New Crossed Roller Bearings, Series XV and XSU 08

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The rolling bearing manufacturer INA Wälzlager Schaeffler oHG has improved its crossed roller bearing line. This type of bearing is used in machine tools, gearboxes, medical equipment, robots as well as in any application in which a single bearing is required to support loads in all directions. By working closely with customers, the company has designed two new series that are cost effective and meet important requirements such as compact design and a high degree of stiffness and precision.

1 Introduction

Although INA received numerous requests from various industrial sectors to continue the development of the company's proven crossed roller bearings, no one expected a completely new series for this bearing. However, the good teamwork effort of design engineers at INA's regional offices and the headquarters design center in Herzogenaurach allowed designers to find new solutions quickly and discuss design issues at international meetings.

A concrete design gradually began to emerge from the list of requirements and the design variants under consideration. The main goal was to find a functional solution that met customer requirements. Two new design series, the XV (Figure 1) and the XSU 08 (Figure 2), were soon available. The new bearings have numerous economical advantages for the user.

2 General Description of Crossed Roller Bearings

As the name implies, the raceways of both bearing rings are arranged in a crosswise fashion. The four raceways (two each in the inner ring and outer ring) form two raceway pairs offset by 90°. These pairs are tilted 45° toward the bearing plane. The rolling elements (cylindrical rollers) provide rolling contact in an X arrangement in the raceways in one of the two raceway systems.

This allows loads from all directions – axial, radial and tilting moment loads – to be supported by a single crossed roller bearing (Figure 4), thus eliminating the necessity of a second bearing as in the conventional locating / non-locating bearing configuration (Figure 3). The requirement for this though is that loads can be transferred through an appropriate fixture to the surrounding structure.

Because of their rolling element arrangement, crossed roller bearings can be designed clearance free or with preload. Although preloaded raceway systems typically have higher and non-uniform frictional torques, these torques are much more uniform than those of four point contact bearings, and there are no peak values.

The constant 45° contact angle and the line contact of the cylindrical rollers play a significant role here. If spacers or cages are used to guide the rolling elements, the sliding components in the raceway can be minimized, which allows a uniform rolling element contact behavior to be achieved. Another advantage provided by the line contact of the rolling elements is the high bearing stiffness, which can be increased even further by preloading the raceway system.

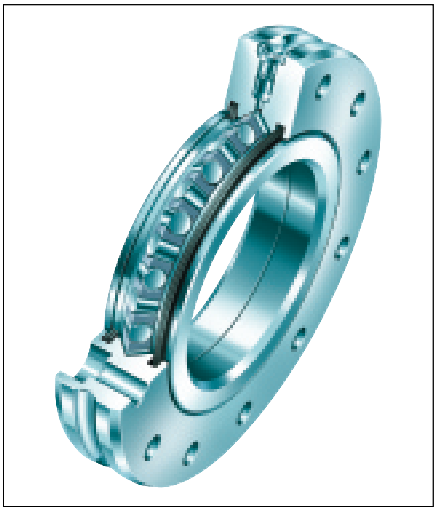

Figure 1 INA crossed roller bearings, series XV

Figure 2 INA crossed roller bearings, series XSU 08

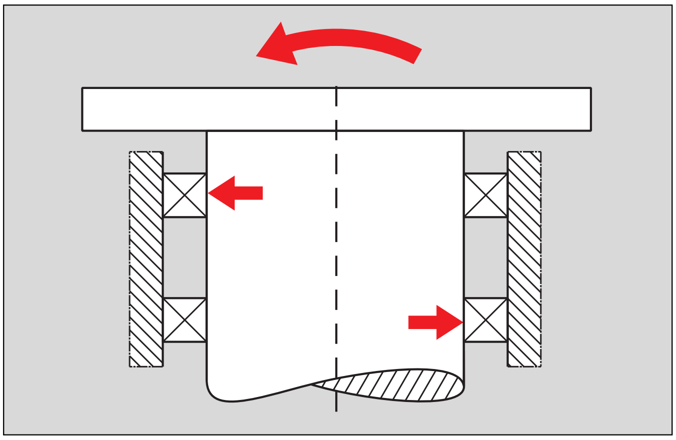

Figure 3 Conventional locating / non-locating bearing supports

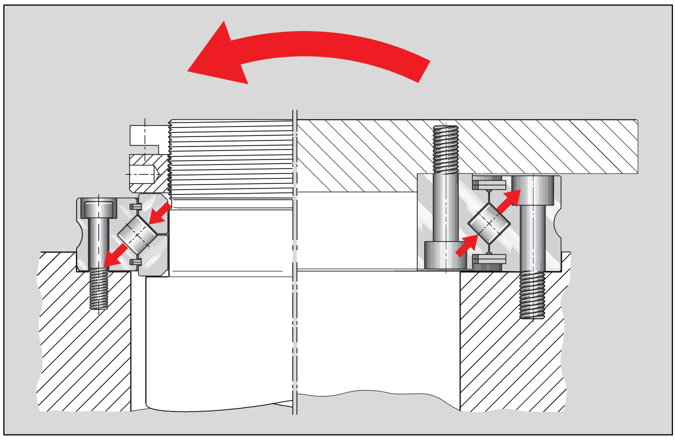

Figure 4 INA series XV crossed roller bearings (left) and series XSU 08 (right)

3 Requirements for the New Development

The new series represent a further optimization of the proven crossed roller bearing designs that have been very successful in a wide variety of applications for many years now. The new design meets the following requirements:

- small envelope
- effective sealing
- high accuracy
- suitable for numerous applications

Depending on the bore diameter, two new series have been designed to meet these requirements.

4 Bearing Solution

4.1 Series XV

For the small bore diameter range from 30 mm to 110 mm, the crossed roller bearing design calls for a split inner ring and a screw-mountable outer ring, making the bearing very easy to install. Bearing clearance or bearing preload can be set through the split inner ring. The gap between both portions of the inner ring is designed so that bearing preload is limited mechanically. When the gap is closed during mounting, the two inner-ring portions are pressed against each other, thus limiting the preload (see Figure 4, XV bearing support). This preload can be achieved with a ZM locknut.

The seals used on both sides prevent contamination from entering the bearing, protect the bearing from lubrication loss and simultaneously secure the inner rings. Lubricating nipples are furnished in the outer ring. They are recessed deep enough so that the bearing can be installed in a housing without any problems.

The crossed roller bearing can be lubricated through the lubricating nipple or through lubrication ducts in the adjacent construction. For the latter method, the outer ring is furnished with an annular groove to distribute the lubricant (the pressed-in lubricating nipples must be removed here). It is recommended that all lubrication ducts are filled with the lubricant to be used before startup operation since otherwise hollow spaces (air bubbles) can lead to lubricant starvation during run-in.

The running accuracy of the bearing rings is 0.01 mm for axial and radial runout, making this design very suitable for applications involving a high degree of accuracy.

The rolling bearing steel used for these bearings guarantee uniform quality and a high load carrying capacity. To utilize the high bearing stiffness, all outer ring locating bores must be used. Users are advised not to use every other hole or fewer when locating the bearings. If this is done, the full load capability cannot be guaranteed since a disturbed load distribution in the raceway system with partial overloading can result, which in turn can have detrimental effects on bearing life.

4.2 Series XSU 08

The bore diameter range for this design series is from 130 mm to 360 mm, and the bearing cross section is constant throughout the entire area.

Outer ring and inner ring can both be mounted with fixing screws. A special rolling bearing steel is used to guarantee uniform quality and high load capability.

Bearing preload is set between 0.002 mm and 0.010 mm. This design also keeps dirt out of the raceway system and protects against lubricant loss. Lubricant can be added through lubrication nipples in the outer ring (two on the circumference and two on the mounting face) or through lubricating ducts in the adjacent construction after the lubricating nipples have been removed.

This bearing design is also highly recommendable for precision applications since the running accuracy of the bearing rings is 0.01 for axial and radial runout.

All locating holes in the bearing should be used so that high stiffness and load capability can be ensured. A disturbed load distribution with partial overloading could otherwise result, which would have detrimental effects on bearing life (see Figure 4, XSU 08 bearing support).

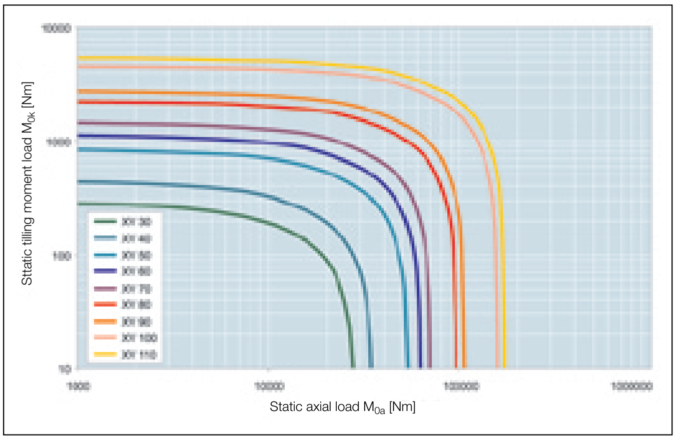

Figure 5 Static limiting load diagram, series XV

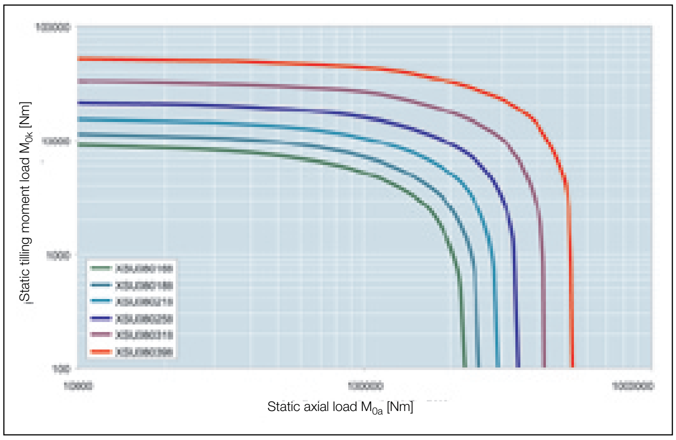

Figure 6 Static limiting load diagram, series XSU 08

5 Static Load Carrying Capacity

The static load carrying capacity of a rolling bearing is dependent on a number of factors. Important factors influencing static capacity include the number, shape and size of the rolling elements, the pitch circle diameter, raceway geometry, the material used as well as heat treatment and heat treat parameters.

Static load ratings and the static limiting load diagram are the measure for the static load carrying capacity of crossed roller bearings.

Since crossed roller bearing geometry allows axial, radial and tilting moment loads to be supported simultaneously in one bearing, an equivalent load must be calculated in order to determine the total static load safety factor via a static load rating. Calculation programs or diagrams can be used for this purpose.

Since axial loads often occur with tilting moments, the axial static load rating is the primary concern.

In the static limiting load diagram, the permissible loads are plotted with respect to the size. Axial and tilting moment load are represented in the diagram. If no additional radial load is present, the permissible combination of axial and tilting moment load can be read straight from the diagram for each size. (Figures 5 and 6). Factors for safety and the application must also be added to these results.

If a radial load is present, other diagrams (not shown here) can be used to determine the effects on equivalent load.

6 Dynamic Load Carrying Capacity

As with static capacity, the dynamic load carrying capacity also depends on several parameters. Dynamic capacity is primarily influenced by the number and shape of the rolling elements, the type of rolling element guidance, bearing material and heat treatment. The main load direction (axial or radial) also affects the dynamic capacity and thus bearing life.

7 Calculated Rating Life

The original formula for the bearing rating life was

$L_h = (C/P)^n$

Over time, comprehensive research has made it necessary to modify this formula to include factors such as material, lubrication and even contamination particles. Further development of the formula will invariably continue.

Details of the particular installation such as the dynamic deformation of the mating parts under various load conditions are also very important for bearing life. The only way to determine the load distribution in the raceway system in order to consider this aspect in life calculations is by using sophisticated computers and PC software programs. Currently these calculations are restricted to special cases.

Calculated rating life is based on a probability theory, and not all of the factors influencing life can be considered. For this reason, real-life run times can deviate from theoretically calculated life ratings.

For bearings bolted to the mating structure, another factor must be considered. If the side of the raceway is considered that is located only by bolts and not supported by the mating components, it can be seen that greater stiffness is present near the screw head and higher elasticity is present between the bolts. For large bolts, an elastic deformation results, which in turn leads to additional disturbance in the load distribution through load peaks. Bearing life is reduced. This “disturbance” increases with the distance between the mounting screws.

In the new bearing series XV and XSU 08, the distance between the bolts has been optimized so that this factor becomes negligible in conventional calculation methods.

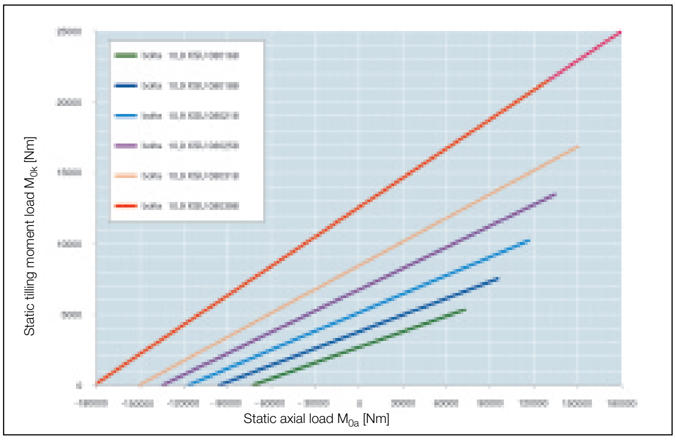

Figure 7 Static limiting load diagram for fixing screws, series XV

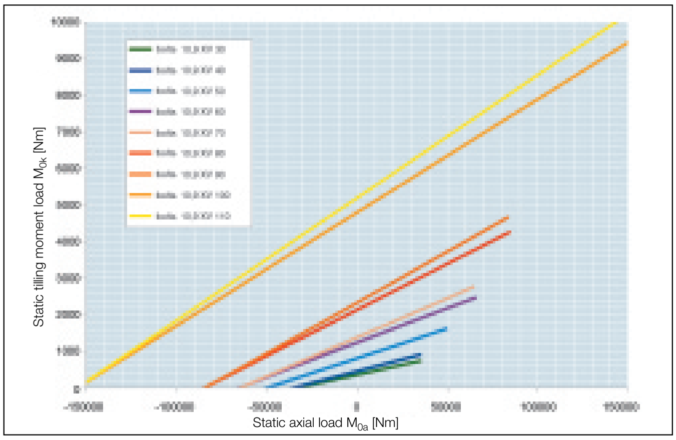

Figure 8 Static limiting load diagram for fixing screws series XSU 08

8 Bolted Connections

As described above, the bolted connection must not be seen in isolation. Similar to the effects on the dynamic load carrying capacity described above (i.e. on bearing life), the effects on static capacity must also be considered.

The general assumption is that fixing screws can be preloaded to approx. 70% of the yield stress. Conventional tightening with a torque wrench puts an additional torsional stress on the bolt so that only 10% of the yield stress remains to transmit external loads. For this tightening procedure, there is a significant scatter in the friction factors for the screw head contact surface depending on the bolt design, the surface roughness of the screw head contact surface and lubricating conditions. This scatter must also be considered when designing the bearing in order to limit the effort required in mounting using workshop equipment.

The tightening torque for both of the new series ensures that the bolts are not too tight or too loose even in the presence of the most unfavorable friction conditions. The bolted connection is also designed so that a high static load carrying capacity and stiffness are achieved, thus guaranteeing that a durable and reliable connection is present (see Figures 7 and 8).

9 Summary

Series XV and XSU08 bearings are designs that have resulted from working closely with users from the industry. Customer requirements such as compact design, high stiffness and precision were given due consideration in transferring the design to a functioning component. The user is supplied with a ready-to-install unit that can be implemented in machine tools, gearboxes, medical equipment and even in handling and robot technology. The advantage that all loads can be supported by one bearing allows a simplified surrounding structure and makes mounting easier. Fewer and simpler components reduce the mass of the unit, thus allowing better performance for less costs.

About the author:

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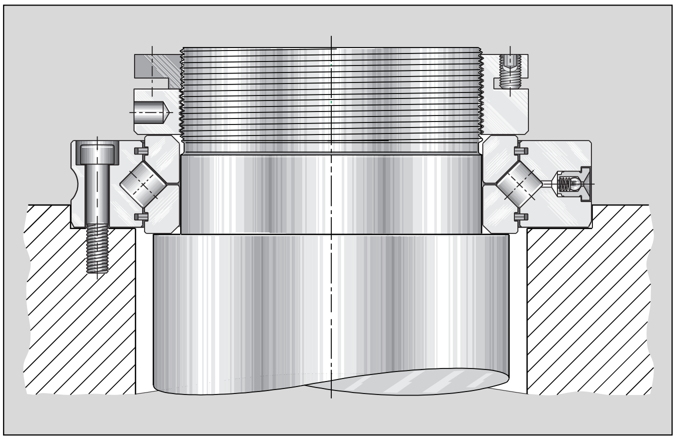

Figure 9 Installation arrangement, series XV

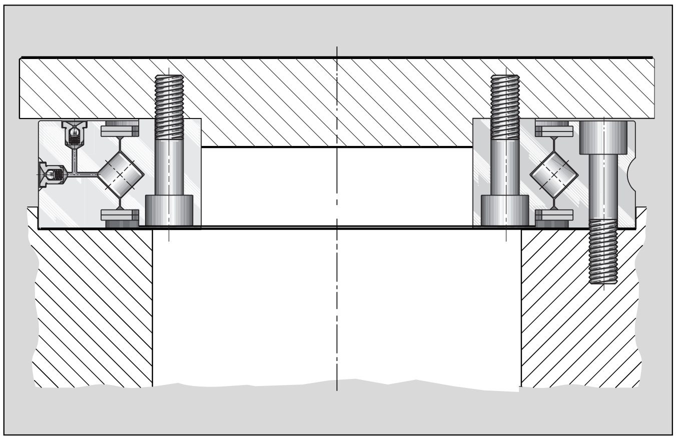

Figure 10 Installation arrangement, series XSU 08

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