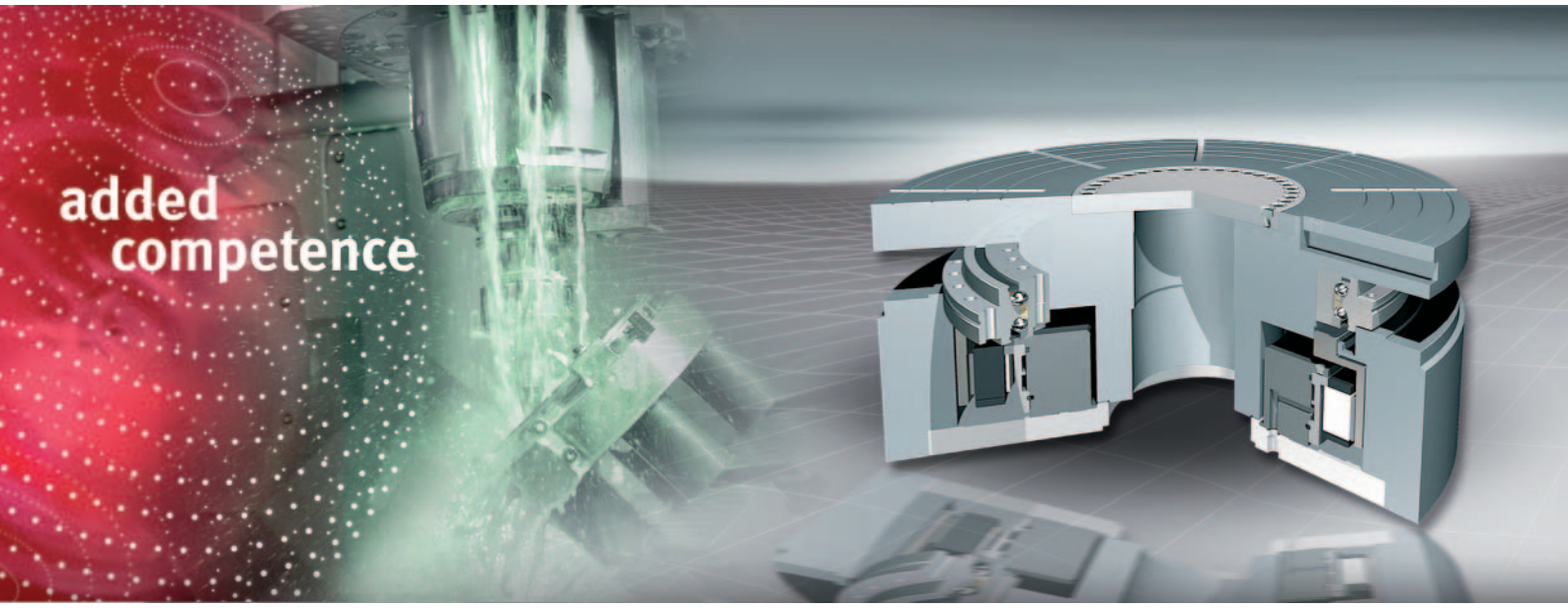


Competence gives security

A competitive edge in rotary axes through experience, simulation, calculation, testing

SCHAEFFLER GROUP

Competence gives security

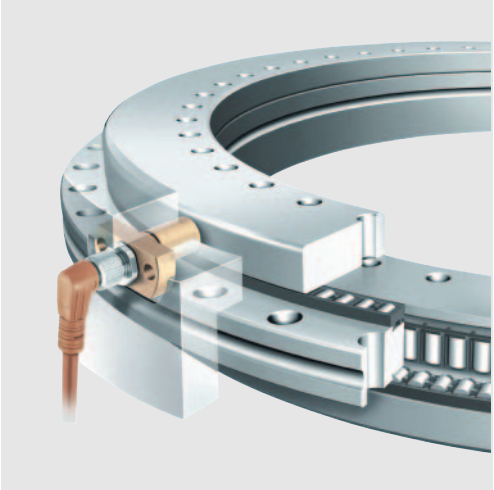


Figure 1: Axial/radial bearing YRTSM

Extremely high machining forces, workpiece mass and machined material volume, high radial, axial and tilting moment loads, highly dynamic accelerations, speeds that were inconceivable some years ago, integral measuring systems capable of measuring angles to an accuracy of a few seconds, very high machining accuracies and surface quality values, long tool life, very low system costs: this is often the content of a design brief when it comes to bearing arrangements for rotary tables, face plates, machining heads and high precision swivel axes.

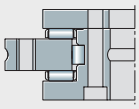
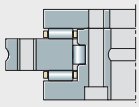
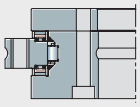
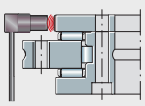
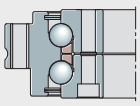
The following paper gives a focussed overview of the design and product competence of the Schaeffler Group on bearing units for rotary axes.

The right bearing for every application

The fact that not every bearing is equally suitable for such complex and multilayered requirements as described in the introduction is understandable. We will not therefore satisfy this challenging area of application with just one design. This would show insufficient thought and would seriously contradict our principle of seeking the best solution in both technical and economic terms for the bearing arrangement.

We therefore have the most comprehensive range of rotary table bearings, as shown in the table.

Based on this product range, proven on many occasions, our customers can select the appropriate bearing for their application. This gives security, a technical advantage and a high level of cost-effectiveness. In the machine tool, only the right bearing arrangement will ensure perfect machining results and the minimum of non-productive time. In bearing selection, we offer support through both our knowledge and our many years of experience in this field, see *A guide to bearing selection*.

Bearing	Characteristic	Preferred area of application
Axial/radial bearing YRT 	■ High rigidity ■ Maximum accuracy	■ For mechanically driven high precision rotary axes
Axial/radial bearing RTC 	■ Lower friction ■ Higher speeds	■ For mechanically driven high precision rotary axes
Axial/radial bearing YRT_{Speed} 	■ High continuous speed ■ Maximum tilting rigidity ■ Very low, uniform frictional torque	■ For bearing arrangements in direct drive high precision rotary axes
Axial/radial bearing with integral angular measuring system SRM 	■ YRT and YRT_{Speed} with new integral angular measuring system SRM	■ Where angular positions must be measured to an accuracy of a few angular seconds
Axial angular contact ball bearing ZKLDF 	■ Low friction ■ Very high continuous speed ■ High rigidity ■ Low lubricant consumption	■ Where the speed capacity of YRT_{Speed} bearings is not sufficient ■ For low-maintenance bearing arrangements

A guide to bearing selection

Rotary table bearings have, due to their geometry and design, quite specific characteristics. For the design of the bearing arrangement, this means: if it is to be operationally secure, low-maintenance or maintenance-free and economical, the correct bearing type of the correct size must be used. This will prevent overdimensioning and at the same time ensure that the bearings have a long operating life.

Step-by-step process

In the design of the bearing arrangement, it is necessary to take account of and weigh against each other a number of performance parameters that, in some cases, differ from each other and, in none too rare cases, conflict with each other. Nevertheless, standardisation can often be achieved within certain limits, since many rotary axis bearing arrangements can be traced back to similar essential parameters.

Based on our long experience in the design of such bearing arrangements, selection is generally found to be carried out in the following stages:

- preparation of a design brief in which all influences on the bearing arrangement are recorded. The more precisely these values are known and the more comprehensively they are taken into consideration, the higher the operational security and cost-effectiveness with which the bearing position can be designed. The influences that come into question here are as follows:
  - loads, speeds, operating temperatures, mounting space, environmental conditions, required rating life, friction, lubrication and maintenance, fitting and dismantling of the bearings, annual quantity required etc.
- preliminary bearing selection in accordance with the catalogue. Specific technical publications provide all the information that is required for preliminary selection of a bearing; see also *Comprehensive product documentation*.
- design of the bearing arrangement using BEARINX®. With the aid of this modern calculation program, it is possible to achieve secure dimensioning of the bearing. This takes account of factors including:
  - the machining forces and the forces arising from the drive system, as well as the workpiece mass
  - the rigidity of the entire system, see also *Overall rigidity of the bearing unit*
  - the influence of heat distribution in the subassembly on the bearing preload, see *Thermal simulation*
  - the influence of lubrication on the basic rating life
  - the holistic consideration of all bearing positions in the machine tool. If required, the bearing positions for the feed and main spindle bearings, rotary table bearings and linear guidance system can be calculated in a system model.

The selection and arrangement can be additionally optimised by the calculation of bearing variants.

Overall rigidity of the bearing unit

The overall rigidity of a bearing position is a description of the magnitude of the displacement of the rotational axis from its ideal position under load. The static rigidity thus has a direct influence on the accuracy of the machining results.
Normally, rolling bearing catalogues only state the rigidity of the rolling element set. Since the deformations are often very small and the bearing rings are very rigid compared to the rolling contact, this is sufficient for most applications. The situation is different for bearing arrangements in machine tools, for example in the case of rotary axes.

Here, standard practice is to use bearing units mounted by means of screws, such as our YRT bearings. In such cases, the rolling element rigidity alone is no longer adequate to describe the rigidity of the bearing position relevant to actual practice. It is rather the overall rigidity of the bearing unit that is decisive here. Naturally, this is the value that we state in the product documentation. It is of greater assistance to our customers if we give them rigidity values that are relevant to their application, see *Figure 2*. The diagram shows clearly the substantial differences and the significance of using data that are not comparable with each other. Furthermore, transparent and comparable statements stand for secure operation of the bearing arrangement and the required quality of the machined products. It is thus possible to achieve the development goals, i. e. the precise and dimensionally stable machining of workpieces even under high machining forces.

Accuracy

Bearings for rotary tables have high running accuracy. In order to transfer this as effectively as possible to the machine subassembly, clearance-free fits on the rotating component are necessary. This is generally only possible by matching the adjacent components to the actual bearing diameter. However, this maximum running accuracy is not required in all applications. It is therefore important that, to begin with, the bearing tolerances have a level of precision appropriate to practice. If the diameter tolerance is too large, the good running accuracy cannot be transferred to the subassembly. As a result, this will reduce the accuracy of the workpieces to be machined.
In selection of the bearing, both accuracies (running accuracy and diameter tolerances) should therefore always be checked, in order to eliminate the need for any additional work, such as grinding of the shaft.

Location

Our rotary table bearings are screw mounted directly to the adjacent construction by means of fixing holes. This gives a considerable reduction in the mounting work required.
The number of screws is defined such that the INA/FAG bearing units are successful with the smallest possible number but, at the same time, ensure maximum frictional locking against slippage of the bearing and the highest rigidity of the screw connection. If fewer fixing screws are

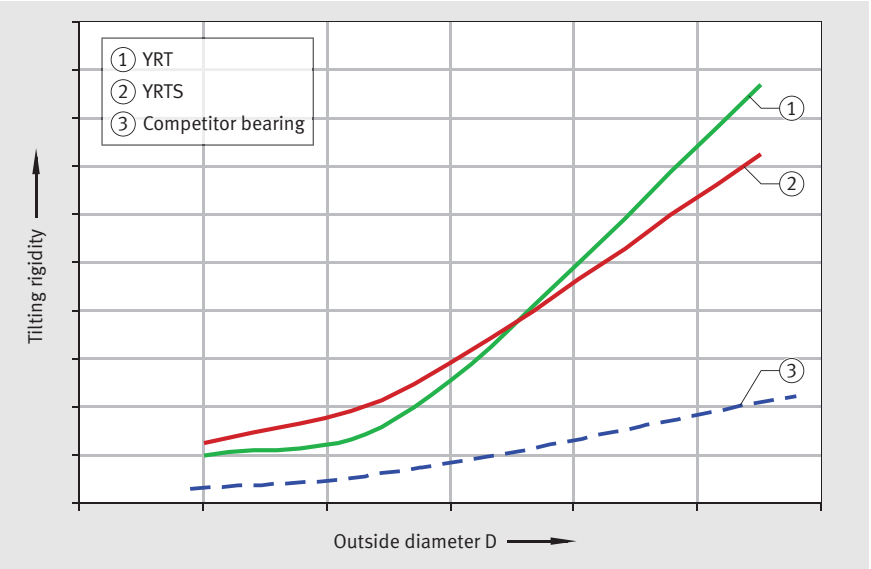


Figure 2: Comparison of rolling element set rigidity as a function of outside diameter D

used for the same thread diameter, the rigidity will be considerably reduced and there is a risk that the bearing will “creep” in a radial direction. In a high accuracy application, the results would be catastrophic.

Thermal simulation

Rotary table systems, combined with direct drives and new bearing technologies, give a clear advantage in dynamic terms. This in turn gives a significant expansion of the application spectrum of rotary axes. The performance capacity of such systems and thus the operational security of the bearing arrangements is often restricted, however, by thermal factors.

In order to minimise the risks in this area, two thermal simulation models of differing complexity were developed as part of a development project for high speed rotary tables. These were a simple model based on analogies from the field of electrotechnical engineering and a complex FEM model incorporating BEARINX®, see *Figure 3*.

The latter also takes account of values such as temperature development, thermal conduction, convection and thermal radiation.
For example, the distribution in the subassembly can be checked and, if necessary, modifications can be made to the motor cooling system or a thermal separation between the bearing and motor can be provided.

Figure 3: Temperature calculation (simulation) for a direct drive rotary table axis

As part of a test-based validation, the different calculation methods can then be compared, see *Figure 4*.

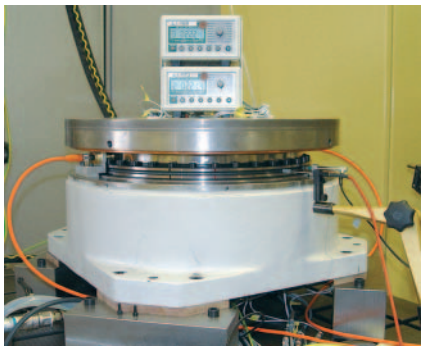


Figure 4: Validation in testing

These tools provide an economical means of supporting the design of highly dynamic rotary axes. It is thus possible to achieve rapid, reliable selection of the bearing, drive, motor and measuring system on the basis of a draft design or to check an already selected combination for its performance capacity and operational security.

Comprehensive product documentation

Comprehensive documentation is available on INA/FAG rotary table bearings. Catalogue HR 1 and Technical Product Information TPI 120 contain comprehensive descriptions of the bearings. TPI 103 provides all the information required for fitting and maintenance of the high precision bearings. Initial operation of the measuring system is described in MON 18, see *Figure 5*.

In conjunction with the comprehensive dimensional and load data in the tables, the designer thus has all the information required for the correct design and reliable operation of the bearing arrangement.

Many errors are possible at the fitting and maintenance stages. If the necessary data are not available, fitting and maintenance defects may easily occur that have a harmful effect in operation. This can be prevented by use of our documentation, which is of course provided both in printed form and as an online version.

There is also a series of special papers and publications covering the subjects of current research relating to bearing arrangements for rotary tables. These publications show fundamental development work and can be obtained upon request.

All-round service based on a systems approach

Our bearings are modelled (simulated) using FEM, thoroughly checked in all aspects and optimised in tribological terms by an experienced lubricant engineering team.

Their function is assured by means of long term tests on in-house test rigs that are designed exclusively for the testing of rotary table bearings.

We analyse the friction in the bearing and apply targeted measures to reduce the friction values in the entire system, see *Figure 6*.

We of course incorporate additional functions in the product, such as precise measurement of the angular position.

Through its IDAM subsidiary, the Schaeffler Group has direct drive technology available as in-house know-how across organisational boundaries.

We carry out measurements directly on customer machinery, run customer-specific application tests and offer support on-site in the mounting of bearings.

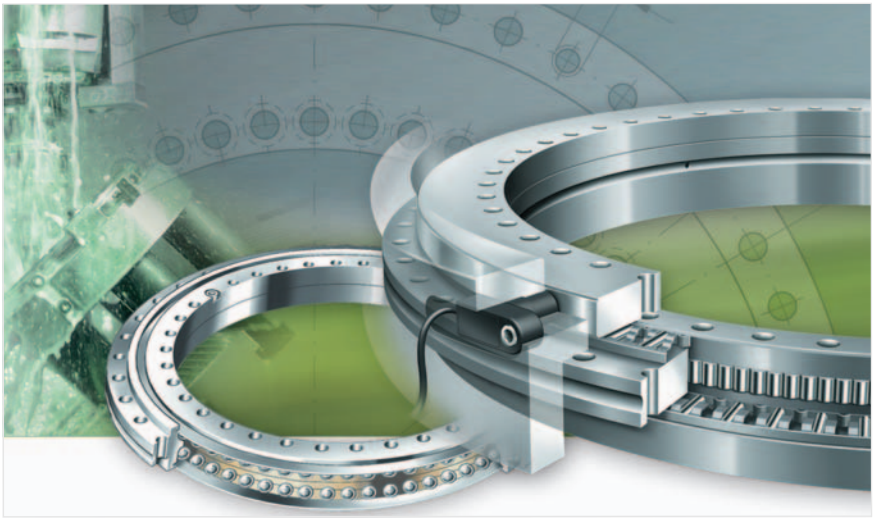


Figure 5: Axial/radial bearings with integral angular measuring system – Initial operation and diagnosis manual

Summary

Bearings for rotary tables must fulfil a whole range of specific requirements in order to achieve long economical running with operational security. Not every bearing is suitable for this complex area of application. A product that appears comparable at first glance may, in our experience, develop very quickly into the opposite of that which was originally planned. In operational terms, this may in the worst case mean unplanned downtime and sometimes high repair costs. It is not a rare occurrence that the bearing must be replaced by one that better fulfils the requirements.

This will incur substantial additional costs, since it is normally necessary to intervene in the adjacent construction itself.

Equally problematic are data that cannot be achieved in practice. If high machining quality is required, for example, it is necessary to take account of the rigidity of the bearing and not simply that of the rolling element set. In order to achieve a high level of security, it is necessary to directly compare the rigidity curves of the bearings in question, see *Figure 2*. This will clearly show how the bearing should be assessed and whether the subsequent machining quality will be achieved.

As a matter of course, our documentation states the rigidity values for the complete bearing, taking account of the screw connections as well.

With thermal simulation applied to this area of application, the Schaeffler Group is currently setting standards.
Anyone using this method correctly can eliminate unnecessary thermal risks in the design of the bearing arrangement, see *Figure 3*.

In total, this means: our systems approach is the basis for product development to your benefit. Talk to us. Your wishes are our challenges.

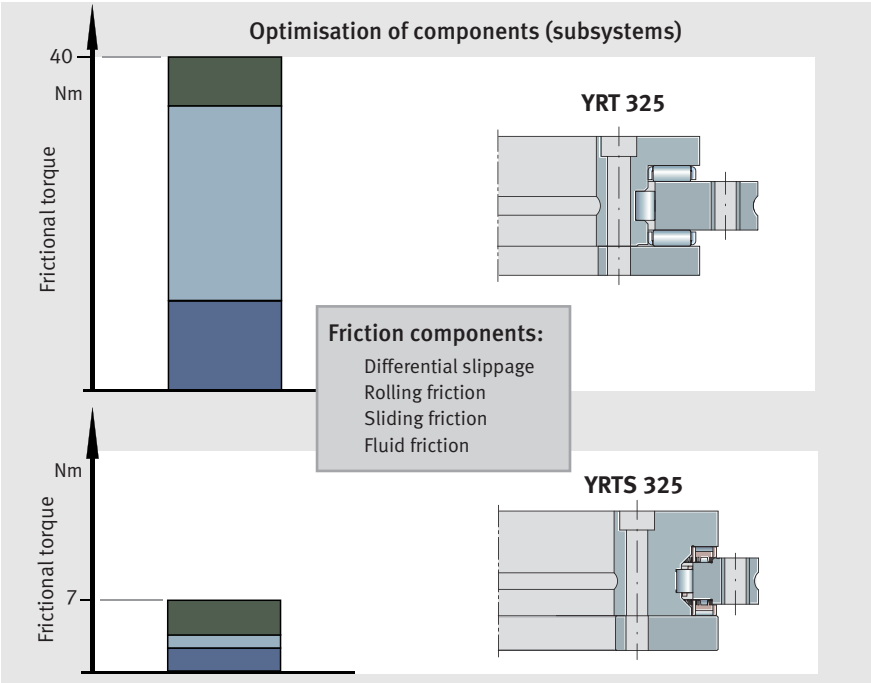


Figure 6: Friction reduction as an example of our systems approach

MATNR 036509841-0000 / SSD 10 / GB-D / 2008031 / Printed in Germany by Mandelkow

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