bearings. With a fixed spindle construction and fixed stiffness of the radial bearing, the result is an optimal bearing distance with which the stiffness at the processing point reaches a maximum.

The spindle deflection from the material resilience of the spindle material is virtually non-damped, the damping of a hydrostatic spindle results almost exclusively from the excellent damping of the hydrostatic bearing. Therefore, when designing a bearing, an effort should be made to keep the stiffness of the spindle as high as possible but the stiffness of the bearing is only to be made as great as required because the vibration absorption power increases with a decreasing stiffness of the hydrostatic bearing. Here, under some circumstances, the highest spindle stiffness is not achieved, however with a somewhat reduced spindle stiffness a considerably better damping results.

5. Bearing models

Our spindles are adapted to each individual case at least initially. However, at least similar spindles will surely be available for the same type of applications. With non-spatially limited spindles, the following design concept is used:

On the central spindle housing, the bearing flange is arranged on both sides with both radial bearings. The patented add-on PM-flow controllers, which have proven effective in our hydrostatic lead screws in thousands of applications, are attached on the grinded surfaces of the square flange external form. Oil distribution grooves have been incorporated into the place face on the bearing flanges, which is pressed into the spindle housing. The axial bearings are arranged on one of the two bearing flanges.

5.1 Sealing.

To seal the spindle against penetrating soiling and foreign fluids as well as prevent the escape of hydrostatic fluid, particularly at high speeds, sealing air-supported labyrinth seals are used. The centrifugal force in the axial sealing gaps supports the sealing effect of the sealing air in these seals. It is strongly recommended for these seals to feed the oil back below in a sufficiently large runback line and not overhead to the hydro unit.

Alternatively, particularly at low speeds, the various known contacting seals or, under extreme conditions and high speeds, air-statically lifting axial face seals can be used. The air-static seals have the advantage of being wear-free and can still be absolutely sealed with a shut-off air pressure supply (and stopped spindle!). Even short-term operation of these axial face seals without a supply of compressed air can, however, result in their total failure.

5.2 Ventilation of the spindle bearings.

In order to achieve the minimum dissipated energy, the spindle may not run “oil-immersed” particularly at lower RPMs. To achieve this, it is not sufficient to provide a ventilation bore hole at the highest point of the spindle housing: it is expected that the spindle housing would not be ventilated, rather oil would escape through this bore hole. In order to ventilate the spindle housing reliability, a relatively small volume of air must be fed to the spindle housing with increased pressure. This ventilation already occurs with the air barrier-supported labyrinth seal and the air-static axial face seal through these components. Excess air escapes with the hydrostatic oil into the tank of the hydro unit and must be removed there.

The construction concept described above has since been implemented in many models of spindles and has been proven to be effective.

6. Requirements to supply the hydrostatic spindles

The function hydro-unit to supply the hydrostatic spindles has the function of collecting oil returning from the spindle, to separate any air admixtures, to filter the oil and to cool it and then to feed the oil using a pressure pump with a prescribed pressure of the spindle. Based on the generally low viscous oils and emulsions or desalinated water, all components of the hydro units must be useful for the media used in each case.

6.1 Air removal.

As explained in section 5.2, the housing of the spindle must be ventilated by a continuous stream of air.

The amount of air fed to the interior of the spindle housing flows with the fluid into the hydro unit and must be removed there. In our hydro units, this occurs using a diagonal fine-meshed sieve.

6.2 Filtering of the hydrostatic fluid.

Our hydro units are equipped with a circulation pump to feed the oil flow by a heat exchanger in the standard version. Normally this circulation pump is combined with the pressure pump so that only a drive motor is required for both pumps. In order to achieve a high service life of the main pump, the main filter is placed in the feed cycle of the circulating pump so that only filtered oil is fed to the pressure pump. To protect the PM-flow controller best from soiling, a second filter is placed after the pressure pump which is supposed to catch rubbed-off parts from the pump and separations from the hoses from the hydro unit to the spindle. This filter is optimally arranged at the spindle. If this is not possible, the filter can be arranged on the hydro unit, but then the hoses to the spindle should be selected in such a way that separations from the interior hose are precluded.

6.3 Cooling the oil.

The oil is either cooled via an oil fluid heat exchanger using an externally supplied "cooling fluid" or using a separate cooling unit. Cooling with an inexpensive oil heat exchanger is only possible with comparably slow-turning spindles with a low friction. In order to keep the temperature of the hydrostatic oil as constant as possible, the temperature of this fluid should fluctuate as little as possible when using the external cooling fluid. If a cooling unit is used for cooling, it should work continuously. Cooling is controlled using a coolant dosage valve.

Two-point-controlled cooling units are only suitable under certain conditions.

With the oil re-cooling systems with cold compressors, which we supply, the oil is generally cooled with a tolerance of ± 0.5 °C to a settable value (approx. -2 to -4 °C) under a guide temperature (alternatively air, machine stand or cooling lubricant temperature. ■

6.4 Oil supply in the event of a power failure.

Particularly very fast-running hydrostatic spindles must work with low-viscous oils and also relatively narrow gaps in order to achieve the best possible characteristics. Emergency running properties can generally not be achieved through sufficient hydrodynamic load. Therefore, care must be taken so that the oil supply is always guaranteed as long as the spindle is turning. This also applies to a loss of power!

There are three alternative possibilities to achieve this goal:

- **Using pressure accumulators in the pressure line.**

This is the most cost-effective solution for smaller delivery quantities from the accumulator, i.e. very short braking times of the spindle and small feed streams to supply the spindle bearing. The disadvantage is that the hydraulic pressure decreases as the accumulator becomes emptier. In order to keep this loss of pressure within limits, the accumulator volume can only be used at approx. 20%, maximum 25% for filling oil. If, for example, a bearing with a required oil flow of 10 l/min with a power loss for example six seconds is supplied with oil via an accumulator, an accumulator with a capacity of approx. 6 litres is required.

The accumulator may only be serviced by a specialist. The function of the accumulator is particularly endangered by gas loss. If this is precluded, the gas pressure must be monitored.

- **By actuating the hydraulic pump motor using the spindle motor used as a generator only in the event of power loss.**

Here the intermediate circuit of the frequency transformer of the spindle motors is coupled with the frequency transformer for the pump motor in such a way that the spindle motor only powers the pump motor in the event of a loss of power to a lower residual RPM - see section 3.3 on this. The remaining, short braking time is bridged by a small hydraulic accumulator.

- **Using an IPS (independent power supply, e.g. battery).**

Here the energy to power the pump motor is obtained from an electrical accumulator. Very long subsequent run times can be achieved with this method ■

6.5 Pressure pumps.

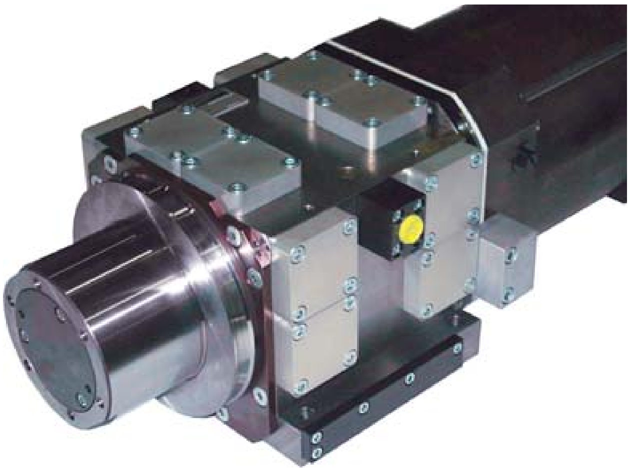
Suitable pumps for the required generally very low-viscous oils are available both with constant as well as adjustable feed volume. ■

7. Hydro units

A hydro unit with an integrated cooling unit is shown on page 17. We offer hydro-units, adapted to the requirements of the spindle bearings with an integrated cooling unit, with plate heat exchanger and circulation pump or only with circulation pump to feed the cooling oil through an external heat exchanger. ■

8. Examples of Hydrostatic Spindles Listed.

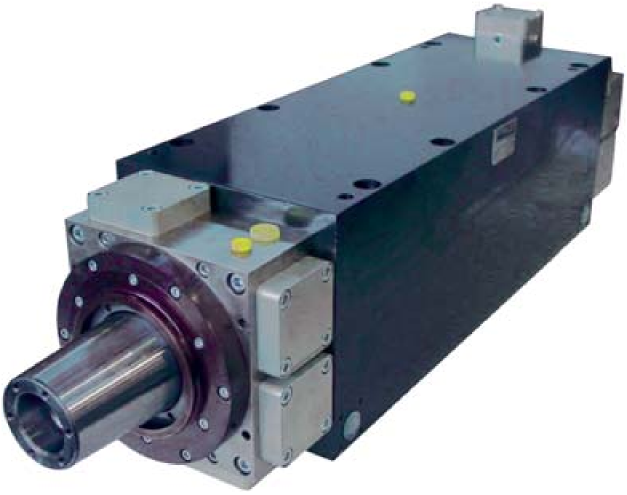
8.1 Motor Spindle for Grinding



Technical Specifications

Speed	0-7600 RPM
Pump pressure	63 bar
Oil type	VG 2
Oil flow max.	10 l/min
max. grinding force axial/radial	2000 N
Stiffness on grinding disk	> 320 N/µm
Motor power	50 kW
Frictional energy at max. speed	1,2 kW
Distance of axis to housing front edge	105 mm
prepared for automatic tool balancer	

8.2 Belt Spindle for Grinding



Technical Specifications

Speed	0-3000 RPM
Pump pressure	50 bar
Oil type	VG 4
Oil flow max.	7,6 l/min
max. grinding force axial/radial	2000/4000 N
Stiffness on grinding disk	> 400 N/µm
Frictional energy at max. RPM	0,8 kW
Distance of axis to housing front edge	100 mm
prepared for automatic tool balancer	

INFO:

Technical data, geometry, connection dimensions, motor and shaft converter can be of course adapted to your needs.
Other standard types and sizes are available.
We look forward to hearing from you.

Special properties of hydrostatic spindles of the HYPROSTATIK® System:

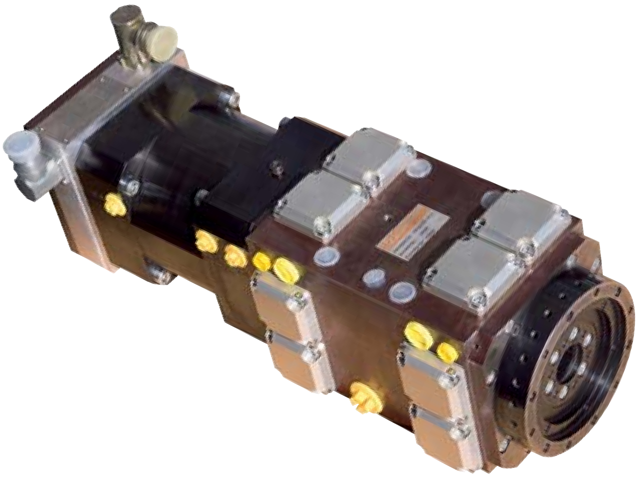
- wear-free and therefore properties independent of use
- extremely high axial and radial run-out quality
- highly static and dynamic radial and axial stiffness
- extremely high damping
- minimal friction and pump power and high load capacity with patented PM-flow controller and optimal configuration using comprehensive calculation programs
- minimal temperature expansion from low °C through good oil cooling and heat insulation between motor and spindle bearing
- excellent balancing quality

The aforementioned properties guarantee:

- best workpiece surfaces, high tool life and high removal rate
- lowest possible form tolerances and best radial and axial run-out quality
- excellent suitability also for borazon grinding disks
- high thermal stability virtually independent of speed
- high level of availability due to wear-resistance and
- minimal service costs and idle times with crash-free operation

Available as a motor spindle with asynchronous or synchronous motor, for direct or belt actuation, prepared to receive a balancing system.

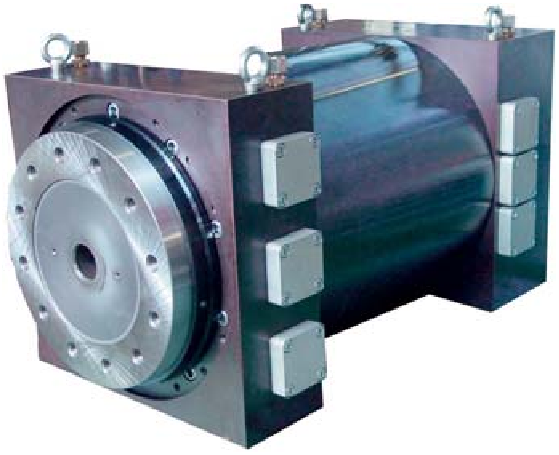
8.3 Motor Workhead Spindle



Technical Specifications

Speed	0-6000 RPM
Pump pressure	50 bar
Oil type	VG 2
Oil flow max.	6 l/min
max. grinding force axial/radial	500 N
Stiffness on the workpiece	approx. 80 N/µm
Motor output	6,3 kW
Frictional energy at max. RPM	0,6 kW
Distance of axis to housing front edge	65 mm
Concentricity and run-out	< 0,15 µm
Spindle lead-through	26 mm
Axis height	65 mm

8.4 Workhead Spindle for Direct Actuation



Technical Specifications

Speed	0-120 RPM
Pump pressure	50 bar
Oil type	VG 10
Oil flow max.	2,6 l/min
max. grinding force axial/radial	3000 N
max. workpiece weight	2000 kg
Stiffness on grinding disk	> 2000 N/µm
Frictional energy at max. RPM	0,14 kW
Concentricity and run-out	< 0,30 µm
for magnetic disks	Ø 1600 mm

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- extremely high axial and radial run-out quality
- highly static and dynamic radial and axial stiffness
- extremely high damping
- minimal friction and pump power and high load capacity with patented PM-flow controller and optimal configuration using comprehensive calculation programs
- minimal temperature expansion from low °C through good oil cooling and heat insulation between motor and spindle bearing
- excellent balancing quality

The aforementioned properties guarantee:

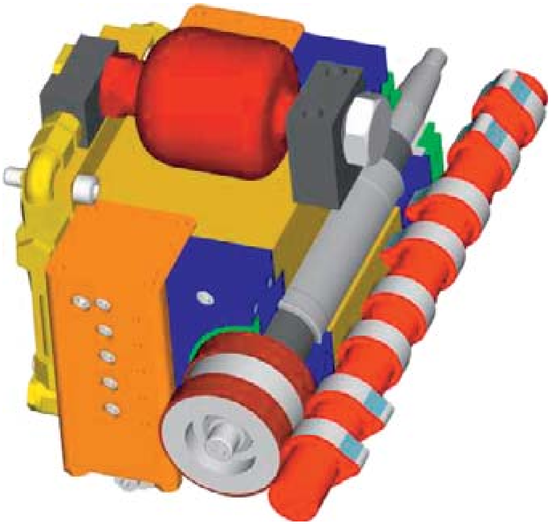
- best workpiece surfaces, high tool life and high removal rate
- lowest possible form tolerances and best radial and axial run-out quality
- high thermal stability virtually independent of speed
- high level of availability due to wear-resistance and
- minimal service costs and idle times with crash-free operation

Available as a motor spindle with asynchronous or synchronous motor, for direct or belt actuation, with customer-specific lead-through bore holes and .C-axis operation.

INFO:

Technical data, geometry, connection dimensions, motor and shaft converter can be of course adapted to your needs.
Other standard types and sizes are available.
We look forward to hearing from you.

8.5 Cam Grinding Spindle



Technical Specifications

Speed	0-25000/35000 RPM
Pump pressure	63 bar
Oil type	VG 2
Oil flow max.	10 l/min
max. cutting force axial/radial	750/500 N
Radial stiffness on grinding disk	120/60 N/µm
Grinding capacity	9/6 kW
Frictional energy at max. RPM	0,9/0,6 kW
Distance of axis to housing front edge	24/16 mm
for CBN disks approx.	Ø 70 / Ø 50

8.6 Disk Spindle for Two-Sided Grinding

Technical Specifications

Speed	0-2000 RPM
Pump pressure	40 bar
Oil type	VG 4
Oil flow max.	7,2 l/min
max. grinding force axial/radial	500 N
max. torque on bearing	60 Nm
Bearing stiffness axial/radial	600/400 N/µm
Frictional energy at max. RPM	ca. 0,4 kW
axial and radial run-out measured	< 0,2 µm
Bore	Ø 90 mm

Special properties of hydrostatic spindles of the HYPROSTATIK® System:

- wear-free and therefore properties independent of use
- extremely high axial and radial run-out quality
- highly static and dynamic radial and axial stiffness
- extremely high damping
- minimal friction and pump power and high load capacity with patented PM-flow controller and optimal configuration using comprehensive calculation programs
- minimal temperature expansion from low °C through good oil cooling
- excellent balancing quality

The aforementioned properties guarantee:

- suitability also for high roughing loads and for hard machining and milling
- lowest possible form tolerances and best radial and axial run-out quality
- high thermal stability virtually independent of speed
- high level of available due to wear-resistance and
- minimal service costs and idle times with crash-free operation

Available for belt actuation. Customer-specific solutions possible.

INFO:

Technical data, geometry, connection dimensions, motor and shaft converter can be of course adapted to your needs.
Other standard types and sizes are available.
We look forward to hearing from you.

8.7 Lathe Motor Spindle

Technical Specifications

Spindle nose	A5 according to DIN 55021
Speed	0-7000 RPM
Pump pressure	80 bar
Oil type	VG 2
Oil flow with rotating oil supply	21 l/min
max. cutting force axial/radial	6,3 kN
Bearing stiffness	> 1000 N/µm
Nominal output (S1)	20 kW
Nominal torque (S1)	125 Nm
Frictional energy at max. RPM	max. 3,6 kW
Spindle	Ø 42 mm
with clamp hydraulic, indexing for C-axis operation	

8.8 Lathe Main Spindle

Technical Specifications

Spindle nose	A8 according to DIN 55021
Speed	0-4000 RPM
Pump pressure	63 bar
Oil type	VG 2
Oil flow	bis 12 l/min
max. bearing force axial/radial	10 kN
Bearing stiffness	> 1000 N/µm
Frictional energy at max. RPM	1,3 kW
Concentricity and run-out	< 0,3 µm
Axis height	165 mm
Spindle boring	Ø 80 mm

Special properties of hydrostatic spindles of the HYPROSTATIK® System:

- wear-free and therefore properties independent of use
- extremely high axial and radial run-out quality
- highly static and dynamic radial and axial stiffness
- extremely high damping
- minimal friction and pump power and high load capacity with patented PM-flow controller and optimal configuration using comprehensive calculation programs
- minimal temperature expansion from low °C through good oil cooling and heat insulation between the motor and the spindle bearing
- excellent balancing quality

The aforementioned properties guarantee:

- suitability also for high roughing loads and for hard machining and milling
- best workpiece surfaces, high tool life and high removal rate
- lowest possible form tolerances and best radial and axial run-out quality
- high thermal stability virtually independent of speed
- high level of available due to wear-resistance and
- minimal service costs and idle times with crash-free operation

Available as a motor spindle with asynchronous or synchronous motor for gearwheel or belt actuation, with customer-specific lead-through bore holes and with indexing, motor spindle with integrated clamping system and rotary transmission lead-through and for C-axis actuation.

INFO:

Technical data, geometry, connection dimensions, motor and shaft converter can be of course adapted to your needs.
Other standard types and sizes are available.
We look forward to hearing from you.

8.9 HSK Milling Spindle

Technical Specifications

automatic tool clamping	HSK40E
Speed	0-42000 RPM
Pump pressure	80 bar
Fluid emulsion or desalinated water:	
max. flow	10 l/min
max. cutting force axial/radial	500 N
Bearing stiffness	200/160 N/µm
Motor power (S1)	15 kW
Torque at max. RPM (S1)	3,5 Nm
Torque at 500 RPM	4 Nm
Frictional energy at max. RPM	approx. 4 kW

8.10 Centre Spindle for Lathes

Technical Specifications

Workpiece receptacle	with internal collet chuck
Speed	0-3000 RPM
Pump pressure	80 bar
Oil flow	30 l/min
max. bearing force axial/radial	10/10 kN
max. bearing torque	500 Nm
Bearing stiffness	approx. 1250 N/µm
Frictional energy at max. RPM	approx. 3,5 kW
Workpiece diameter	Ø 115 mm
Drive	Belt or gearwheel

INFO:

Technical data, geometry, connection dimensions, motor and shaft converter can be of course adapted to your needs.
Other standard types and sizes are available.
We look forward to hearing from you.

Special properties of hydrostatic spindles of the HYPROSTATIK® System:

- wear-free and therefore properties independent of use
- extremely high axial and radial run-out quality
- highly static and dynamic radial and axial stiffness
- extremely high damping
- minimal friction and pump power and high load capacity with patented PM-flow controller and optimal configuration using comprehensive calculation programs
- minimal temperature expansion from low °C through good oil cooling and heat insulation between the motor and the spindle bearing
- excellent balancing quality

The aforementioned properties guarantee:

- suitability also for high roughing loads and for hard machining and milling
- best workpiece surfaces, high tool life and high removal rate
- lowest possible form tolerances and best radial and axial run-out quality
- high thermal stability virtually independent of speed
- high level of available due to wear-resistance and
- minimal service costs and idle times with crash-free operation

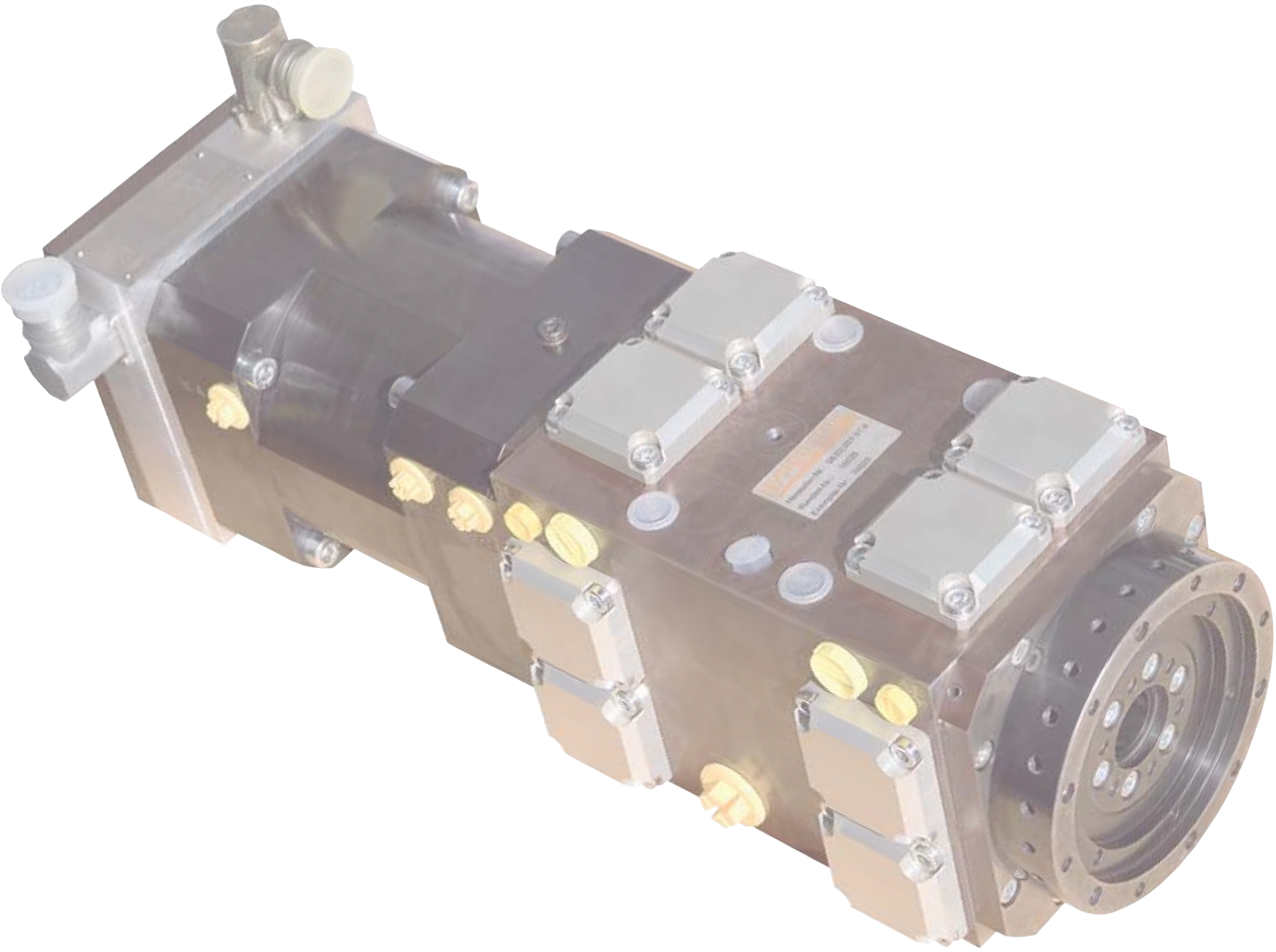
HSK spindle available as a motor spindle with asynchronous or synchronous motor. With integrated clamping system and rotary transmission lead-through and with cleaning air when idle or coolant supply.
Centre spindle available for gearwheel or belt actuation, with customer-specific ead-through bore holes and integrated clamping system.

8.11 Special hydro units for spindles

Technical Specifications

Tank volume	100-200 litres
Pump pressure	40-120 bar
Oil types	Water or low-viscous oils
Fluid flow to	8-25 l/min
with integrated cooling unit	3,0 or 5,0 kW

or cooling with plate heat exchanger with monitoring devices, adapted to the requirements of the spindles, quiet with minimal space requirements.



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