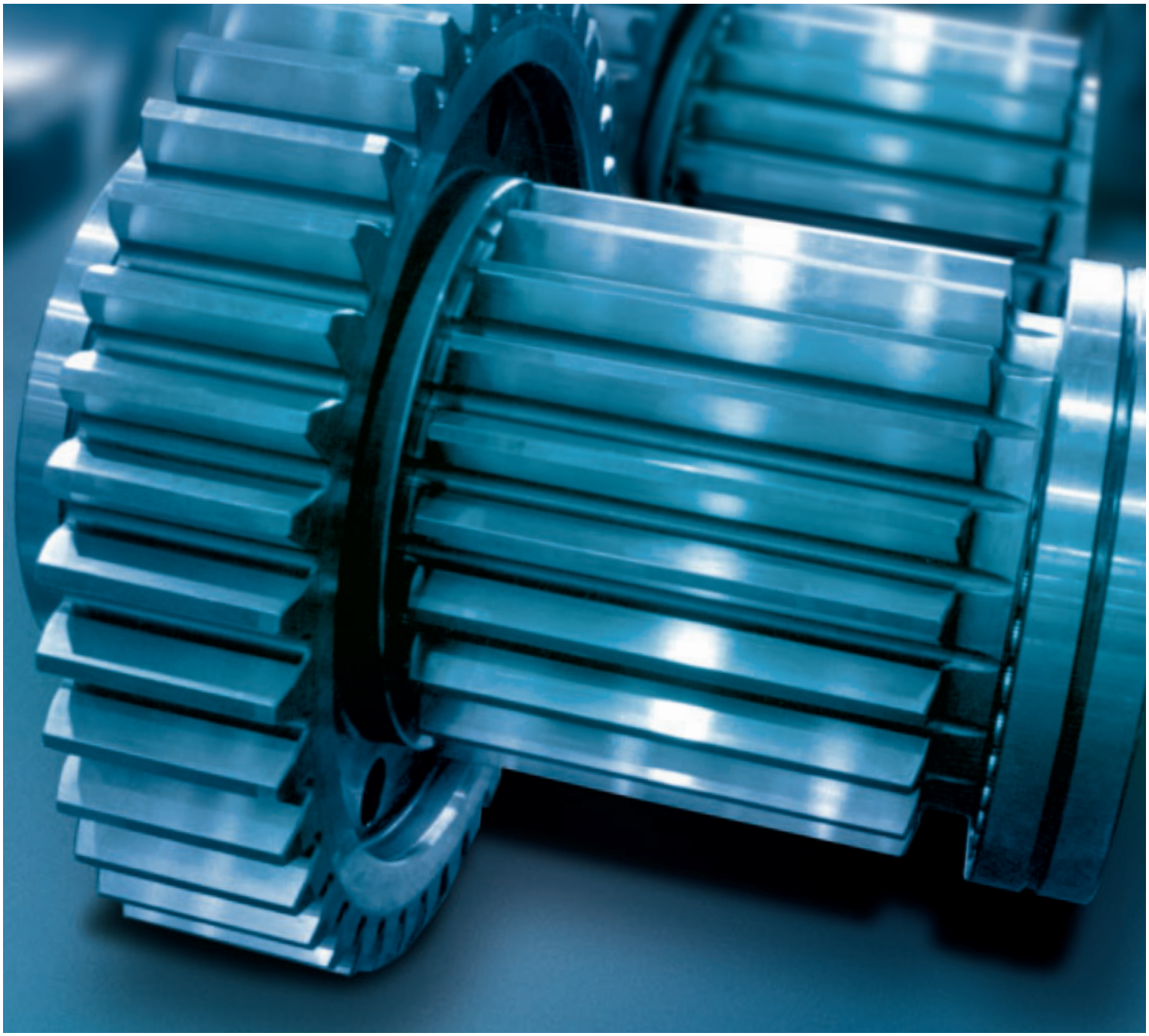
MOTION & CONTROL
NSK

Rolling bearings for industrial gearboxes: performance at it's best

Excellent Performance through Premium Rolling Bearings:
NSK has the Knowledge & Position of a Global Supplier



NSK Technology – Designed to Move – Day by Day

NSK stands for motion in all areas of application, all over the world. From industrial plants to household appliances. In a global technology network of more than 40 plants more than 23,000 staff members ensure that approximately three million new bearings with NSK-trademark are produced daily. The incredibly large range of NSK bearings are employed in all sorts of application areas and guarantees that our clients will find the perfect solution for their requirements.

We are there when you need us

Products and solutions by NSK do not only provide optimum support for gears, but their inherent control over dynamic performance delivers on client requirements. The areas of application range from computer disk drives, tunnel-boring machines, wind generator plants, washing machines, plants for semiconductor production and rolling mills. NSK stands for perfect bearing performance no matter how contaminated the environment or how severe the operating conditions. NSK rolling bearings are employed in the steel industry and in machine tools. They ensure reliable operation of wind turbines and operate just as effectively in pumps for industry and household as in compressors. The NSK product range comprises of miniature bearings with a bore diameter of 1 mm up to rolling bearings with a diameter of 5 metres. No matter the size, NSK is committed to developing ever improved solutions.

Our incentive is continuous change

NSK products are not only known for their high reliability, high heat and seizure resistance and long bearing life, but they are also known to be highly economical and environmentally sound. However, in a world that is continuously changing, a company which promotes highest standards needs to aim high. NSK is permanently developing new rolling bearings that even exceed these high quality standards. Large sums of money are invested in basic research, material technology and lubrication technology. We are first when it comes to developing solutions for tomorrow.

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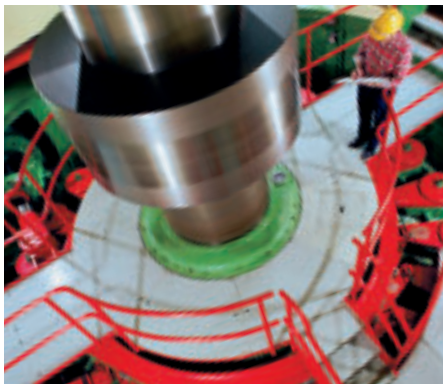





When everything is in motion, you need strong support, and NSK provides a wealth of support. As global supplier of rolling bearing technologies we are very familiar with the stresses caused by motion and the factors involved in its control. More than 23,000 staff members employed with NSK know exactly which bearing type is the right one to provide optimum performance within any one of the units – backed by more than 110 years of experience.

Focus on performance of outstanding nature

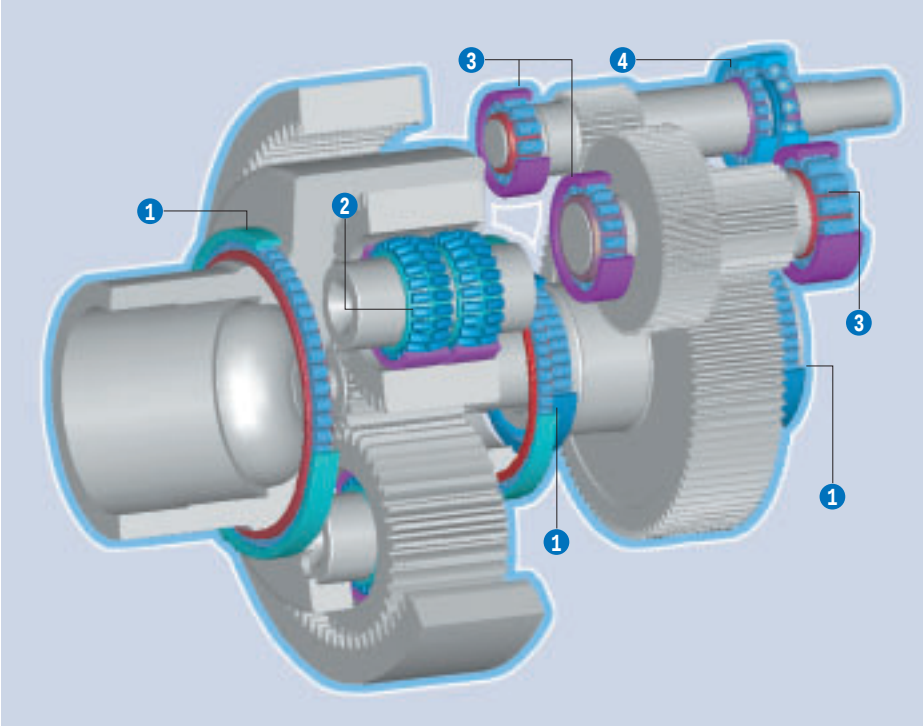
The textbook says: Gearboxes are systems for converting and translating motion. The designer says: bearings for industrial gearboxes are a means of supporting the torque and speeds of the drive end to the required turning moments and speeds of the engine – according to the individual and specific operating processes. And what does the engineer say from experience? Above all, bearings for modern industrial drive systems face the most demanding and most versatile requirements. Features, including sufficient availability, long life, economy and best combination features of weight and performance, are only a few examples out of many.

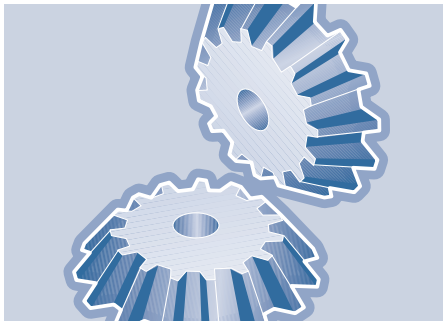
Just as versatile as their functional demands

To achieve the desired torque and speed, a certain degree of fatigue strength and life needs to be guaranteed for all components. In addition, sufficient cooling and noise levels need to be achieved for maximum performance. These features have always been fundamental for gear operation. Considering the various areas of application, however, the number of gear types is increasing, as are the issues concerning the demands for smooth gear operation. For example, environmental conditions (such as contamination, water and shock loads) affect bearing performance, as do specific operation modes, such as stop-start mode or stand-by operation. The inherent operating requirements for precision gears, such as employed in press printing machines, vary from those employed in wind generator plants, which require a high degree of maintenance free operation.

When selecting a suitable bearing type the special operating conditions at the respective bearing seat is taken into consideration.

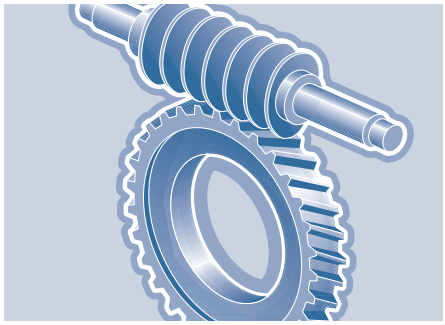
1. Cageless cylindrical roller bearing for low speed and high radial loads.
2. Spherical roller bearing for ultra-high loads and components in oblique arrangement.
3. Cylindrical roller bearings for high speed and high loads, functioning as a floating bearing.
4. Four-point bearing, acting as the locating bearing for high speed stage, while the cylindrical roller bearing takes the radial load.





Hypoid bevel gears

The larger-sized pinion which is part of this hypoid bevel gear integrating an offset pinion shaft facilitates lower peripheral force while the turning moment (torque) remains constant and the offset axis provides for higher strength of pinion support in both directions. Low noise generation constitutes a further advantage. However, a disadvantage is increased friction due to additional sliding motion.

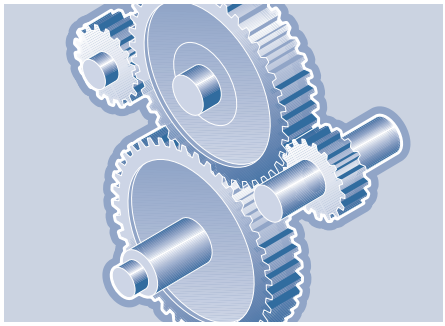


Worm gear

A particular advantage is translating motion within a single stage. In most cases the axis of worm and worm gear intersect below 90°, provided there is sufficiently high clearance between the axes. During operation vibration is absorbed to a high degree and noise generation during operating routine is low. However, the high friction reduces the degree of efficiency. This gear is mostly employed in combination with a globoid gear with cylindrical worm made from steel, because these can be subjected to tempering and grinding.

Epicyclic gear

Utilising planetary wheels with their internal gears Epicyclic gearboxes hold significant advantages over other gearbox types. Volume and weight are reduced. Due to low rolling speed and low sliding speed within the tooth system, noise generation can also be reduced. An increased degree of efficiency can be achieved due to the fact that part of the energy is translated to the coupling performance – these advantages often compensate for increased efforts on maintenance.



Spur gear

Parallel axis gears generally fall into two main types - Spur gears and Helical gears. Whilst spur gears have the advantage of ease of manufacture and accuracy, smooth operation and high load capacity are achieved through helical gears (albeit with the need to react the thrust loads from helical gears). Double helical gears constitute a sub-type with increased load capacity and larger face width.

Bevel gear

There are three types of design depending on tooth traced characteristics. If spur gearing is employed tooth engagement acan cause high noise generation. Although Helical bevel gears also employ straight tooth profiles they afford reduced noise levels, due to improved mesh characteristics. The third type of design employs spiral bevel gears and curved-tooth bevel gears. This type of design not only operates at lowest noise levels, but is also the ideal design if high performance needs to be translated.

NSK rolling bearings meet tomorrow's requirements

The history of developing and designing gears is the history of continuously improving performance. In the course of time gears have become increasingly powerful – thus the requirements for bearing performance are continuously increasing. NSK rolling bearings have not only kept pace: great ideas have ensured that they have always been one step ahead. However, capacities for high performance can only be fully utilised if the correct rolling bearing is fitted in the right place. For this purpose numerous vital criteria and important features need to be systematically considered and analysed. These issues concern bearing life, static bearing capacity at maximum load, extreme load on part of the engine as well as the limiting speeds.

The issue concerning load

First the input torque needs to be determined. If the torque is variable, it is important to determine the intervals at which the torque varies. Also what are the estimations for tooth loads and bearing loads? It is also necessary is to determine if there are further loads that are affecting performance (apart from the tooth loads) e.g. loads applied externally to either input or output shafts.

The issue concerning speed

It is important to determine the level of speed and sense of rotation. Do operating modes include stand-by mode? Interaction between the level of load and the level of speed needs to be evaluated.

The issue concerning space for assembly

Are there certain dimensions stipulated for assembly? If dimensions may be altered the range of dimensions must be specified. If the space for assembly is not sufficient, problems may exist finding a solution for optimum bearing selection. In this case it needs to be determined to which extend the dimensions may be altered without causing any non-permissible effects.

The issue concerning shaft arrangement

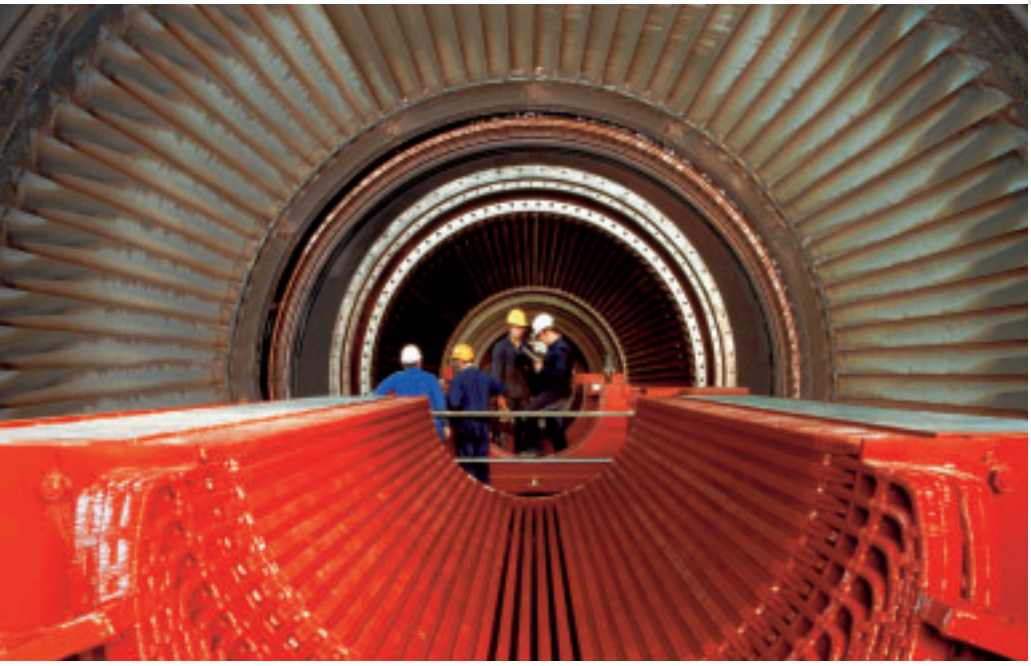
Another vital issue is to determine whether the gear shafts are to be arranged horizontally, vertically, or inclined. Do the shafts change position during operation? Lubrication methods and sealing are highly dependent on the position of the shafts. Are the shafts arranged on one level? This issue is important with regard to bearing load. Another issue: Are hollow shafts or solid shafts employed? Are the bearings supported within the housing or other shafts? This issue affects load on the main shaft.

The issue concerning shaft guidance

The selection of the bearing type, design and arrangement are issues that highly dependent on the standards and operational requirements which the shaft guiding function needs to fulfil. It is important to determine the effects that internal clearance and bearing stiffness may have on tooth engagement. In addition, it has to be determined to which degree axial shift of the shaft is permissible or whether shaft guidance is to be performed free of clearance.

The issue concerning strength of the connecting parts

Does deformation of the housing need to be taken into consideration with a certain bearing seat? Does misalignment at the bearing seats caused by shaft bending affect performance? Such issues can cause distinct additional loads within the bearings and therefore need to be fully understood.



The issue concerning friction

One issue is to determine whether specific friction performance is required to maintain accurate motion. Another other issue is to determine whether support is to be provided for a special gear that requires a low level of heat generation during operation.

The issue concerning bearing life

This issue is quite simple: What are the actual requirements for bearing life? This is driven by the area of application intended for gear operation. If proven and historically reliable calculation approaches for determining bearing life are applicable, dimensioning can be based on standard values. If such data is not available, however, more complex calculations for determining bearing life need to be performed.

The issue concerning safe static capacity

It is important to analyse whether certain operating routines require particular focus on safe static bearing operation, e.g. if the bearing is employed in excavators which have to cope with sudden, strong impacts. Significant plastic deformation has to be minimised to prevent premature damage and to guarantee smooth operation.

The issue concerning environmental conditions

This is a complex issue. Environmental conditions, i.e. whether the machine has to operate in a roofed building or whether it is exposed to dust, sand, strong insolation, high humidity or rain, all affect lubrication, selection of the bearing type, sealing and fits. Are there any aggressive agents? What is the ambient temperature? Is the bearing exposed to separate heating or cooling? Do other machines cause vibrations when the gear is in standstill operating mode?

The issue concerning lubrication

It needs to be determined whether there are certain conditions stipulated for lubrication of the rolling bearings or if oil lubrication is required in individual cases. Is centralised oil lubrication feasible for all bearing seats? Does discharge of lubricant (even in very small quantities) affect operation of the plant or the overall production process?

The issue concerning assembly

It is vital to understand whether mass production is planned or whether products are to be individually hand built. As a rule rolling bearings made to bespoke designs need to be assembled with the help of special gauges. Of course, costs for such devices are more likely to amortise in series production. However, it is not only essential to determine the complexity of bearing design for initial assembly. If the gears are to be disassembled at regular intervals due to maintenance, easy handling is highly dependent on assembling and disassembling of the bearing.

The issue concerning economy

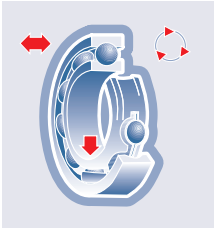
Is increased complexity of bearing design justifiable in terms for the benefit of increased bearing performance and operational reliability? And above all, it needs to be determined whether increased costs for the bearing are acceptable in view of easier handling during maintenance.

Vital features affecting performance

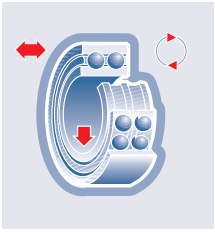
All elements of a machine, for example, components of a wind generator plant have to cope with high stress factors where arduous environmental conditions prevail. Maximum reliability is required while maintenance is to be reduced to a minimum. We have learned from experience that fatigue life of a gear, moreover fatigue life of the total plant is to a high degree dependent on the right selection of bearing type, i.e. from selecting particular bearing types. This decision has to be taken prior to calculation and design of the bearing.

The right selection makes the difference

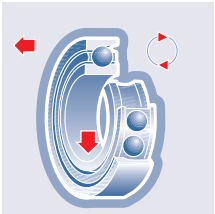
Of course, this preview can only deal with the most important, i.e. basic bearing types, without considering further important parameters, such as size, internal clearance, cage material and design. Our product range gives an insight to the scale of the application spectrum of our products: You can select from more than 35,000 different types of ball bearings and roller bearings, which fulfil practically any requirement on part of engineers from all branches of industry and for all sorts of applications. Yet in our global technology network, NSK engineers keep working on new developments to implement customised applications promptly and efficiently.



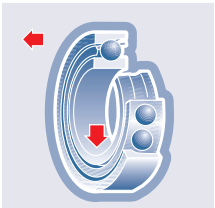
Single-Row Ball Bearings
Suitable for small and average radial loads and minor axial loads in both directions.
Extremely high speed possible.
Excellent noise performance.
Also available in pre-lubricated sealed versions.



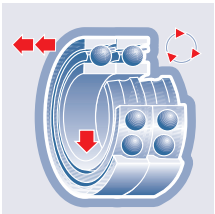
Double-Row Ball Bearings
Suitable for average radial loads and minor axial loads in both directions.
Suitable for average speed.
Sensitive to misalignment.



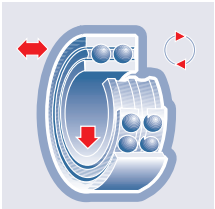
Maximum Type Ball Bearing
Only suitable for medium radial loads and small axial loads in one direction.
High speed is possible.
Separable.



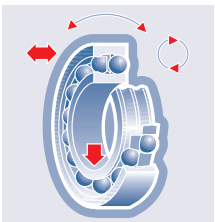
Single-Row Angular Contact Ball Bearings
Suitable for average radial loads and average axial loads in one direction.
High speed is possible. Certain design versions are also suitable for ultra-high speed.



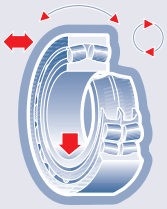
Angular Contact Ball Bearings, single row, in pairs
Suitable for high radial load and high axial load.
Depending on arrangement axial loads are possible in one or two directions.
Suitable for high speed. Certain design versions are also suitable for ultra-high speed.



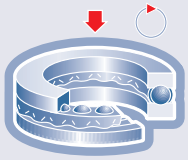
Double-Row Angular Contact Ball Bearings
Suitable for average radial loads and minor to average axial load in both directions.
Average to high speed possible.
Sensitive to misalignment.



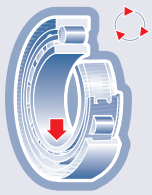
Spherical Roller Bearing
Suitable for very high radial loads.
Axial load in both directions possible.
Average speed possible.
Can take small degrees of misalignment.
Mounting with adaptor sleeve possible.



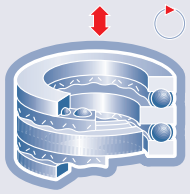
Self Aligning Ball Bearing
Suitable for average radial loads and minor axial load in both directions.
Average and high speed possible.
Can take small degrees of misalignment.
Mounting with adaptor sleeve possible.



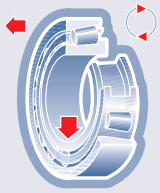
Thrust Deep Groove Ball Bearing
Suitable for average axial load in one direction.
Radial load is not permissible.
Suitable for lower speed.
Minimum axial load required
Separable.



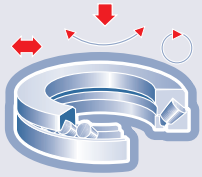
Cylindrical Roller Bearing
Suitable for high radial load.
Depending on bearing type, axial loads in one or two directions are also possible.
Well suitable for high speed.
Normally separable.



Thrust Deep Groove Ball Bearing - accommodating loads in two directions
Average axial load in both directions possible.
Suitable for low speed.
Minimum axial load required.
Separable.



Tapered Roller Bearing
Suitable for high radial load and axial load in one direction. When arranged in pairs axial load in both directions possible.
Suitable for average speed.
Separable.



Thrust Spherical Roller Bearing
Suitable for very high axial load in one direction.
Radial load only permissible up to 55 % of axial load.
Only suitable for lower speed.
Accommodates misalignment.
Oil lubrication is recommended.
Separable.

Vital features affecting gear performance

- ⟵ Only one direction.
- ⟷ Both directions.
- ●●●● Very well suitable.
- ●●● Well suitable
- ●● Suitable under certain conditions
- ● Poorly suitable
- × Not suitable
- ✻ Applicable
- ✻ Applicable, but axial extension and axially adjustable features need to be guaranteed

1 Single row deep groove ball bearing
2 Separable ball bearing
3 Single row angular contact ball bearing
4 Double row angular contact ball bearing
5 Duplex angular contact ball bearing
6 Four-point bearing
7 Spherical roller bearing
8 Cylindrical roller bearing
9 Double row cylindrical roller bearing
10 Cylindrical roller bearing with single direction rib
11 Cylindrical roller bearing with L-shaped thrust collar
12 Needle roller bearing
13 Tapered roller bearing
14 Two row or multi row tapered roller bearing
15 Spherical roller bearing
16 Thrust deep groove ball bearing
17 Thrust deep groove ball bearing with adjustable washer
18 Angular contact thrust ball bearing – accommodating loads in both directions
19 Thrust cylindrical roller bearing
20 Thrust tapered roller bearing
21 Thrust spherical roller bearing

Bearing types/features	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Radial loads	●●	●	●●●	●●●	●●●	●	●●	●●●	●●●●	●●●	●●●	●●●	●●●	●●●●	●●●●	×	×	×	×	×	●
Axial loads	⟷ ●●	⟵ ●	⟵ ●●●	⟵ ●●●	⟵ ●●●	⟵ ●●●	⟷ ●	×	×	⟵ ●●	●●	×	⟵ ●●●	⟵ ●●●	⟷ ●●	⟵ ●●●	⟵ ●●●	⟷ ●●●	⟷ ●●●●	⟷ ●●●●	⟵ ●●●●
Combined loads	●●	●	●●●	●●●	●●●	●●	●	×	×	●●	●●	×	●●●	●●●●	●●●	×	×	×	×	×	●
High speed	●●●●	●●●	●●●●	●●	●●●	●●●	●●●	●●●●	●●●	●●●	●●●	●●●	●●	●●	●●	×	×	●●	●	●	●
High accuracy	●●●●		●●●●		●●●●	●●●		●●●●	●●●●				●●●			●●●		●●●●			
Low torque	●●●●							●●●													
Strength					●●●			●●●	●●●●	●●●	●●●	●●●	●●●	●●●●				●●●	●●●●	●●●●	
Angle alignment	●●●	●	●	●	●	●	●●●●	●●	●	●●	●●	●	●●	●	●●●●	×	●●●●	×	×	×	●●●●
Provides self-aligning features							✻								✻		✻				✻
Thrust bearing		✻				✻		✻	✻	✻	✻	✻	✻	✻		✻	✻	✻	✻	✻	✻
Floating bearing	✻			✻	✻	✻	✻				✻			✻	✻						
Free-end bearing	✻			✻	✻	✻	✻	✻	✻			✻		✻	✻						
Taper pipe bore on the inner ring							✻		✻						✻						
Comments		A	B		C	D		E	F	G	H		I	J					K		L

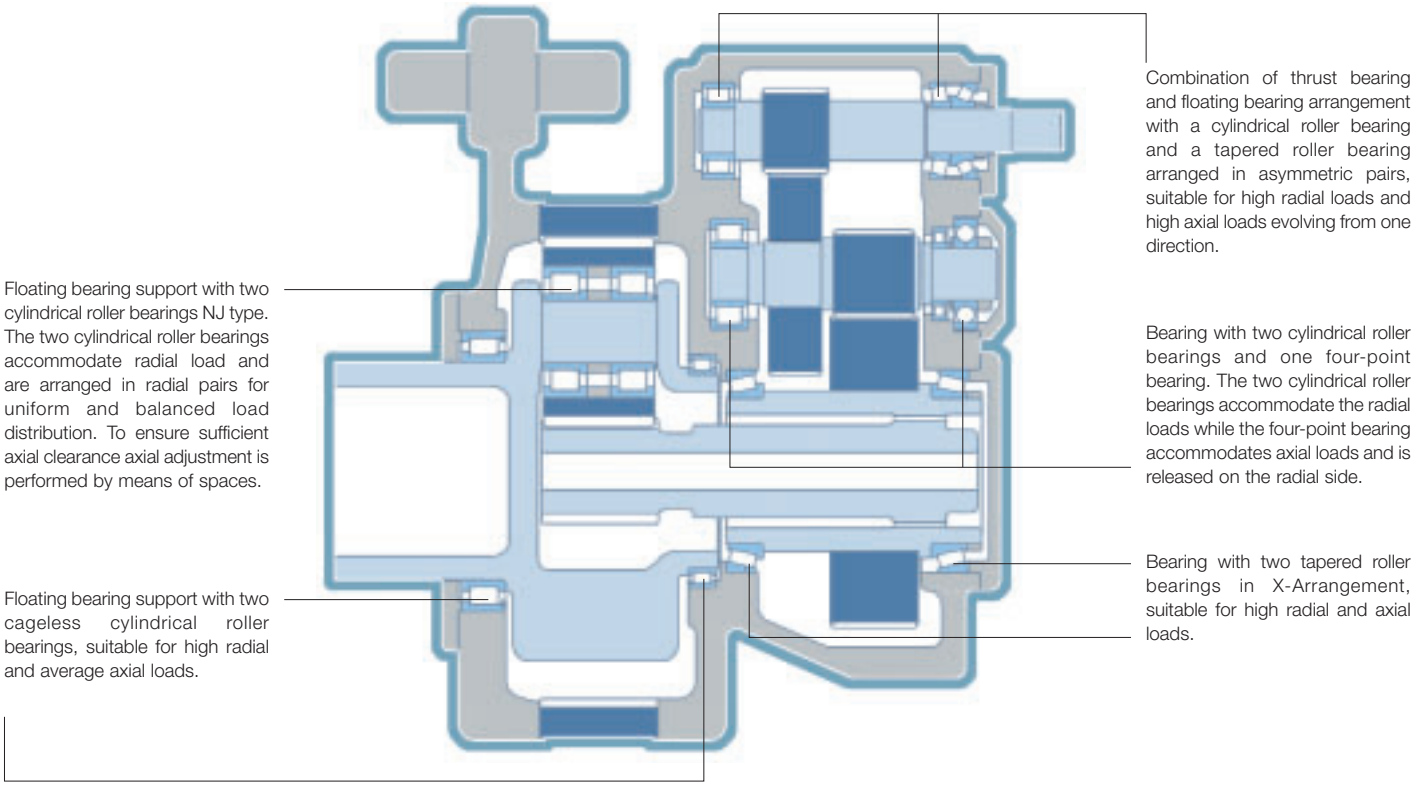
A In general two bearings are mounted face-to-face
B Contact angle of 15°, 25°, 30° and 40°. In general two bearings are mounted face-to-face.
C Combination of DF and DT-bearings is feasible, however, not employed at their rear (free) end. Desired clearance needs to be adjusted.
D Contact angle of 35°
E Including N-Type
F Including NNU-Type
G Including NF-Type
H Including NUP-Type
I In general two bearings are mounted face-to-face. Desired clearance needs to be adjusted.
J KH and KV-Types are also available, however, not suitable to be employed at their rear (free) end.
K Including needle thrust roller bearing
L Oil lubrication recommended

We hold much in store for you

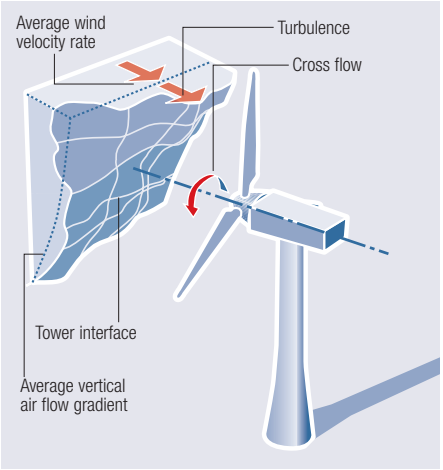
A rotating gear shaft requires at least two bearings for optimum support and guidance with regard to the stationary element. NSK rolling bearings do not only accommodate the respective radial and axial loads, but they also ensure accommodation of shaft expansion. A fundamental issue concerns the arrangement of a thrust (fixed) bearing and floating bearing and any necessary set-up adjustments.

Support by means of fixed and floating bearings

The position of the thrust bearing on the shaft and in the housing has to be set in an axial direction, i.e. it needs to guide the shaft axially and it needs to accommodate the axial loads of the gear mesh. Fit variations of bearing positions on the shaft and in the housing, as a result of production tolerances and operating temperatures, are compensated and balanced by the floating bearing. These compensating and balancing features are vital for preventing strain on the bearing. The floating bearing takes the radial loads and accommodates axial movement. The selection of the bearing type employed as thrust bearing is dependent on the axial load levels and the requirements put forward for precise axial guidance of the shaft. Bearing types suitable for accommodating combined stress factors may be employed as thrust bearing. These include deep groove ball bearings, spherical roller bearings as well as double row angular contact ball bearings. Single row angular contact ball bearings mounted in pairs and tapered roller bearings may also serve as fixed bearings, as do thrust bearings that are assembled in combination with a radial bearing.



Cylindrical planet gears in different bearing arrangements



Air Flow Profile of a Wind Generator Plant
Partial wind velocity depends on rate, place and time and results in considerable dynamic load impacts affecting the plant as well as subassemblies including the rolling bearings.

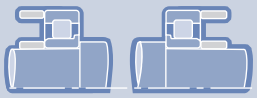
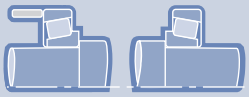
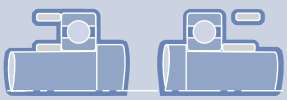
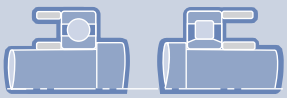
Adjusted bearing support

This arrangement does not provide for a particular thrust bearing. The shaft is guided axially in one direction by each of the two bearings. However, there is the risk of mutual strain impacts with this bearing type. Basically all bearing types, which are in a position to accommodate axial loads in at least one direction, besides accommodating radial loads, can be employed. These including deep groove ball bearings, spherical roller bearings, angular contact ball bearings and tapered roller bearings. If accurate shaft guidance is required as, for example, with pinion support integrating spiral bevel gears, adjusted bearing support is of particular advantage.

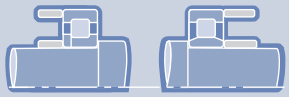
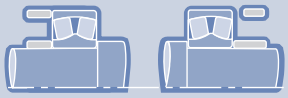
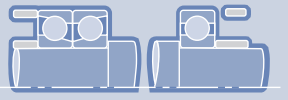
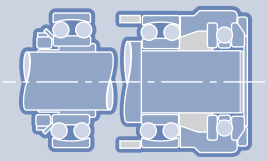
Floating bearing support

The conditions applying to floating bearing support are similar to that of adjusted bearing support. However, axial adjustment of the shaft is feasible to a certain extent. On measuring the extent of axial adjustment, negative thermal conditions are taken into consideration in order to avoid that the bearing is exposed to axial strain impacts. The extent of axial clearance is subject to clearance tolerances. Generally floating bearing support is selected if toothing requires released axial setting or if highly accurate axial shaft guidance is not of particular importance.

Preview of Bearing Arrangements

		Comments	Fields of application
Bearing arrangement - adjusted or floating -		Floating bearing support for average radial loads. Outer rings are frequently adjusted by means of springs.	Small electric motors and gears.
		Floating bearing support for high radial loads. Force fit for inner and outer ring feasible. Mutual strain on the inner ring rib needs to be avoided.	Small and medium-sized gears, vibration engines.
		Standard bearing for high loads. Well suitable for short distance between the bearings, because the distance between the bearings increases due to O-Arrangement. Adjusting internal clearance is feasible during assembly.	Bevel pinion with integrated shaft in gears, wheel bearings in vehicles.
		X-Arrangement is selected if force fit for inner ring is required. Easy handling of assembly and positioning. X-Arrangement reduces bearing support clearance. Adjusting bearing clearance is required on assembly.	Small and medium-sized gears.
		Suitable for high speed and average radial and axial loads. If certain design versions are employed, preload (e.g. by means of spring support) is possible. Adjustment of bearing clearance and preload is required on assembly.	Small gears, machine tools.
Combination of thrust bearing and floating bearing arrangement		This bearing type is frequently employed if load on the bearing seats is uniform and balanced. Lower axial loads. To reduce noise thrust bearing is often adjusted by means of springs.	Small electric motors, gears.
		This arrangement is frequently employed. Loads on the bearing seats vary. Lower axial loads.	Medium-sized electric motors, ventilators, gears.

Combination of thrust bearing and floating bearing arrangement

	Comments	Fields of application
	Intended for higher radial loads and lower axial loads. Due to the disassembly feature of the cylindrical roller bearings, these are well suitable for assembly requiring a force fit of the inner ring and outer ring.	Gears, traction motors.
	Intended for high radial loads of both bearing seats with average axial loads. Not sensitive to misalignment.	Gears, roller conveyors, paper machines.
	Intended for high radial and average axial loads at high speed. (To avoid radial load of the deep groove ball bearing, which is employed for the function of an axial bearing the housing above the deep groove ball bearing needs to be released).	Gears, ventilators.
	Intended for high radial and average axial loads.	Gears, paper machines.
	Intended for high radial and axial loads. X-Arrangement of the tapered roller bearing allows misalignment to a slightly higher extend than does O-Arrangement.	Pinion shafts in gears.
	Intended for average axial loads. The angular contact ball bearings need to be employed in universal combination (BG) or mated design. Often a cylindrical roller bearing is employed for the function of the radial bearing.	Fields of application with high requirements on axial guidance.
	Bearing employed in the event of misalignment and high axial loads in one direction. The combination of spherical roller bearings and thrust spherical roller bearings is also often employed. It needs to be observed that the centres of the thrust bearing are in conformity. Axial minimum load is to be observed. Also well suitable for vertical assembly (post cranes).	Thrust bearing blocks employed in crafts, post cranes.

The key to the perfect solution

Having selected the bearing type, the next step is to determine the required bearing size and bearing design to come to a solution that considers all aspects for high capacity and efficient design. One criterion is of paramount significance: estimating bearing life. For a long time experts have been aware of the fact that a host of features regarding stress factors and influencing magnitudes are to be considered for providing a reliable estimation. NSK's latest developments include optimised methods and calculation procedures that increase accuracy for estimating bearing life.

A host of features to be considered

Numerous magnitudes and influencing features are to be considered when determining bearing life. In this context the individual area of application, the type and bearing load capacity as well as speed are just as important as the design surrounding the bearing, i.e. the properties of the shaft and the housing, their material and tolerances. Outer sealing, lubrication method, operating temperature and ambient temperature All these forces, which affect the gear system, need to be taken into consideration, calculated and assessed. Further influencing factors are, for example, load evolving from coupling, cardan shafts and belt drives, and loads evolving from the shaft and gears, and many more, all of which are just as important as the environmental conditions prevailing on the site. Briefly put: We are dealing with complex calculations. NSK has developed numerous methods and procedures for assessing and analysing these complex calculation issues.

The conventional calculation methods

Conventional standardised calculation methods for determining bearing life are also referred to as catalogue method. These are stipulated in ISO 281. The parameters involved are: bearing load, speed, load rating and bearing type. The bearing life figures resulting are: L10 or L10h.

Standard conventional methods

$$L_{10} = \left(\frac{C}{P}\right)^p \qquad L_{10h} = \frac{10^6}{n \cdot 60}\left(\frac{C}{P}\right)^p$$

- **C** Dynamic load rating
- **P** Dynamic equivalent load
- **p** Exponent (3 for ball bearing, 10/3 for roller bearing)
- **n** Speed

Modified calculation for bearing life

$$L_{na} = a_1 \cdot a_{DIN} \cdot \left(\frac{C}{P}\right)^p$$

$$L_{na} = a_1 \cdot a_{DIN} \cdot \frac{10^6}{n \cdot 60}\left(\frac{C}{P}\right)^p$$

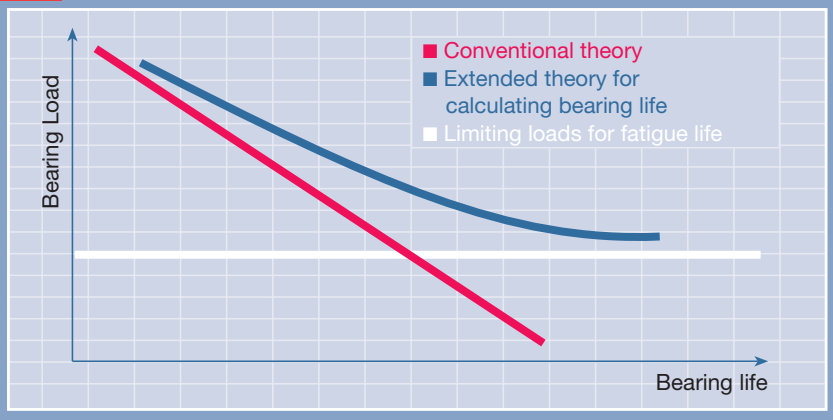
- a_1 Coefficient for anticipated bearing life
- a_{DIN} Coefficient regarding affects of operating conditions

The extended standardised calculations according to ISO 281, supplement 1 and 4, go further and take the limiting loads for fatigue life of the bearing, the lubrication parameter, and the degree of lubrication purity into account and thus provide a more accurate outline of the bearing operating condition and performance. The bearing life figures resulting are: L10a or L10ah. Both are generally approved methods, but as seen before, there is always potential for improvement.

The ABLE-Forecaster

The ABLE-Forecaster (Advanced Bearing Life Equation) is the latest software, which NSK has developed for increased accuracy in estimating bearing life. The standardised calculations according to ISO 281 have been extended: the main difference (and progress) is the fact that this method is based on information resulting from actual applications and tests performed over a period of several decades. In addition, this advanced calculation method, which NSK has developed, considers a great variety of features, including actual environmental conditions, limiting loads for fatigue life, lubrication parameters as well as contamination factors and material.

New: ABLE-Forecaster

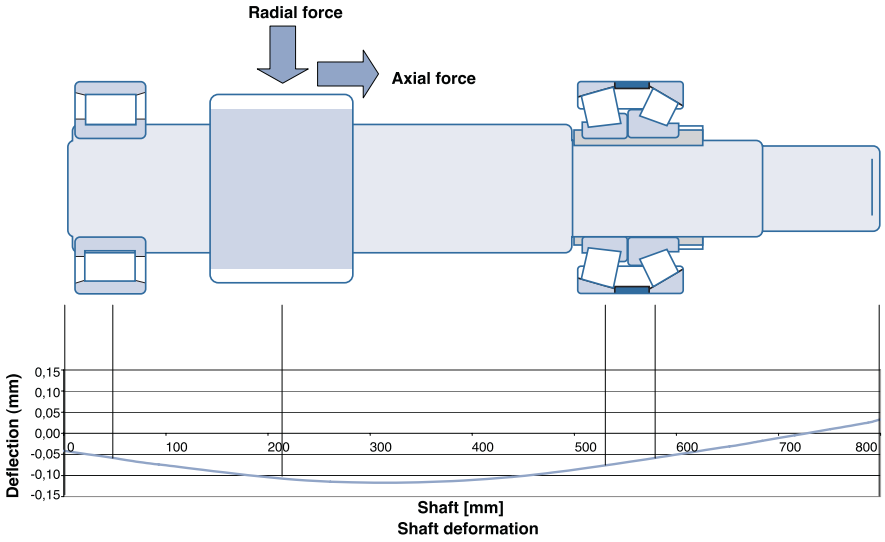


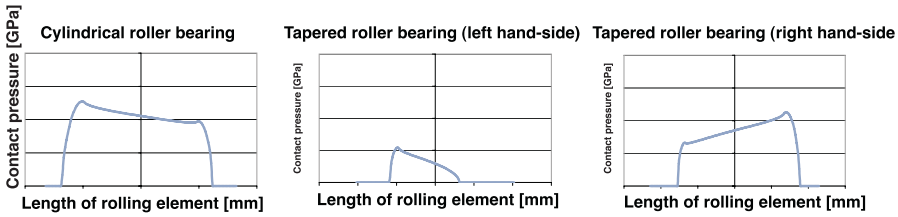
$$L_{NSK} = a_1 \cdot a_{NSK} \cdot L_{10h}$$

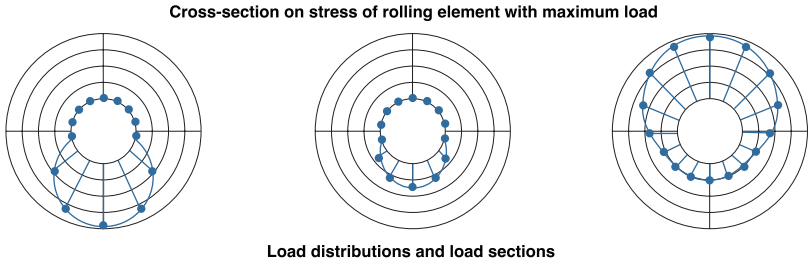
- a_1 Coefficient for anticipated bearing life
- a_{NSK} Coefficient for operating conditions

A further invention: STIFF

STIFF is a programme developed by NSK that considers important parameters such as deformation of the shaft and housing, misalignment, displacement of the bearing itself (and adjacent bearings) as well as internal operating cycles. The conventional methods merely analyse the rolling bearing itself, regardless of other features affecting bearing life. STIFF works from the principle of a bearing-shaft-housing-system. The software is outstanding due to its calculation scope and provides results that allow several analyses within a short period of time. Additionally it eliminates many time intensive tests of special rolling bearings and adjustments with regard to the individual application conditions.





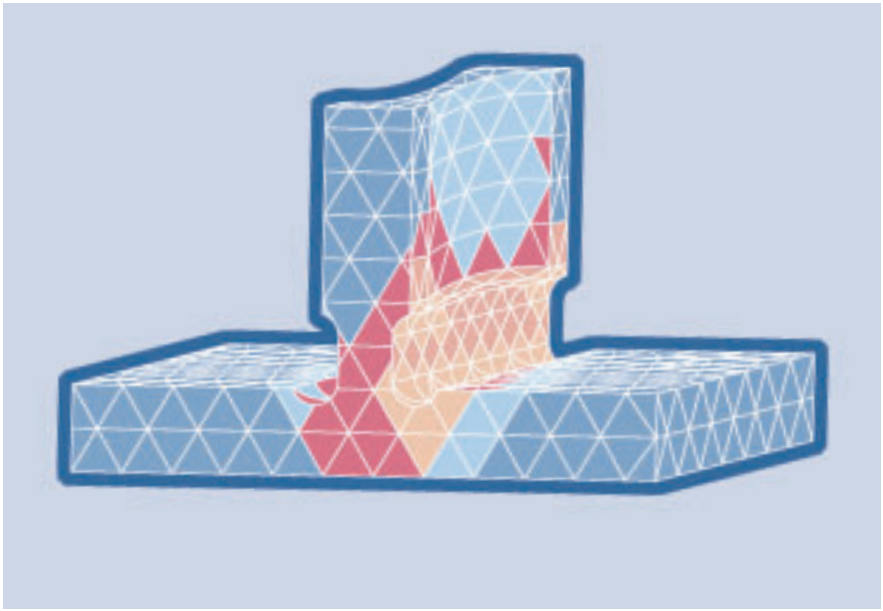


Calculation procedures on estimating bearing life • STIFF-Programme	
Estimating strength	**Analysis of component deformations** ■ Parameter: – Load on components and component deformation – Loads on bearings and bearing deformations resulting thereof
Estimating factors affecting performance	**Analysis of internal friction conditions** ■ Kinematic aspects of the rolling elements ■ Tilt and skew motion of the rolling element ■ Thickness of lubrication film supplied ■ Heat generation and dynamic torque
More accurate estimates on bearing life	**Analysis of internal stress factors of the rolling element** ■ Contact pressure and internal load distribution
Estimating reliability and operational safety	**Wear parameter** ■ PV-Value (resulting from contact potential and peripheral velocity; this value gives evidence of potential states of friction and wear)

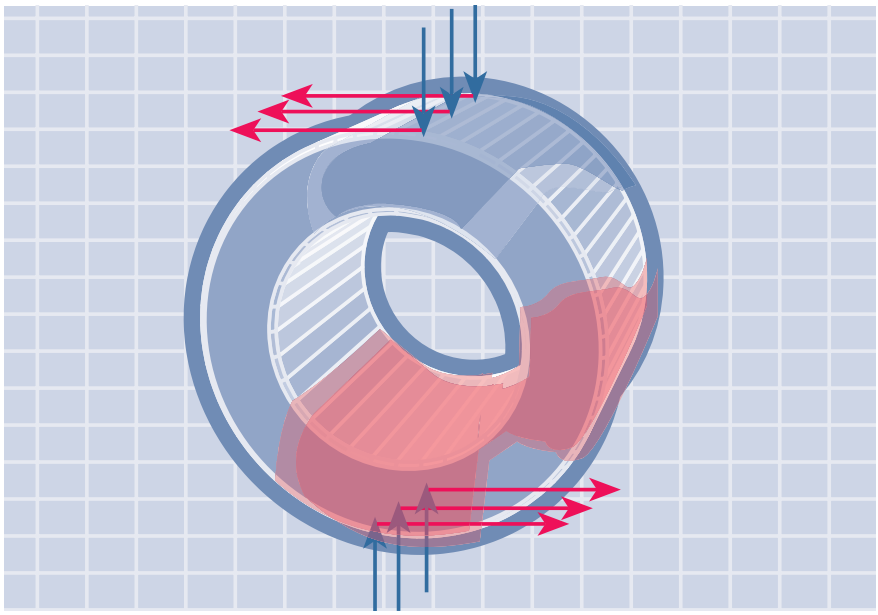
Even more tools – developed on the basis of experience and skills

Another example for a calculation method employed by NSK is FEM Analysis. The Finite Element analysis examines the distribution of stress factors within the bearing and its components and thus provides optimum support for non-standard applications. Frequency analysis, on the other hand, examines noise generation of the rolling bearing within the application from which performance and operating characteristics of the bearing system can be understood. Adding to these bespoke calculation capabilities are a host of bearing calculation programmes for speeding up more routine analyses.

Optimised cage design: On the basis of the FEM-Analysis, component parts with stress levels beyond allowable levels can be examined. Such areas can be re-designed enabling stress levels within the bearing to be reduced and thus improve bearing performance.



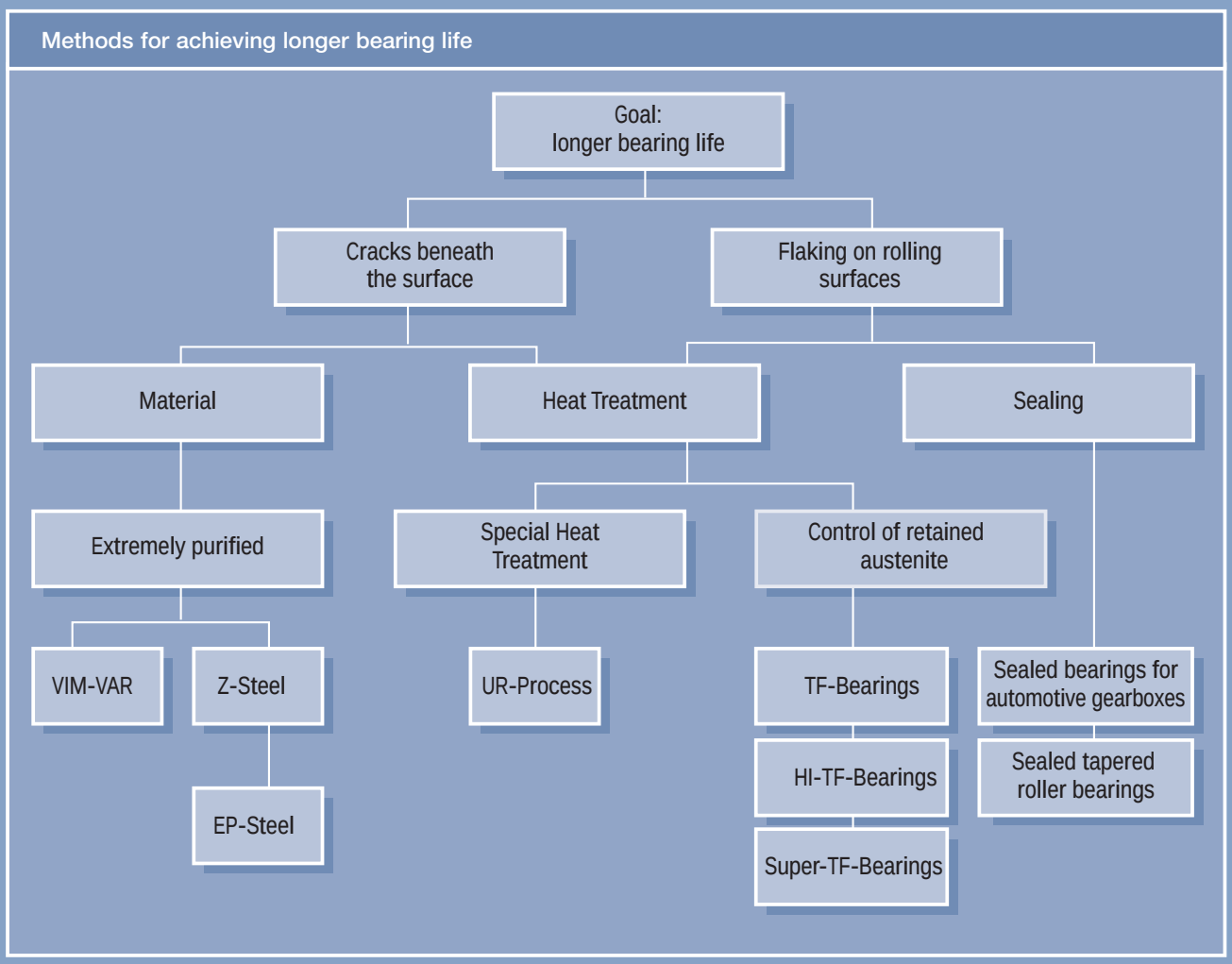
Planet gears are thin-walled machine parts exposed to high stress. On evaluating planet gear deformation, internal geometry aspects of the bearings were analysed and adjusted for uniform and balanced distribution of load. Thus improved bearing life was achieved.



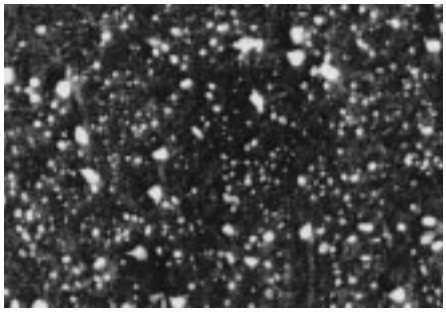
NSK - Absolutely tough

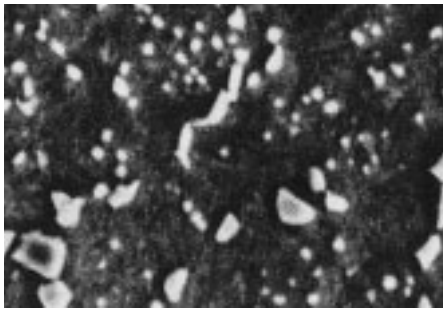
NSK is first when it comes to developing rolling bearings which can cope with high stress factors and severe operating conditions. NSK rolling bearings stand for high reliability, long life and high resistance to wear and seizure. High investments, in particular for basic materials technology research, ensure that our demanding goals are achieved.

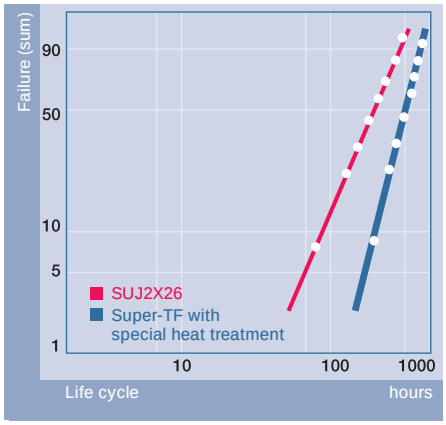
Investing in new methods has paid dividends as many recent achievements reveal: NSK has developed a ground-breaking material that sets new benchmarks, in particular when it comes to operating conditions in contaminated environment or if high stress factors are encountered. The new materials can be employed for a wide range of bearing types.



Distribution and size of carbide and carbonitride particles in Super-TF-Material (left) compared to distribution and size in a standard-material (magnified by 4.000).







Longer bearing life due to the Super-TF material.

Cause and effect

All rolling bearings have a limited fatigue life, which shows as soon as fine cracks develop beneath the surface resulting in flaking on the contact areas of rolling element and rolling surface. The life is highly dependent on the degree of pureness inherent to the steel employed for the rolling bearings. Failure before the end of the calculated bearing life, however, is more frequently caused by flaking formation directly at the contact surfaces, which is due to stress at the rolling surfaces. Contamination of the lubricator caused by metallic particles, sand particles, or improper handling during assembly or maintenance is often the reason for premature failure of the rolling bearing. To fight these causes for failure NSK has now succeeded in developing a new material: Super-TF for rolling bearings operating under high stress conditions. A new material that undergoes a new heat treatment method.

Simply tough: Super-TF

The development process was aimed at improving the properties of the previous TF-material. For this purpose NSK developed a material composition and heat treatment process that ensures even distribution of the carbide particles within the bearing steel while at the same time minimising the size of the particles. In addition, NSK has employed a new method to bond even finer particles of carbides and nitrides in steel – a method that has been patented in Japan and overseas.

Rolling bearings made from Super-TF Material not only have a longer bearing life under contaminated lubrication conditions – about ten times above that of standard material – but their resistance against flaking, wear and thermal stress factors is also superior to the previous TF-material. An impressing price-performance ratio for the client.

Main fields of application

Super-TF technology can be applied in a wide range of bearing types, for example, cylindrical roller bearings, tapered roller bearings, spherical roller bearings, deep groove ball bearings as well as angular contact ball bearings.

So everything runs smoothly

About 40% of damage that rolling bearings suffer prior to the end of estimated bearing life is caused by improper lubrication. Damage becomes obvious in the form of wear, insufficient and uneven lubrication, flaking, seizure, fatigue damage or overheating of the bearings. All are caused by deficient lubrication – too much lubrication is also one of the causes – and all could be avoided if more attention were paid to the individual application demands for lubrication. Optimum separation of the contact surfaces by a lubrication film is not the only function of a lubricant in rolling bearings. Reducing friction, preventing contamination, protection against corrosion and aiding heat transfer, are all important features for applying suitable lubrication of the rolling bearings.

Separating the contact surfaces

To continually meet the requirements of this feature permanently, a straightforward method for specifying the state of lubrication maybe referred to. Based on the theory of elasto-hydrodynamic lubrication, the ratio of actual to required oil viscosity during operation needs to exceed a factor 1. According to ISO 281 nominal bearing life expressly refers to this minimum value. The required viscosity is driven by the operating speed and the rolling element pitch circle diameter.

Oil or grease?

Commonly rolling bearings are lubricated with the same oil as is employed for the gears. A key advantage of oil lubrication is the numerous possibilities to ensure permanent lubrication of all contact points. In this context selective supply and discharge of oil constitutes another advantage. In addition, oil is an effective medium to transfer heat from the contact points and replacing the lubricant is usually straightforward. Grease lubrication on the other hand, contributes to application sealing and can offer lubrication without maintenance.

Lubrication for the purpose of heat reduction

Rolling bearings which operate at high speed run the risk of excessive heat generation due to friction of the bearing and churning of the lubricant. This may result in unacceptable temperature rise of the gearbox components. Heat transfer is thus essential for preventing overheating of the bearing. Various methods are available for this purpose, but one procedure has proven to be particularly effective with respect to large machines employing large rolling bearings, e.g. pressing machines, paper machines, steel processing machines: heat transfer is effected by means of higher lubricant volume supplied under pressure. The actual operating conditions of the gear serve as basis for calculating the lubrication quantity required for sufficient heat transfer.

$$Q_{10} = \frac{0.19 \times 10^{-5}}{T_2 - T_1} \, d \, \mu \, n \, F \, (N)$$

Q	Oil supply (litre/min)
T_1	Oil temperature at inlet (in C°)
T_2	Oil temperature at outlet (in C°)
d	Bearing bore diameter (in mm)
e	Dynamic friction coefficient (see table)
n	Speed (rpm)
F	Radial load on bearing (in N)

Friction coefficient for a variety of bearing types

Bearing type	Friction coefficient μ
Spherical roller bearing	0,0028
Thrust spherical roller bearing	0,0028
Tapered roller bearing	0,0022
Angular contact ball bearing	0,0015
Radial deep groove ball bearing	0,0013
Cylindrical roller bearing	0,0010

Damage caused by lubrication problems

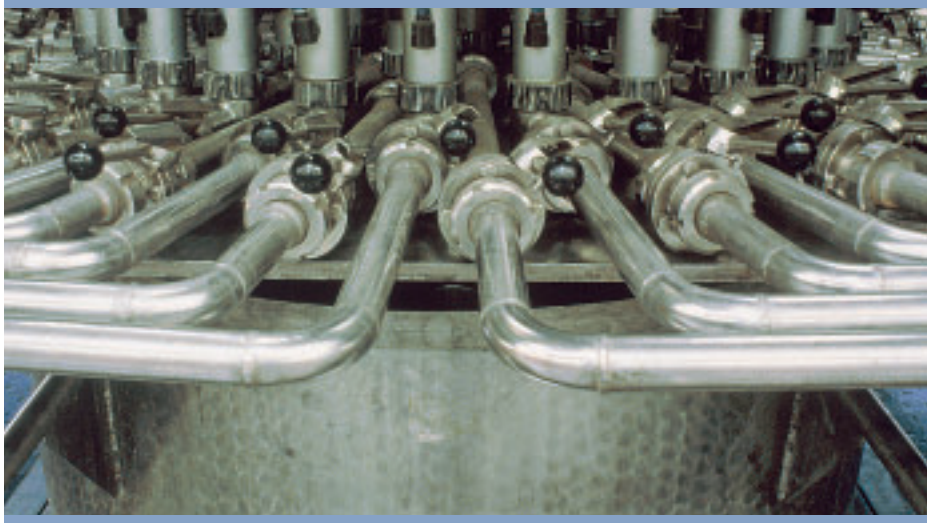
Damage symptom	Cause	Reason
Noise	Insufficient lubrication	In places of component contact a lubrication film is not formed. Lubrication film is insufficient to totally separate components.
	Inappropriate lubrication	Application film too thin due to insufficient viscosity of oil or grease base oil. When grease is employed, the structure of the thickener may have an unfavourable effect (grease component particles cause noise generation).
	Contamination	Foreign particles disrupt lubrication film causing noise generation.
Cage wear	Insufficient lubrication	In places of component contact a lubrication film is not formed. Lubrication film is insufficient to totally separate components.
	Inappropriate lubrication	Insufficient viscosity of oil or grease base oil; lubricant does not contain additives for protection against wear.
Wear at rolling elements, rolling surfaces, rib surfaces	Insufficient lubrication	In places of component contact a lubrication film is not formed. Lubrication film is insufficient to totally separate components. Fretting corrosion from oscillating relative movement.
	Inappropriate lubrication	Insufficient viscosity of oil or grease base oil. Lubricant does not contain additives for protection against wear or EP-Additive (for high load).
	Contamination	Particulate or liquid contaminants with corrosive or abrasive effects.
Fatigue spalling	Insufficient lubrication	In places of component contact a insufficient lubrication film to support high contact stresses. Wear.
	Inappropriate lubrication	Insufficient viscosity of oil or grease base oil. Lubricant pressure-viscosity characteristics insufficient.
	Contamination	Ingress of hard particles resulting in indentations and thus high surface stress. Corrosion damaging contact surfaces.
High temperature rise of bearing, seizure (overheating)	Insufficient lubrication	In places of component contact a lubrication film is not formed. Lubrication film is insufficient to totally separate components.
	Inappropriate lubrication	High friction and temperature rise due to sporadic component contact.
	Contamination	High lubrication friction with average and high speed, in particular on sudden lubrication supply.
Degraded lubricant (discoloured, solidified, reduced lubrication performance)	Insufficient lubrication	Operating temperature exceeds temperature permissible for lubricant (causing breakdown and residue).
	Inappropriate lubrication	Re-lubrication intervals or lubricant change period too long.

Monitoring through lubrication

Monitored parameters	Method	Detectable or avoidable damage type
Lubrication	Analysis (water content, contamination content, pH, saponification number)	Fatigue wear, wear, corrosion, inappropriate lubrication.
Lubrication system	Oil pressure, oil condition, oil flow and oil temperature.	Hot running, wear.

Proper dimensioning

If the inner ring of a rolling bearing element is fitted to the shaft, without employing further attachment devises, there is often the risk of damaging peripheral slippage between the inner ring and the shaft. This slippage, commonly referred to as creep, may cause particles to separate from the surfaces resulting in wear, which in turn, causes considerable damage to the shaft. Particles from metallic abrasion can enter into the inside of the bearing and damage the rolling surfaces. In addition, metallic abrasion can cause excessive temperature rise and vibration.
It is important to prevent creep by providing a sufficient and permanent seat for safe attachment of the ring – either on the shaft or in the housing. However, an interference fit is not always required for rings where the load does not move with respect to it. Depending on the field of application a clearance fit may be employed for either the inner or outer ring. For example, if the bearing needs to move in the axial direction for the purpose of assembly, disassembly or to accommodate thermal expansion. In this case lubrication or other suitable procedures need to be considered to avoid damage at the contact points caused by creeping.



Procedures for perfect fit selection

To calculate the proper fit for the bearing seating, it is important to consider the bearing load. At the load application point the inner ring of the bearing undergoes radial compression while opposite to this point the ring expands. This effectively reduces the component interference. The method shown in Equation method 1 may be employed for calculating fit reduction. In practice, the actual interference level selected should always exceed the result from Equation 1.

Equation method 1

$$\Delta d_F \geqslant 0.08 \sqrt{\frac{d}{B}}\, F \times 10^{-3}\ (N)$$

Δd_F	Required Interference fit
d	Bore diameter (mm)
B	Width of inner ring (mm)
F	Radial load (N)

Equation method 2

$$\Delta d_F \geqslant 0.02 \frac{F_1}{B} 10^{-3}\ (N)$$

Δd_F	Required Interference fit
B	Width of inner ring (mm)
F	Radial load

Calculation on the basis of Equation 1 is sufficient for comparatively low loads, expected in most areas of application. If higher loads are expected, however, Equation 2 should serve as basis for calculation.

Fits for rolling bearings in housings – Recommendations

Load regime			Examples	Tolerance for housing bores	Axial adjustment of the outer ring	Comments
Solid housings	Rotating outer ring load	High loads on bearing in thin-walled housings or high impact loads	Wheelset bearings in automobiles (rolling bearing), blade wheels employed in cranes	P7	Not feasible	—
		Normal or high loads	Wheelset bearings in automobiles (ball bearings), vibration screens	N7		
		Low or variable loads	Rollers employed in conveyer belts, crane sheaves, tension rollers	M7		
	Rotating inner ring load	High impact loads	Train engines			
		Normal or high loads	Pumps, crankshafts, main bearings in medium-sized and large engines	K7	Generally not feasible	In case that axial adjustment is not required
Solid and split housings		Normal or low loads		JS7 (J7)	Feasible	Axial adjustment of the outer ring is required
	Rotating inner ring load	Loads of all kind	General fields of application, railroad axes	H7	Can be easily performed	—
		Normal or high loads	Bearing housings	H8		

Comments: 1. This table is applicable for housings made of cast-iron or steel. Housings made from light alloy generally require heavier fits than stated in this table.

Fits for rolling bearings and housings – Recommendations

Ratio of load			Examples	Tolerances for housing bores	Axial adjustment of the outer ring	Comments
Solid and split housings	Rotating outer ring load	High temperature rise of the inner ring caused by the shaft	Paper dryer	G7	Can be easily performed	—
Solid housing		Accurate operating routine/performance desired for normal and low loads	Ball bearings employed at the rear end for grinding spindles, free-end bearing for ultra-high speed centrifugal compressors	JS6 (J6)	Feasible	On high loads a fit that is tighter than K may be required. If high true running accuracy is required, the tolerances of the fit should be reduced.
	Load direction not determined		Ball bearings employed at the face for grinding spindles, fixed-end bearings for ultra-high speed centrifugal compressors	K6	Generally feasible	
	Rotating inner ring load	Accurate operating routine/performance and high strength with variable loads	Cylindrical roller bearings for main spindles in machine tools	M6 or N6	Not feasible	
		Minimum noise level required	Electrical household appliances	H6	Can be easily performed	

Fits for rolling bearings and shafts – Recommendations

Ratio of load		Examples	Shaft diameter (mm)			Shaft tolerance	Comments
			Ball bearing	Cylindrical roller bearings tapered roller bearing	Spherical roller bearing		
Radial bearings with tapered bores							
Rotating outer ring load	Easy axial movement of the inner ring on shaft is desired	Wheels on rigid wheel shafts	All shaft diameters			g6	Employ g5 and h5 if high accuracy is required. With large bearings f6 can be employed for easy axial movement.
	Easy axial movement of the inner ring on shaft is not required	Crane sheaves, tension roller				h6	
Load on rotating inner ring, the direction of load is not determined	Low and variable loads (<0,06 Cr)	Electrical household appliances, pumps, ventilators, transportation vehicles, high-accuracy machines, machine tools	< 18	–	–	js5	—
			18 – 100	< 40	–	js6 (j6)	
			100 – 200	40 – 140	–	k6	
			–	140 – 200	–	m6	
	Normal loads (0,06 to 0,13 Cr)	General fields of application for bearings, medium-sized and large engines, turbines, pumps, main bearing in engines, gears, wood working machines	< 18	–	–	js5 (j5 – 6)	k6 and m6 can be employed for single-row tapered roller bearings and single-row angular contact ball bearings – instead of k5 and m5.
			18 – 100	< 40	< 40	k5–6	
			100 – 140	40 – 100	40 – 65	m5–6	
			140 – 200	100 – 140	65 – 100	m6	
			200 – 280	140 – 200	100 – 140	n6	
			–	200 – 400	140 – 280	p6	
			–	–	280 – 500	r6	
			–	–	over 500	r7	

Fits for rolling bearings and shafts – Recommendations

Ratio of load		Examples	Shaft diameter (mm)			Shaft tolerance	Comments
			Ball bearing	Cylindrical roller bearings tapered roller bearing	Spherical roller bearing		
Rotating inner ring load or direction of load not determined	High loads or impact loads (> 0,13 Cr)	Wheels on rigid wheel shafts	–	50 – 140	50 – 100	n6	Internal clearance needs to be higher than C0
			–	140 – 200	100 – 140	p6	
			–	over 200	140 – 200	r6	
			–		200 – 500	r7	
Only radial loads			All shaft diameters			js6 (j6)	—
Radial bearings with tapered bores							
All types of load		General fields of application for bearings, railroad axes	All shaft diameters			H9/IT5	IT5 and IT7 imply that shaft deviation from its geometrical structure, e.g. round or cylindrical is not to exceed the respective tolerances of IT5 and IT7.
		General fields of application for bearings, railroad axes				H10/IT7	

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