The Highest Performance Rotary Axis in the World

Double the speed for rotary tables

SCHAEFFLER GROUP
INDUSTRIAL

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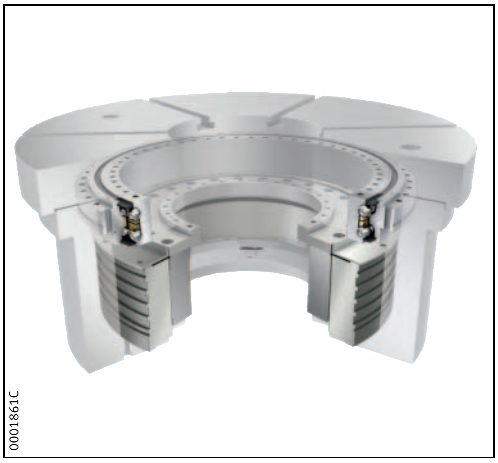

Figure 1: Rotary axis with axial angular contact ball bearing ZKLDF and torque motor RKI

For the compact bearing support of rotary tables, Schaeffler Group Industrial has improved the internal construction of the double row axial angular contact ball bearing ZKLDF to the extent that the limiting speed is double its former value. At the same time, the frictional torque is reduced while the high accuracy and rigidity of the bearing are maintained without compromise. Especially when used in combination with the new torque motors RKI from IDAM, which now also have significantly higher speeds, new possibilities are opened up in the field of turning and milling that could not previously be achieved using standard components.

Higher speeds, lower friction

The continuing development of machining centres requires bearing arrangements with increasing performance characteristics.

Rotary tables for machine tools are often equipped with an additional main spindle function for turning operation. The speed, frictional torque, rigidity and accuracy of the rotary table bearings must fulfil the requirements associated with these highly dynamic machining cycles. The limiting speed is of particular importance here. It determines the smallest turning diameter to which the cutting speeds can be used that are ideal for the cutting process, *Figure 2*.

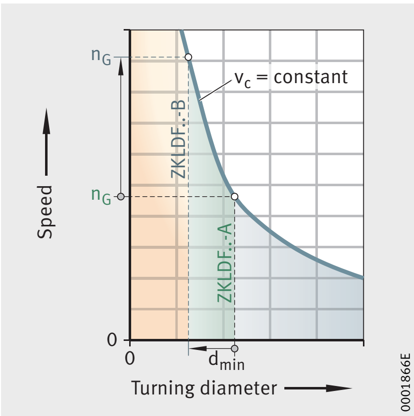

Figure 2: Larger turning diameter range through increased limiting speed with ZKLDF..-B

In terms of the performance capacity of the machine tool, this means: maximum productivity and excellent surface quality, even with small machining diameters.

In the bearing arrangement, it is therefore necessary to minimise the influences of friction while maintaining or even improving other performance characteristics such as load carrying capacity and rigidity.

The new Generation B of the bearing series ZKLDF with its improved internal construction demonstrates the success of Schaeffler Group Industrial in doubling the former limiting speeds n_G of almost all sizes.
For example, the limiting speed of series ZKLDF325 in its predecessor version A is increased from 1 000 min^{-1} to a limiting speed of 2 000 min^{-1} for the new design B, *Figure 3*.

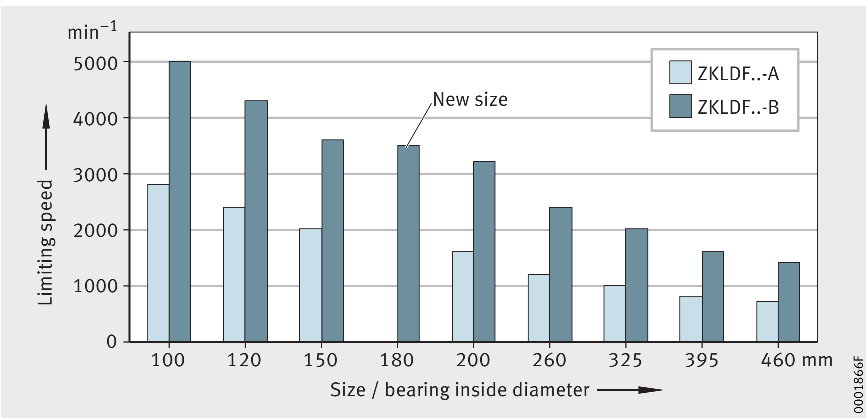

Figure 3: Increase in limiting speed with ZKLDF..-B

Significant reduction in frictional torque and induced heat

In order to achieve the speed increase, the bearing frictional torque was for example significantly reduced while the high level of rigidity was maintained, *Figure 6*. At any selected operating point, for example at 1 000 min^{-1} and without external load, the bearing frictional torque of size 325 is reduced from 3,8 Nm to 1,3 Nm. This reduction to almost one third of the original value not only allows the increase in speed as described but also reduces the extent of the heating caused by friction. A lower bearing temperature leads to smaller thermally-induced changes in the geometry of the machine structure. As a result, higher machining accuracy is achieved.

In practice, this means: even at the maximum constant speed of 2 000 min^{-1}, size 325 for example reaches an averaged bearing frictional torque of approx. 3 Nm and an equilibrium temperature on both bearing rings of only 20 K higher than the ambient temperature, *Figure 7*.

Expanded relubrication options

As part of the changeover to Generation B, the bearing design has been optimised further. In order to expand the relubrication options, the new Generation B has not only a lubrication groove on the bearing outside diameter but also an additional lubrication duct in the screw mounting face of the bearing.

Lubricant feed can thus be carried out irrespective of the radial seat design of the bearing, *Figure 4* and *Figure 5*.

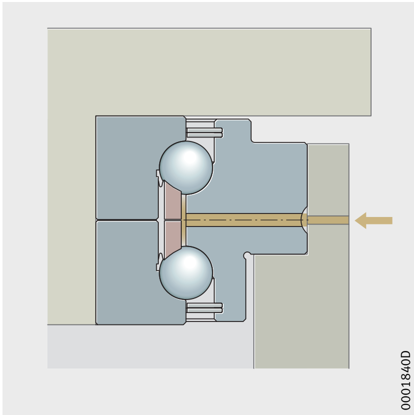

Figure 4: Relubrication via the lubrication groove in the outer ring

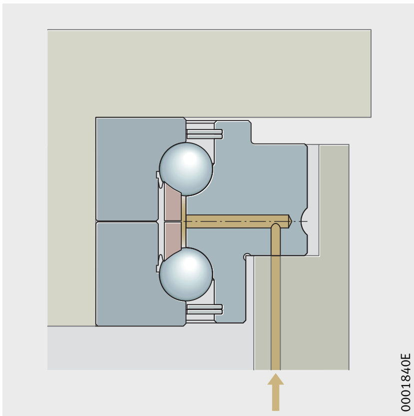

Figure 5: Relubrication via the outer ring screw mounting face

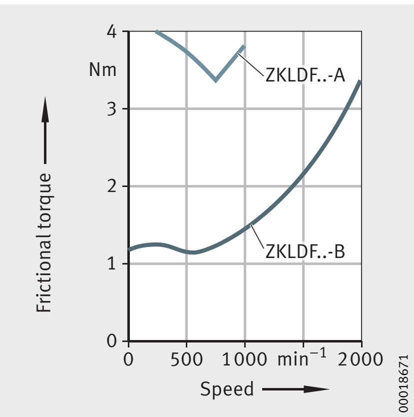

Figure 6: Reduction in frictional torque without any effect on high rigidity

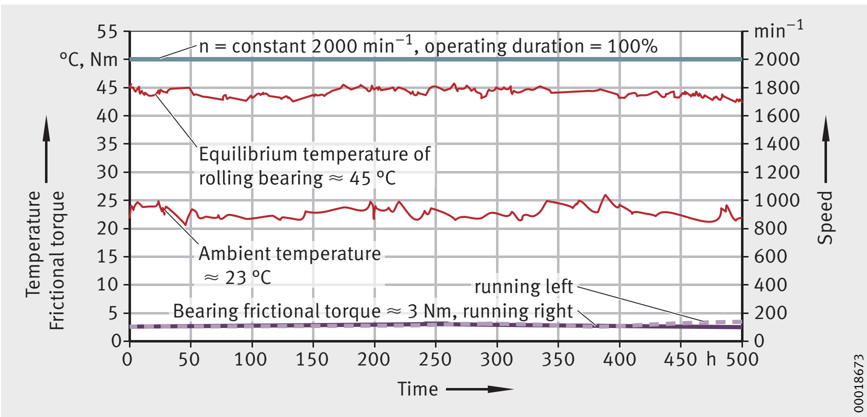

Figure 7: Reduced bearing friction for minimal heating even during long term operation

High performance direct drive of the rotary table using torque motors RKI

The new series of rotary high performance direct drives RKI from IDAM offers outstanding and previously unattainable performance characteristics, *Figure 8*.

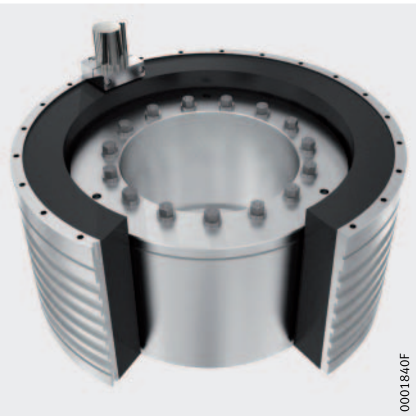

Figure 8: Direct drive of series RKI

With an increase of more than 400% in speed and a torque approx. 30% higher compared with series RI, the new direct drives RKI are extremely attractive for use in machine tools.

Downsizing may also be a convincing option. For the same power level, motor sizes can be adjusted and the costs for the inverter and motor reduced.

Design of the series RKI

The new direct drive RKI does not have the surface magnets on the rotor that are used in the standard series RI. The rotor in series RKI comprises an assembly of steel sheets with numerous embedded magnets. This can also be described as a magnet system that bundles the magnetic flow. The magnetic flow density B in this case is approx. 30% higher compared to similar surface magnets. The formula $F = B \cdot I \cdot l$ that can be used to calculate the force generated in a motor shows clearly that the 30% increase in flow density B feeds directly and proportionately into the generated force. It can be assumed that the current carrying capacity I and coil length l are unchanged.

It can also be seen that a torque up to 30% higher can be generated from a motor (stator and rotor) simply by replacing the rotor. The additional torque gained has an influence on the countervoltage and thus on the speed adjustment of the entire system.

Whenever a magnet moves past the coil, the magnetic field induces a voltage in the coil.

The magnitude of this voltage is dependent on the speed of the magnet.

The higher the relative speed between the two, in other words the more rapidly the field changes, the greater the induced voltage. The problem with this effect is that, where high countervoltages are present, it is no longer possible to implant a current into the motor. In this case, strong vibrations will normally occur before the axis can no longer be measured.

The time at which the effect begins to act is substantially dependent on two values: the intermediate circuit voltage of the inverter and the inductance (countervoltage constant) of the motor. The maximum permissible intermediate circuit voltage of common inverter models is normally restricted to between 540 V and 600 V.

This means that the only possibility for changing the speed of a motor lies in adjustment of the winding.
The inductance of the motor is reduced by processing of a thicker wire.
The extent to which the inductance decreases corresponds approximately to the increase in the amperage required by the motor. If the inductance is halved, this corresponds to approximately twice the current.

Torque, load pulsation and latching forces

Each system is designed for certain current densities in the winding.
For example, the operating principle is secured not by sending one ampere through 50 turns with a conductor cross-section of 1 mm^2 but by sending two amperes through 25 turns with 2 mm^2.
The current density within the motor thus remains the same.

In a direct comparison between a standard drive of series RI with winding WL and series RKI with the same winding WL, it can be clearly seen that the achievable speed in this design of series RKI is reduced, *Figure 9*.

In the case of the new series RKI with high current winding Zx, however, a higher torque and a significantly higher speed can be achieved.

Through adjustment of the winding, the mechanical power can be increased by a factor of five.

A focus just on efficiency and thus the extent of power loss as heat at a given torque shows a further significant improvement. A direct comparison is possible with the aid of the motor constant.
The motor constant k_m ($Nm/W^{1/2}$) indicates how much heat is generated at a particular torque. The power loss is calculated as $P_v = (M/k_m)^2$ which means that, if the constant k_m is halved, the loss is increased by a factor of four.
A comparison of series RI and RKI shows that up to 60% of the power loss can be saved for the same output torque.
A a result, less heat is generated and the requirement for cooling is reduced accordingly. This in turn leads to lower operating costs (TCO).

Applications

With all these advantages, series RKI is predestined for use in low speed and high speed rotary axes as well as high power spindle applications.
Due to the increase in power, it is possible to either downsize or upgrade the application without the need for fundamental changes to the design.

The fastest rotary axis

Through the combination of axial angular contact ball bearings ZKLDF of Generation B with torque motors RKI, rotary axes using standard components can be achieved with previously unattainable performance characteristics.
In this way, these products make a decisive contribution to increasing the productivity of machine tools.

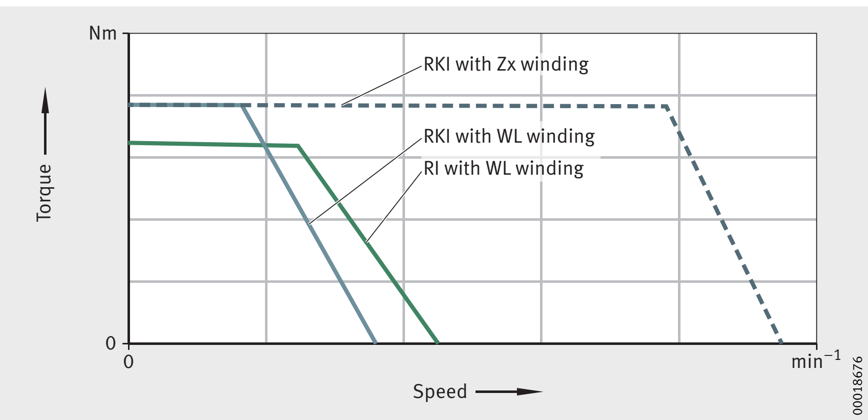

Figure 9: Comparison of torque and speed of series RI and RKI with different windings

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