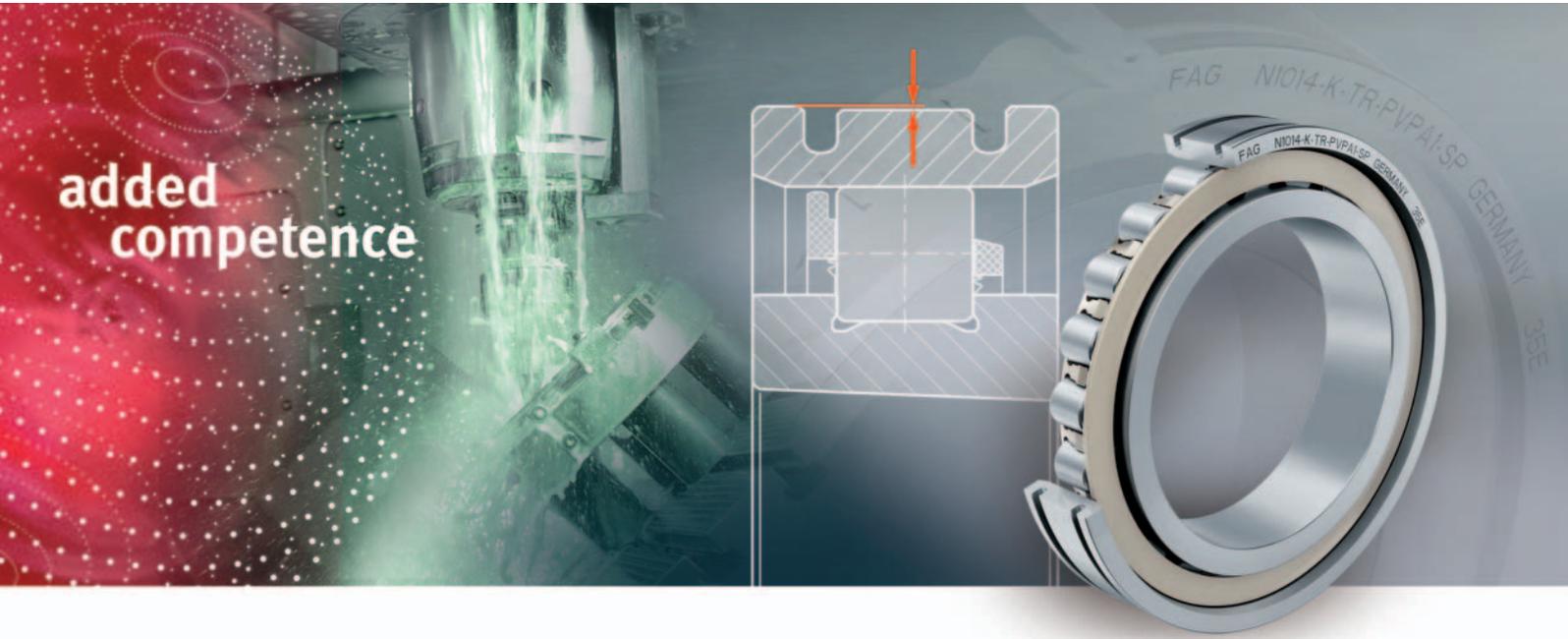




**FAG**



## FAG N..-TR – Cylindrical Roller Bearings

Thermally robust components for motor spindles

## FAG N..-TR – Cylindrical Roller Bearings

Ordering example: N1014-K-TR-PVPA1-SP



Figure 1 · Cylindrical roller bearing N..-TR

**The new thermally robust FAG high precision cylindrical roller bearing N..-TR combines for the first time, through its new design, the secure non-locating bearing function of cylindrical roller bearings with suitability for very high speeds and varying temperature differentials, Figure 1.**

With its clear advantages, the N..-TR will represent the ideal non-locating bearing for a large number of motor spindle applications and will in future have a considerable influence on designs in this field:

- secure non-locating bearing function
- compensation of temperature fluctuations
- very high speed capability
- optimum lubricant distribution.

### The motor spindle today:

#### a complicated compromise solution

In order to compensate thermally induced changes in length between the shaft and housing, the single row high precision cylindrical roller bearing without a rib on the outer ring, acting purely as a radial bearing, is fundamentally the ideal non-locating bearing. The tapered inner ring allows the radial internal clearance of cylindrical roller bearings to be adjusted during mounting such that the bearings run free from clearance or with a slight preload in operation, Figure 2. For applications in motor spindles, however, the standard high precision cylindrical roller bearing has so far had two decisive disadvantages: on the one hand, it often does not reach the speeds on the non-locating bearing side that are achievable on the operating end and, on the other hand, frequently changing

temperature differentials between the shaft and housing can lead to very high loads at the rolling contact as a result of changes in radial internal clearance, Figure 3. Radial distortions increase the contact pressure and cause a further increase in friction, the bearing undergoes increasing overheating, the radial distortions increase further and ultimately the bearing fails.

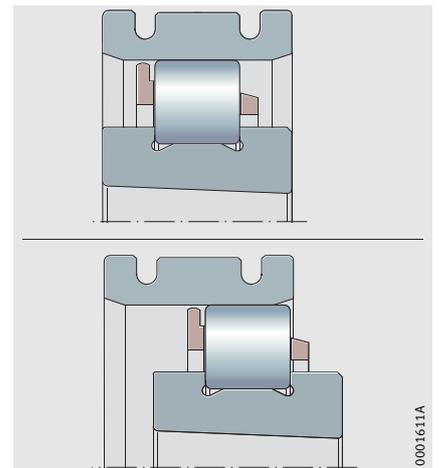


Figure 2 · Cylindrical roller bearing – sliding function in the non-locating bearing

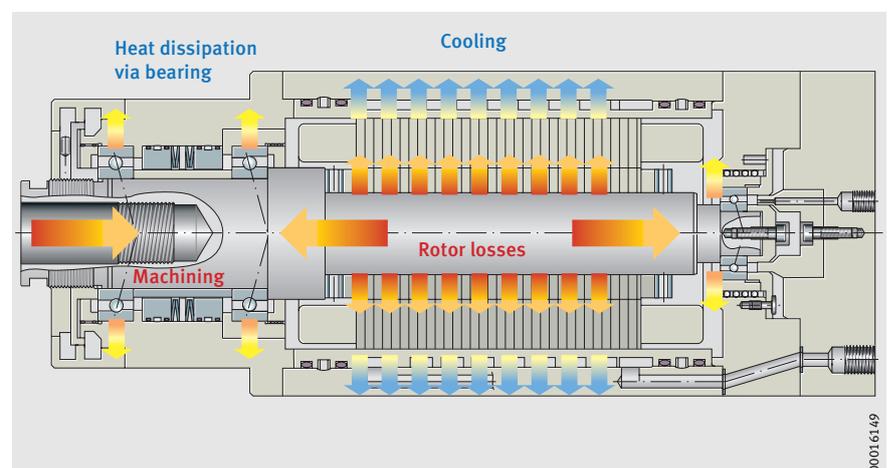
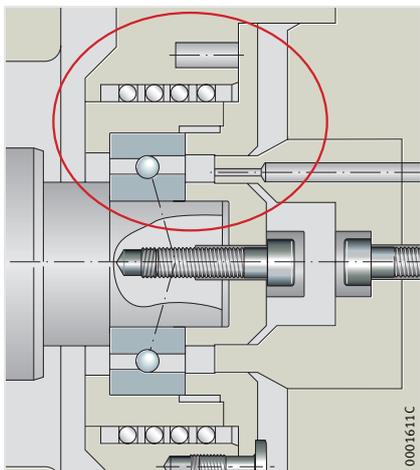


Figure 3 · Heat sources and heat sinks in motor spindles

Current non-locating bearing positions in motor spindles are therefore normally designed using angular contact ball bearings, but these are essentially compromise solutions: the sliding function is facilitated by a spring adjustment mechanism between the outer ring and housing. If it jams as a result of temperature differentials between the outer ring and housing or tilting of the outer ring in the housing, it will tend to fail. In order to safeguard the non-locating bearing function, a complicated adjacent construction with a sliding bush and a linear ball bearing is therefore frequently selected, *Figure 4*.

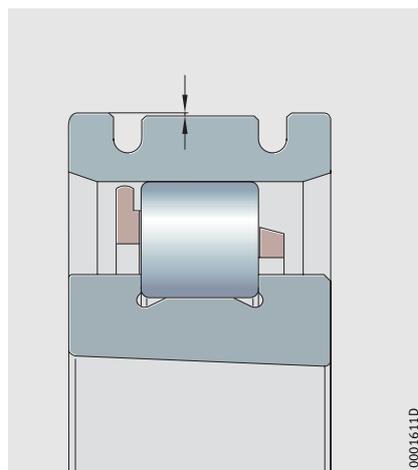


*Figure 4* · Complicated compromise solution: spring-adjusted non-locating bearing with sliding bush

The sensitivity of standard cylindrical roller bearings to fluctuations in radial internal clearance thus leads in very high speed ranges, especially in motor spindles, to susceptible and complicated design solutions with numerous interfaces, a large number of components and considerable mounting work.

*The solution of the future:*  
**Radially elastic system with standard dimensions**

The thermally robust cylindrical roller bearing is equipped with an elastic outer ring that can compensate the distortions due to changes in radial internal clearance. The outer ring, which conforms to standard dimensions as before, has two undercuts, *Figure 5*.



*Figure 5* · Elastic outer ring

Between the undercuts, the outside diameter has a slight radial recess. As a result, the central portion of the outer ring can expand in a radial direction as the temperature differentials vary and the bearing can undergo “radial respiration”.

When changes in radial internal clearance occur, the contact pressures during operation undergo smaller increases and this prevents the vicious circle of reductions in radial internal clearance and further increases in friction from starting. Even at a temperature differential of 40 K, the contact pressure is still significantly below the fatigue limit of 1 500 MPa.

**Lower strain on lubricant**

The maximum speed of bearings is restricted principally by the friction created in the bearing. If the heat generated in operation can be held to a constant value or can optimally be dissipated to the adjacent area, the bearing temperature will remain in the permissible range and the lubricant will achieve a long operating life.

Due to the consistently lower friction associated with this situation, the reduced contact forces and contact pressures lead to reduced strain on the lubricant.

Radially respiring system:

- Secure non-locating bearing function and compensation of temperature fluctuations.
- Normal force and contact pressures as a function of the temperature differential for a bearing N1011-K-PVPA1-SP of standard design mounted free from clearance and a corresponding bearing N1011-K-TR-PVPA1-SP with an elastic outer ring, *Figure 6*.

### Suitability for very high speeds

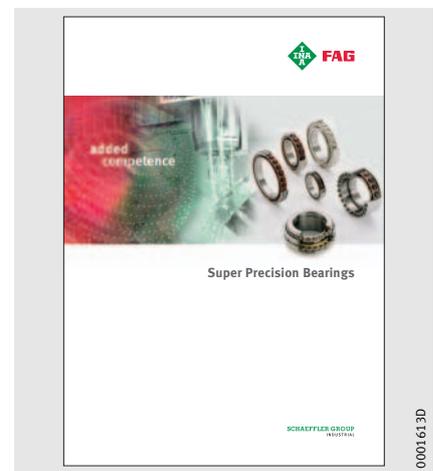
The FAG high speed cylindrical roller bearings that have been available in the market for two years already have a speed capacity that is 60% higher than the previous standard. These bearings can achieve speed parameters with steel rolling elements that were previously only possible with ceramic rolling elements. The increase in speed was

achieved through the intelligent minimisation of friction occurring in the two essential heat sources in the bearing, the rolling contact and the cage friction.

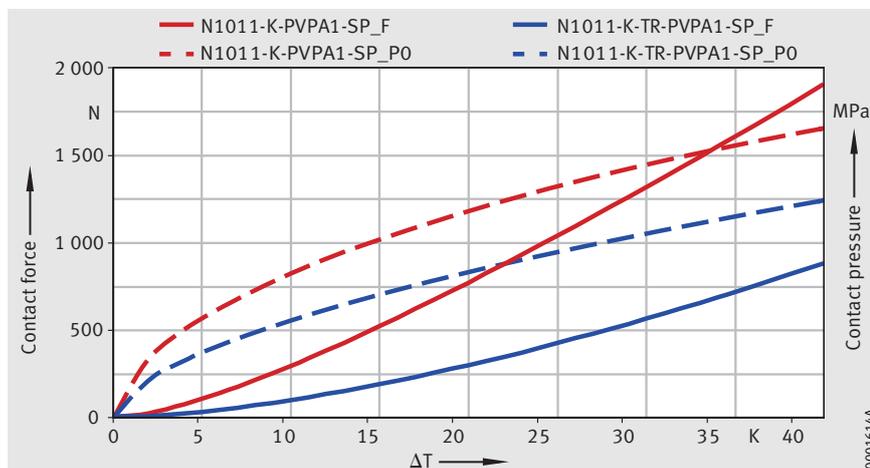
High precision cylindrical roller bearings are fitted as standard with a brass cage guided on the rolling elements. On the other hand, high speed cylindrical roller bearings are fitted with a PEEK cage with optimised friction, guided on the outer ring.

Furthermore, the friction in the rolling contact has been reduced by means of an optimised contact geometry on the roller and inner ring. In the design with the PEEK cage, thermally robust cylindrical roller bearings have the same optimisation of the internal design as high speed cylindrical roller bearings and achieve even higher speeds.

Further information on these bearings is given in Catalogue AC41130, Super Precision Bearings, and can be requested or viewed directly at [www.schaeffler.com](http://www.schaeffler.com) or [www.fag.com](http://www.fag.com), *Figure 7*.



*Figure 7* · Catalogue AC41130, Super Precision Bearings



*Figure 6* · Comparison – contact force and contact pressures

### Optimised lubricant distribution

Cylindrical roller bearings react sensitively to overlubrication. With grease lubrication in particular, it is important that grease is distributed rapidly and that excess grease between the rolling elements is removed so that there is no damage due to high churning work in overrolling motion.

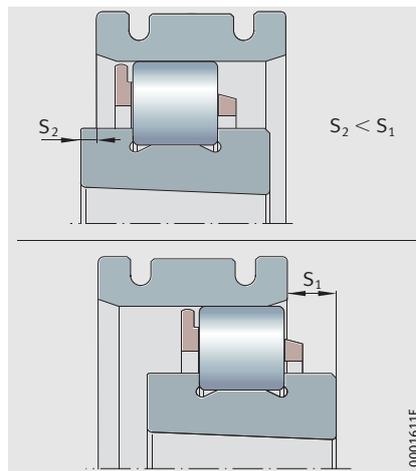
A PEEK cage guided on both sides on the outer ring ensures low friction in operation. A further advantage of this cage is that at least one cage crosspiece is always guided on the outer ring irrespective of the position of the inner ring.

The possible displacement of the inner ring is therefore equally large in both directions and is restricted, as in the cylindrical roller bearing with a cage guided on the rolling elements, by the width of the outer ring guideway.

The disadvantage of the cage guided on both sides is, however, that excess lubricant between the rolling elements can only be transported outside with difficulty due to the small guidance gap. As a result, there is an extended grease distribution process in bearings lubricated with grease and a risk of lubricant damage due to overrolling.

#### **Cage guided on one side**

On the non-locating side of motor spindles, displacement in operation occurs in one direction only. Due to heat losses from the motor and the external cooling, the shaft is at a higher temperature than the housing. As a result, the inner ring moves away from the motor. This allows the use of a cage guided on one side, since the cylindrical roller bearing is always mounted such that the larger diameter of the inner ring bore is located on the motor-facing side, *Figure 8*.



*Figure 8* · Cage guided on one side – displacement distances  $S_1$  and  $S_2$

#### **More rapid grease distribution process, lower temperature level**

With a cage guided on one side, excess grease can be conveyed out of the bearing at a significantly faster rate. As a result, the time required for the grease distribution process is reduced. The risk of grease damage due to overrolling is significantly reduced. The experience of customers shows a more rapid grease distribution process with lower maximum temperatures. After running-in, a lower temperature level with narrower scatter is achieved.

#### **Summary**

The new high precision cylindrical roller bearing FAG N...-TR with a radially elastic outer ring makes it possible, for the first time, to achieve excellent compensation of temperature fluctuations together with very high speed capability on the non-locating bearing position for the motor spindle. The optimised lubricant distribution as well as a lower temperature level in operation provide additional security for the non-locating bearing function.



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