ISSN 1983-4764

FOUR ROW TAPERED ROLLER BEARINGS IN WORK ROLLS[1]

NEW GENERATION OF SKF TAPERED ROLLER BEARINGS FOR WORK ROLLS IN ROLLING MILLS

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Abstract

SKF is long acquainted with the use of rolling bearings in rolling mills. As early as 1922 SKF introduced roller bearings as roll neck bearings in its Hofors Bruk steel mill in Sweden. Since then both, builders and operators of rolling mills have benefited from innovative SKF bearing technology. SKF four-row tapered roller bearings are available in different designs and a wide range of sizes appropriate to the application. These include: TQO and TQI configuration (face-to-face or back-to-back arrangement); Sealed and open bearings; Bearings with and without extended inner rings; Bearings with a cylindrical and tapered bore; Bearings with and without spacer rings. Features of these SKF bearings include: Logarithmic contact profile between rollers and raceways provides a more favorable stress distribution in the bearing and considerably enhances operational reliability; Special roller end/flange contact geometry designed to promote lubrication and minimize friction.

Key words: Taper; Spacer less; 4 rows; Explorer.

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ISSN 1983-4764

Methodology

Through practical examples show the benefits of easier and reduced maintenance without the use of special tools, and at the same time allowing for longer service life and reduced grease consumption.

DISCUSSION

Unique design features

The technical development of SKF four-row tapered roller bearings has been driven yet further. The internal geometry of all SKF tapered roller bearings has been optimized for maximum service life. The result: SKF Explorer four-row tapered roller bearings, which set a new standard for performance and reliability.

Favorable stress distribution
The logarithmic contact profile between the rollers and raceways (Figure 1) has greatly improved the load distribution (Figure 2) in the bearing under all load and misalignment conditions.

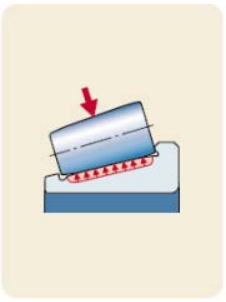

Figure 1 - Improved roller / raceway contact.

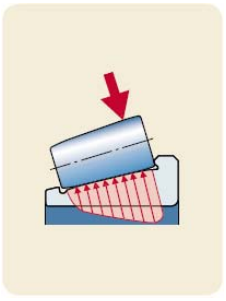

Figure 2 - Improved load distribution.

Efficient lubrication
The superior logarithmic profile and the optimized surface finish of the roller and raceway contact surfaces not only improve lubrication conditions but will in most cases, increase the service life of the lubricant

ISSN 1983-4764

Efficient lubrication of the flange

The optimized design of the inner ring guide flanges, combined with the design of the roller ends (Figure 3), promote the formation of a lubricant film in the sliding roller end/flange contact area.

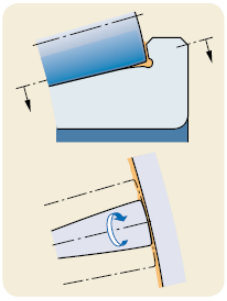

Figure 3 - Improved roller end / flange contact.

Well-designed seals

The radial shaft seal used in an SKF four-row tapered roller bearing is shaped like the letter C to clear the cage. This design (Figure 4) enables the bearing to incorporate rollers that are equal to, or just slightly shorter than the rollers used in an open bearing. Consequently, the load carrying capacity of a sealed bearing is the same or very similar to an open bearing.

A stainless steel garter spring provides a requisite pressure on the sealing lip to prevent contaminants from entering the bearing via the inner ring.

The seals are thermally and chemically stable and can withstand high sliding velocities.

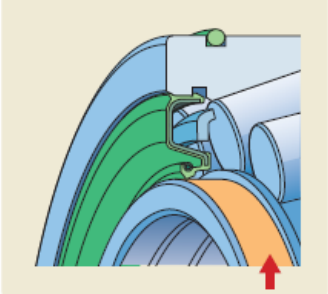

Figure 4 - Well-designed seals.

O-rings inserted in grooves in the outer ring outside surface prevent contaminants from penetrating between the outer rings and the chock bore.

Eliminate spacer rings

Bearings without spacer rings (Figure 5) are generally the better solution and have two main advantages:

• They comprise fewer component parts and can thus be mounted more easily and quickly.

• Four separate outer rings provide better, more even load distribution and consequently, longer service life.

ISSN 1983-4764

Figure 5 - Bearings without spacer ring – detail.

The performance of the previous standard tapered roller bearings has confirmed the benefits of the improved roller/raceway geometry and the optimized roller end/flange contact. In addition, the SKF Explorer bearings provide the following customer benefits

• Higher load carrying capacity
• Longer service life
• Unique inspection/maintenance capabilities
• Improved sealing.

Higher load carrying capacity

The steel used for SKF Explorer bearings is extremely clean and homogenous, and has very low oxygen content (Figure 6). The reduced number of inclusions increases fatigue strength, and wear-resistance. This results in higher dynamic load carrying capacity, but also enhances the ability of the bearing to accommodate heavy static loads as well as shock loads.

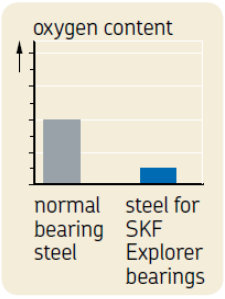

Figure 6 - Bearing steel – oxygen content.

Longer service life

Increased dynamic load carrying capacity implies longer service life and this is reinforced and extended by the benefits derived from

• A further refinement of the contact geometry
• An increase in flange strength
• A higher manufacturing quality.

A new heat treatment process provides an excellent balance between material hardness and toughness. The high surface hardness increases wear-resistance, which is particularly important under the tough operating conditions in rolling mills, characterized by contaminants like scale and water.

ISSN 1983-4764

The lubrication conditions within the bearing have also been improved. The special surface finish of the rolling elements and raceway, combined with a modified design of the cage pockets, maximizes the effects of the lubricant, particularly at the sliding contact surface between the rollers and cage. These improvements enable the bearing to run cooler, smoother and quieter.
Finally, the precise matching between the roller rows distributes loads more evenly over the four rows of rollers.

Improved sealing
The new seals (Figure 7) incorporated in SKF Explorer four-row tapered roller bearings are made of environmentally friendly hydrogenated acrylonitrile-butadiene rubber. The new seal, which is retained more firmly in the outer ring than previous designs, improves sealing efficiency against the inner ring contact surface.

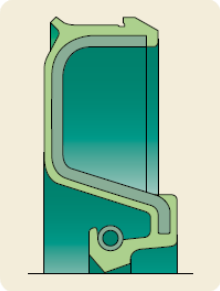

Figure 7 - New seal.

Unique inspection/maintenance capabilities
Under the operating conditions that most four rows tapered roller bearings must endure, maintenance and periodic inspection is essential.
However, with the newly developed SKF cage and seal, which enable the bearing to be disassembled, inspected and reinstalled, maintenance is faster and easier than ever before. The seals (Figure 8) as well as the cage and roller assemblies (Figure 9) can be removed, for a more complete inspection. If wear or damage is detected, the bearings can also be refurbished by an SKF Industrial Service Centre, saving you time and the expense of buying a new bearing.

Figure 8 - Disassembly of bearing cage.

ISSN 1983-4764

Figure 9 - Disassembly of seals.

Efficient refurbishment
SKF Explorer four-row tapered roller bearings have decisive advantages when it comes to refurbishment:
• The cage and roller assemblies can be easily dismantled from, and reassembled to the inner rings, enabling full inspection and eventual refurbishment.
• When needed, cage and roller assemblies and inner and outer rings of various bearings can be combined to form “new” bearings.
To do this, the ring side faces need regrinding, which is also possible for inner rings. This work is best carried out in an SKF Industrial Service Centre.
• The new seal design enables quick removal and installation.

Application advice

Design of bearing arrangements
Roll neck requirements
In most rolling mill applications four-row tapered roller bearings are mounted with a loose fit on the roll neck. The roll neck journal and the axial abutment for the inner rings must have a certain minimum hardness.
The recommended hardness is
• 45 Shore (≈ 34 HRC) for the roll neck surface
• 60 Shore (≈ 45 HRC) for the axial abutments for the inner rings.

Axial location of inner rings on the roll neck
When installing four-row tapered roller bearings, there should be between 0,4 and 1,3 mm of axial clearance between the inner rings and the abutments (Figure 10). This is particularly important for bearings with spacer rings. For applications where spacer rings are not used, this axial clearance is attained automatically if dimensions A, C and L are within the recommended tolerances (Figure 10). By adhering to the tolerances, expensive lock nuts and time-consuming clearance adjustments are no longer necessary

ISSN 1983-4764

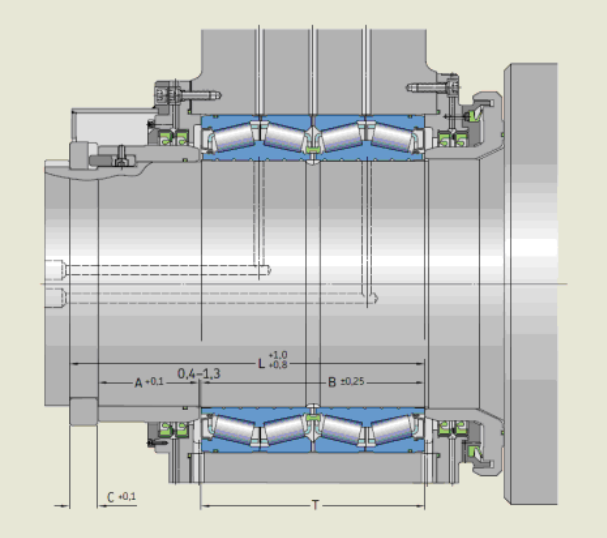

Figure 10 - Standard application of a grease-lubricated four-row tapered roller bearing with the inner rings positioned axially.

Drain slots in the housing

Applications with sealed four-row tapered roller bearings should be equipped with drain slots at the 6 o'clock position (Figure 10), to allow any water entering via the external seals to drain away.

Lubrication

No bearing arrangement can function properly unless it is adequately lubricated. Depending on the design, several options are available for the lubrication of SKF four-row tapered roller bearings.

Bearings without seals can be lubricated with grease (continuously or periodically) or with oil: oil bath, oil bath supplemented with oil-air, oil mist or circulating oil.

Sealed bearings can be lubricated with grease or oil-air. If the bearings are going to be re-lubricated or if oil-air is used, the bearing must have a relubrication feature (lubrication slots in the outer ring side faces).

Sealed four-row tapered roller bearings are manufactured to two designs

• Grease or oil lubricated bearings that will be relubricated, designation suffix VA901, E1, VA903 or E3

• Completely sealed bearings, only for grease lubrication, designation suffix VA902 or E2

Completely sealed bearings without a relubrication feature

Sealed bearings that do not have a relubrication feature (lubrication slots in the outer ring side faces) are not pre-greased at the factory.

These bearings should be filled with high quality grease, such as SKF LGHB 2, prior to installation.

Depending on the operating conditions, these bearings can be operated in the chock for between 1000 to 1500 hours before they should be removed, washed, inspected and regreased. When re-installing the bearings, be sure to rotate the

ISSN 1983-4764

outer rings 90 degrees from their original position so that a fresh load zone is available.

Oil-air lubrication for sealed bearings

To improve operational reliability and economy while reducing environmental impact, SKF recommends the oil-air lubrication method, particularly in cold rolling mills. The oil-air mixture, which is introduced via the relubrication feature uses about one tenth of the lubricant that an oil mist lubrication system uses.

The quantity of the lubricant of each inlet depends on its position (Figure 11). With an oil-air system, oil that has a viscosity of up to 700 mm²/s does not need to be pre-heated and can be very accurately metered, virtually eliminating the possibility of over-lubricating the bearings and generating additional heat.

Another advantage of the oil-air system is that the air, which exits via the seals, is clean and will not contaminate the environment.

The escaping air also enhances the efficiency of the labyrinth seals.

Air supplied to the bearing should be dry to prevent the ingress of moisture and the onset of corrosion.

Because the conditions in the chock are relatively clean, the use of the oil-air method can appreciably extend the service life of the bearings.

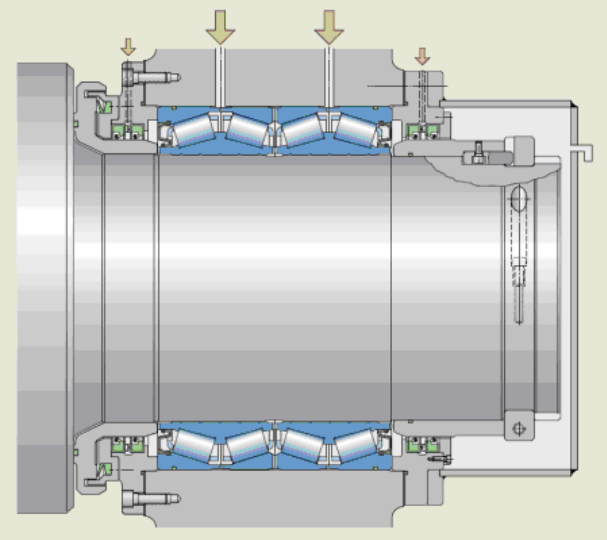

Figure 11 - Sealed four-row tapered roller bearing lubricated by oil-air.

Mounting

Four-row tapered roller bearings are high precision mechanical components and should therefore be handled with appropriate care when mounting and dismounting. It is important to use the appropriate tools and to follow the instructions supplied with each bearing.

Matching bearing components

When mounting four-row tapered roller bearings, the individual components of the bearing must be mounted in the correct order. Parts belonging together are

ISSN 1983-4764

identified by letter markings. All the components of one bearing are also marked with the same serial number so that the parts of one bearing are not mixed with those of another when several bearings are mounted at the same time.
Note: To make sure that the bearing components are mounted in the correct order, a sheet containing mounting instructions is included with each bearing. This carefully describes the various steps involved.

Loaded zone marks
In the majority of cases in rolling mills, the outer rings of the bearings are subjected to a constant load direction. This means that only a section of the outer ring raceway supports the load. For this reason, the outer rings are divided into four zones which are indicated by the markings I to IV on the side faces of the rings. The markings indicating load zone I are also indicated by lines extending across the whole width on each outer ring. When mounting for the first time it is customary to install the bearing so that the zone I lie in the direction of the load.
After each inspection, the outer rings should be turned so that another zone becomes the loaded zone. The order I, III, II, IV is recommended.

Dismounting
Four-row tapered roller bearings are dismounted in the reverse order of mounting. Bearings that are to be reused after dismounting should be treated with the same care as when mounting.
The bearing components should be carefully washed and oiled. If damage is detected in the outer ring raceway, the rollers and inner ring raceways must also be checked for damage. Bearings that show damage can often be refurbished by an SKF Industrial Service Centre.

Inspecting bearings
The inner rings of SKF Explorer four-row tapered roller bearings can be separated from their cage and roller assemblies to enable a complete inspection. Separating the cage and roller assemblies from their inner ring requires special skills and suitable tools or damage to the bearing components could result. To help avoid these problems, SKF Industrial Service Centers can provide technical support regarding the inspection and refurbishment of bearings.

Storing bearings
Prior to packaging, SKF four-row tapered roller bearings are coated with an environmentally friendly rust inhibitor. If left in their original, unopened container, in an area where relative humidity does not exceed 60 %, these bearings can be stored for several years.
The bearings should be stored on a flat, stable surface that is not subjected to repeated vibrations and should not be removed from their package until just prior to mounting.

ISSN 1983-4764

Designs
Most SKF four-row tapered roller bearings conform to the TQO configuration, which denotes two roller and cage assemblies arranged face-to-face (figs. 12 to 18). They can be supplied in open or sealed versions to different designs. These make up the standard SKF assortment.

Four-row tapered roller bearings that are to be mounted with a loose fit on a roll neck are normally supplied with helical grooves in the bore of both inner rings. The helical grooves store lubricant to reduce roll neck wear and prevent the bearing bore and roll neck from corrosion. They also collect contaminants and wear particles that might otherwise promote wear or damage.
Bearings with helical grooves in their bore also have lubrication slots in the side face of the inner rings and may also have lubrication slots in the outer ring side faces.
The lubrication slot on each inner ring enables a fresh supply of lubricant to be delivered to the helical grooves.

Open bearings
Standard TQON design bearings are supplied with window-type, stamped steel cages, without spacer rings (Figure 12). Spacer rings are available in the TQO design (Figure 13).

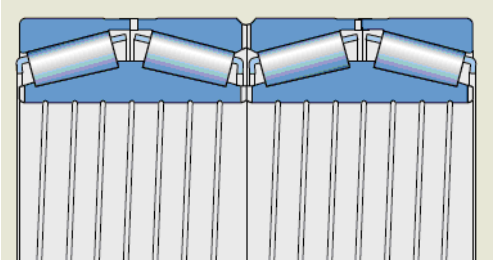

Figure 12 - TQON design - Open bearing without spacer rings.

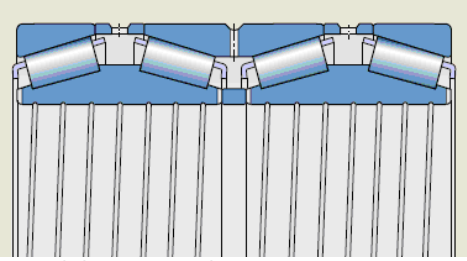

Figure 13 - TQO design - Open bearing with spacer rings.

Larger size bearings in the TQON.1 design are for applications that require extremely high load carrying capacity. These bearings have a special pin-type steel cage that uses pierced rollers (Figure 14).

ISSN 1983-4764

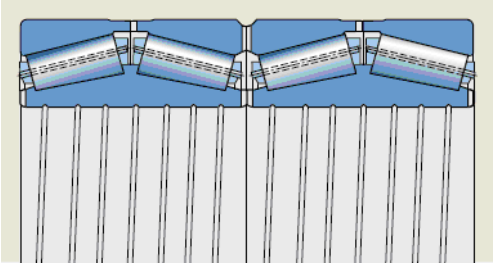

Figure 14 - TQON.1 design - Open bearing without spacer rings with pierced rollers and pin-type steel cage.

Four-row tapered roller bearings are also produced with extended inner rings, which can serve as counter faces for radial shaft seals. These bearings are supplied as standard with a window-type steel cage, without spacer rings in the TQOEN design (Figure 15), or with spacer rings in the TQOE design.

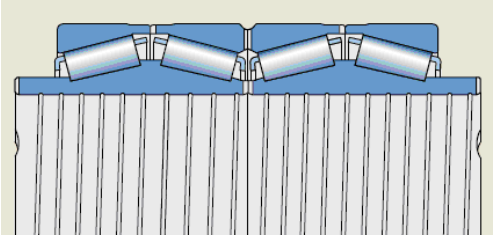

Figure 15 - TQOEN design - Open bearing with extended inner rings. The extended inner rings act as a seal counterface for radial shaft seals.

Sealed bearings

Whenever possible, sealed bearings should be used for rolling mills. Compared with open bearings they offer the following advantages

- Longer service life
- Reduced grease consumption (by up to 90 %)
- Extended maintenance intervals
- Grease is retained within the bearing
- Less surplus grease to contaminate the milling emulsion, to improve both the rolling process and product quality
- Reduced environmental impact.

Sealed bearings can simply replace open bearings as part of a rebuild or refurbishment because the boundary dimensions are the same.

Sealed bearings are fitted with specially designed, C-shaped, radial shaft seals on both sides. This enables the bearing to incorporate rollers that are equal to, or just slightly shorter than the rollers used in an open bearing. Consequently, the load carrying capacity of a sealed bearing is the same or very similar to an open bearing. The seals permit high sliding velocities and are intended for operating temperatures between –20 and +140 °C.

SKF Explorer four-row tapered roller bearings have sheet steel reinforced radial shaft seals made of hydrogenated acrylonitrilebutadiene rubber (HNBR) that are snapped into the groove in the outer ring.

ISSN 1983-4764

Standard bearings contain sheet steel reinforced seals made of fluoro rubber (FPM) that must be staked into a groove in the outer ring. Fluoro rubber seals require special handling.
O-rings inserted in grooves in the outer ring outside surface prevent dirt or water from entering between the outer rings and the chock bore that otherwise would contaminate the lubricant.
Standard TQOSN design sealed bearings are supplied with window-type, stamped steel cages, without spacer rings. (Figures 16 to 18), however, spacer rings are available in the TQOS design. (Figure 13 + seals).

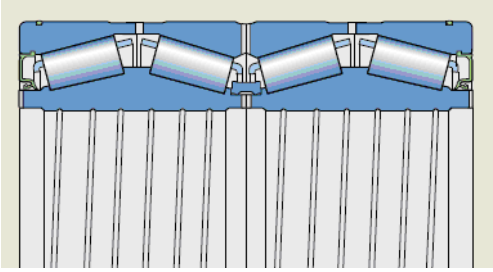

Figure 16 - TQOSN design, VA 901 or E1 designation suffix Sealed bearing without spacer rings, with lubrication slots in the outer ring side faces and a seal between the inner rings.

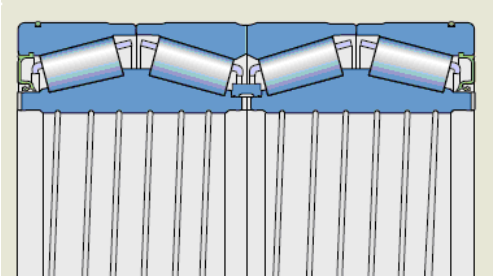

Figure 17 - TQOSN design, VA 902 or E2 designation suffix Sealed bearing without spacer rings, no relubrication features.

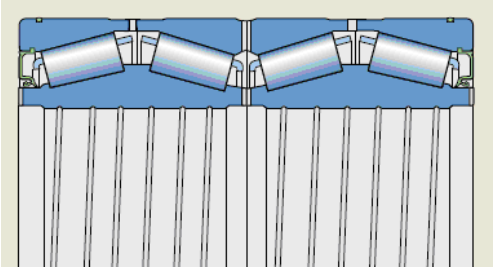

Figure 18 - TQOSN design, VA 903 or E3 designation suffix Sealed bearing without spacer rings, with lubrication slots in the outer ring side faces but without a seal between the inner rings.

Larger size sealed bearings in the TQOSN.1 designs are for applications that require extremely high load carrying capacity. These bearings have a special pin-type steel cage that uses pierced rollers. (Figure 14 + seals).

ISSN 1983-4764

Sealed four-row tapered roller bearings are also produced with extended inner rings which can serve as counter surfaces for radial shaft seals. These bearings are supplied as standard without spacer rings in the TQOESN design (Figure 15 + seals) or with spacer rings in the TQOES design.
Depending on the relubrication needs, sealed four row-tapered roller bearings can be supplied to three standard design variants
• Designation suffix VA 901 (standard bearings) or E1 (SKF Explorer bearings). These sealed bearings (Figure 16) can be relubricated via vertical slots in the outer rings. Bearings without spacer rings have a steel reinforced acrylonitrile-butadiene rubber seal between the two inner rings.
Bearings with spacer rings have two O-rings that act as seals between the inner rings. The O-rings have a permissible operating temperature range from –40 to +100 °C
• Designation suffix VA902 (standard bearings) or E2 (SKF Explorer bearings). These sealed bearings (Figure 17) have no lubrication slots and cannot be relubricated. Otherwise they have the same features as bearings with designation suffix VA901 or E1.
• Designation suffix VA903 (standard bearings) or E3 (SKF Explorer bearings). These sealed bearings (Figure 18) have vertical lubrication slots in the outer rings. They do not have a seal between the inner rings.

SKF Explorer bearings
SKF Explorer four-row tapered roller bearings are available as open bearings without spacer rings or as sealed bearings. The helical groove in the bore and case hardened bearing rings are standard for SKF Explorer bearings and are thus not identified by suffixes in the designation.

Dimensions
The boundary dimensions of four-row tapered roller bearings have not been standardized by ISO. The dimensions of many of the cones and cups of inch-size bearings do, however, conform to the ABMA Standard 19-1974 or ANSI B3.19-1975. The bore and outside diameters often approximate ISO 15:1998 Diameter Series 9 or 0.

Tolerances
SKF four-row tapered roller bearings are produced with dimensional accuracy corresponding to the Normal tolerance classes for metric and inch-size bearings, respectively.
The running accuracy of all bearings is to tolerance class P5 specifications for metric tapered roller bearings.
The width tolerance of the inner rings is
• ± 0,25 mm for bearings without spacer rings
• ± 1,524 mm for bearings with spacer rings.
The tolerances for metric bearings conform to ISO 492:2002 and those of the inch-size bearings follow class 4, ISO 578:1987 and ABMA Standard 19.2-1994.

ISSN 1983-4764

Internal clearance
SKF four-row tapered roller bearings are supplied as ready-to-mount bearings with an axial internal clearance adapted to the actual application. For SKF Explorer bearings the mean value of the axial internal clearance expressed in µm is shown in the designation suffix, preceded by the suffix C, e.g. C300 for a mean clearance of 300 µm (from 270 to 330 µm).
Influence of operating temperature on bearing material SKF four-row tapered roller bearings are subjected to a unique heat treatment process that enables the bearings to be operated up to +150 °C without any inadmissible dimensional changes occurring.

Minimum load
In order to provide satisfactory operation, four-row tapered roller bearings, like all ball and roller bearings, must always be subjected to a given minimum load. Otherwise the inertia forces of the rollers and cages, and the friction in the lubricant, can have a detrimental influence on the rolling conditions in the bearing arrangement and may cause damaging sliding movements to occur between the rollers and raceways.
The requisite minimum load to be applied can be obtained from Frm = 0,02 C
Where Frm = minimum radial load, kN
C = basic dynamic load rating, kN
The weight of the components supported by the bearing, together with external forces, usually exceeds the requisite minimum load.
If this is not the case, the four-row tapered roller bearing must be subjected to an additional radial load.

CONCLUSIONS

Comparative load ratings
For rolling mill applications, load ratings are typically not calculated according to ISO 281:2007 but are calculated by a different method based on a rating life of 90 million revolutions (500 r/min for 3 000 operating hours). As a direct comparison of these load ratings with ISO load ratings is not possible, even if they are converted for 1 million revolutions (ISO life definition) “comparative” load ratings calculated by the same non-ISO method are provided in the product tables. These comparative load ratings cannot be used to calculate life according to ISO standards.