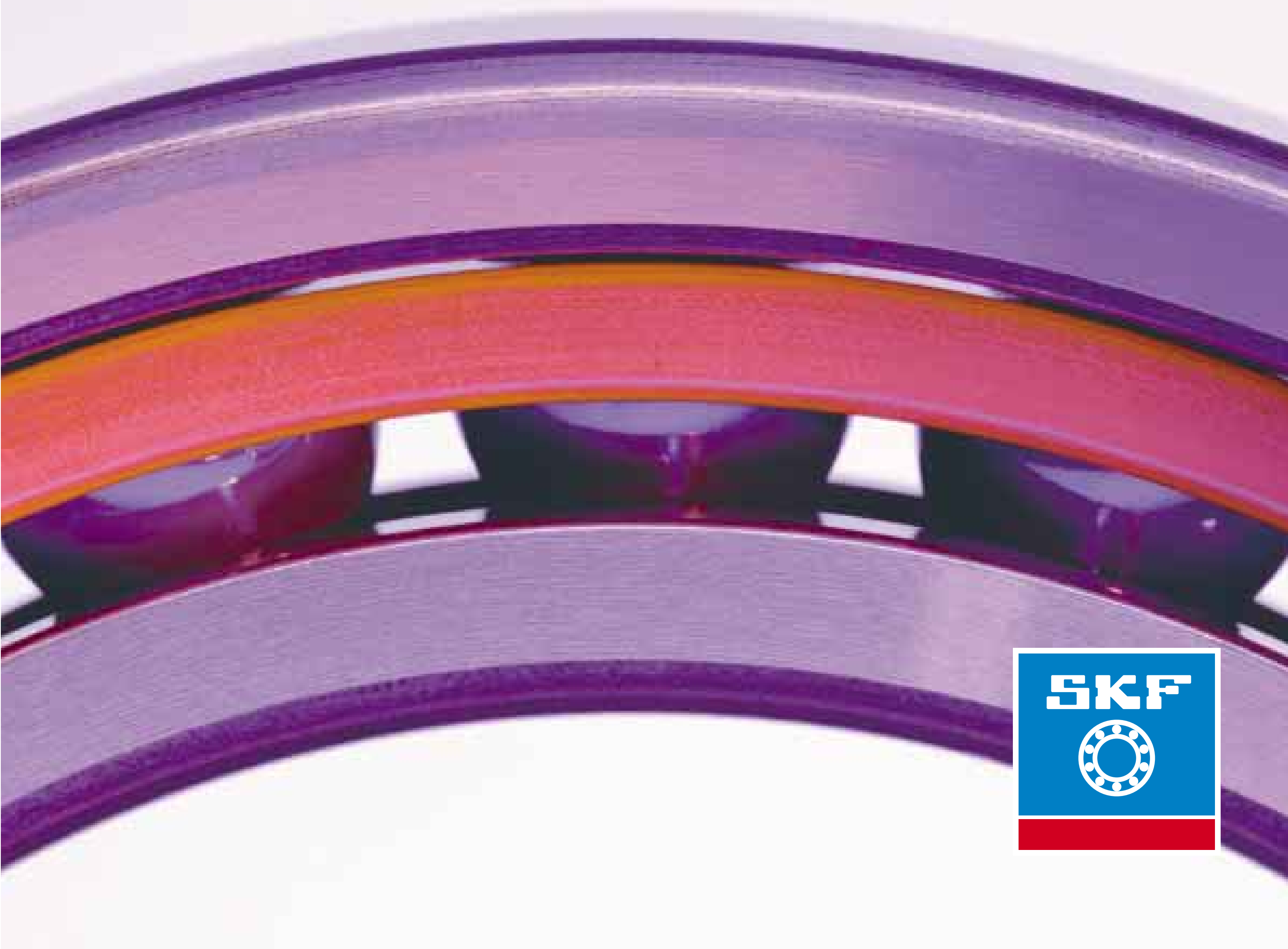
High precision hybrid bearings for increased spindle performance



Made by SKF® stands for excellence. It symbolises our consistent endeavour to achieve total quality in everything we do. For those who use our products, "Made by SKF" implies three main benefits.

Reliability – thanks to modern, efficient products, based on our worldwide application know-how, optimised materials, forward-looking designs and the most advanced production techniques.

Cost effectiveness – resulting from the favourable ratio between our product quality plus service facilities, and the purchase price of the product.

Market lead – which you can achieve by taking advantage of our products and services. Increased operating time and reduced down-time, as well as improved output and product quality are the key to a successful partnership.

Contents

Why hybrid bearings add performance to the spindle

Even though rolling bearings are also known as antifriction bearings, they still have a certain amount of friction in operation.

Low friction in all moving parts is one of the keys to good spindle performance. The hybrid angular contact ball bearing with steel rings and ceramic balls is a recent development and represents a high-performance bearing for machine tool spindles. The bearing provides improved performance in all major respects. And the benefits to machine tool productivity are as many as the bearings.

- Last four to six times longer than conventional high precision spindle bearings.
- Make it possible to accelerate and retard the spindle to an extent unachievable with bearings having steel balls.
- Extremely high speeds and accuracy.
- The lubrication will cause fewer problems and so will vibrations.

All these properties are the result of a significant reduction in friction. And SKF is pledged to a never-ending fight against friction.

Top grade bearings for a wide range of general industrial applications
The high precision hybrid angular contact ball bearings for machine tool spindles are not the only hybrid bearings in the SKF range. This range includes hybrid bearings of various designs for applications such as high speed compressors, turbomolecular pumps, racing car wheels, gearboxes, gyroscopes, aircraft engines, and other exacting applications.

Ceramic balls made of silicon nitride add spectacular performance to the machine tool spindle

How reduced friction enhances your competitive strength

The lower friction of the hybrid bearings increases productivity. That is the simple summation of the superior performance achieved by using hybrid bearings in your machine tools. An additional benefit is that the hybrid bearings also upgrade the working environment

Lower friction increases the speed capability
In the laboratories of SKF, also in service at customers and in-house production, an increase of speed capability up to 20 % has been achieved by using standard hybrid bearings instead of all-steel bearings. By using specially designed hybrid bearings the spindle speed can be increased by up to 60 %.

The reason for this is the better kinematic and tribological properties of the ceramic balls. The smoother surface, the smaller contact ellipse and lower thermal expansion result in lower friction torque (➔ **diagram 1**). It is also possible to increase the speed without influencing the accuracy of the spindle operation.

The almost 60 % lower density compared with steel has the effect of considerably reducing the stresses caused by centrifugal forces (➔ **diagrams 2 and 3**). Balls with a low mass undergo smaller changes of the contact angle when the bearing is under load. The smaller the variation of the angle, the greater the accuracy in the dynamic performance of the bearing. This is an important factor in the high speed capability of these bearings.

Lower friction reduces the operating costs
Because of the reduced demands on lubrication low cost grease lubrication can be adopted where an expensive and sophisticated oil lubrication system was necessary before. The lower friction also results in reduced power loss and consequently energy saving; by 15 to 20 % (➔ **diagram 4**). This is clear and concise evidence of reduced friction.

Furthermore, the hybrid bearings give a considerably stiffer spindle. A machine tool spindle with a high level of stiffness will machine to a certain quality more quickly than a machine with a lower level of stiffness. The higher finishing capability will of course improve productivity through faster output.

Lower friction increases bearing life
A hybrid machine tool spindle bearing lasts much longer than an all-steel bearing of the same size. Up to six times longer (➔ **diagram 5**). This is due to minimal wear on account of built-in tribological advantages and the durable ceramic which does not suffer undue damage from poor lubrication. Such a spindle will also enable a wider operating speed range making it possible to adapt the spindle speed to the operating demands in each specific case.

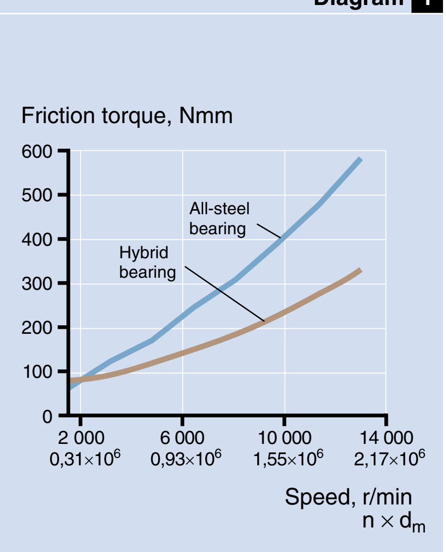
Lower friction increases production quality
The spindle stiffness plays an important role in the total machine stiffness, and thereby also the output quality.

A stiff spindle is achieved by preloading the bearings to a certain degree. The stiffer the bearing, the stiffer the spindle. But the preload will increase when the temperature rises during operation in an all-steel bearing because of thermal expansion.

The ceramic balls are less sensitive to temperature differences. They will, therefore, allow a certain preset preload of the bearing to be maintained without any risk of its alteration due to change of temperature. Also,

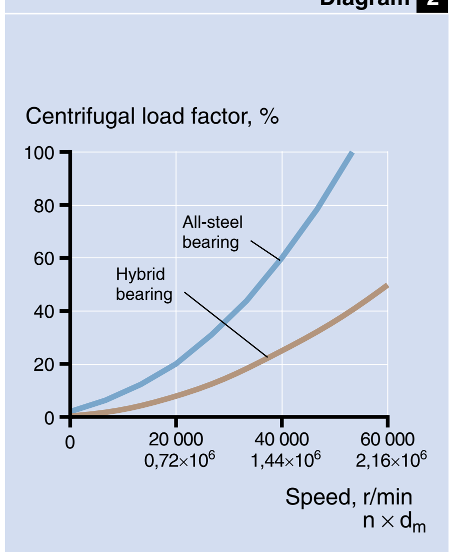
Comparison made between 71926 ACD bearings

Diagram 1



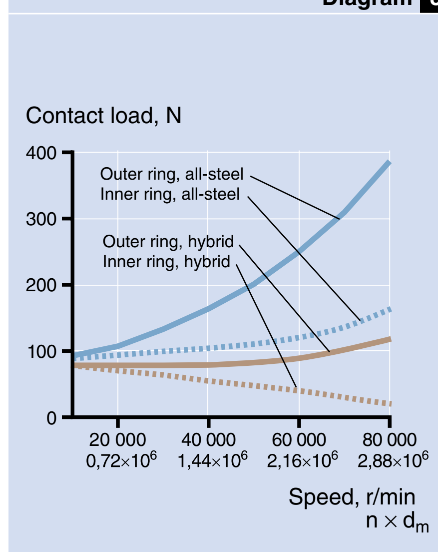
Comparison made between 7005 CC bearings

Diagram 2



Comparison made between 7005 CC bearings

Diagram 3



because of the lower density, the reduction of both centrifugal loads and gyroscopic moments prevents any change in the bearing contact angles. As the alteration of the contact angle is one primary cause of the stiffness reduction under dynamic conditions, significant improvement of the total stiffness is achieved (➔ **diagrams** 6 **and** 7).

Moreover, the very smooth surface of the balls reduces vibration, so adding a further contribution to the higher quality of the production output.

Lower friction improves the working environment

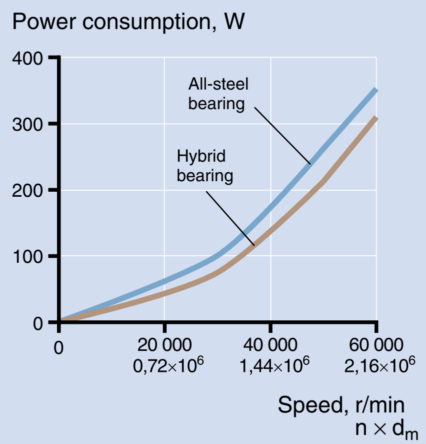
Hybrid bearings can be grease lubricated to a much larger extent than steel ball bearings. Expensive oil lubrication systems which tend to pollute the environment can be replaced by simple grease lubrication even where speed and bearing loads are high. People working in the factory premises will benefit from a cleaner working environment with little or no pollution from oil mist in the air.

Another advantage with the hybrid bearings is the reduced noise level. This is due to the much smaller vibrations generated by the smoother ceramic balls compared with all-steel bearings.

Ultimately there is a significant environmental benefit thanks to the lower friction and the correspondingly reduced energy consumption.

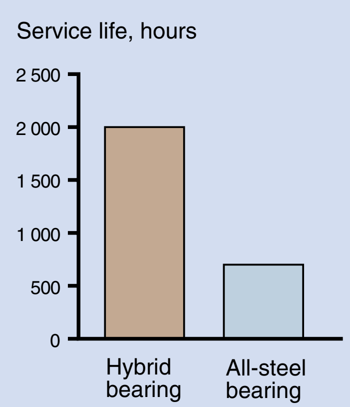
Comparison made between 7005 CC bearings

Diagram 4



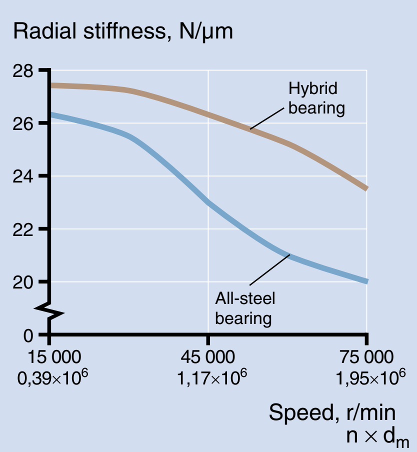
Comparison made between bearings on a grinding machine spindle
7202 CD at one end and 7002 CD at the other

Diagram 5



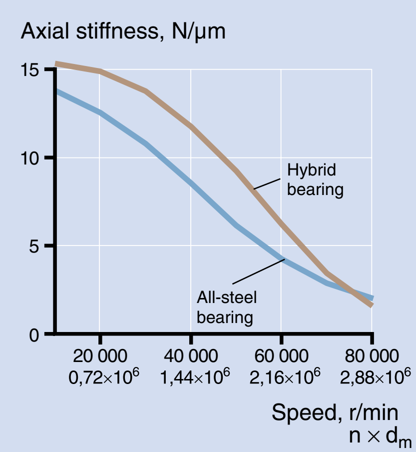
Comparison made between 7003 CC bearings

Diagram 6



Comparison made between 7005 CC bearings

Diagram 7



A wide range of hybrid angular contact ball bearings

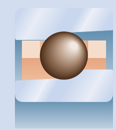
SKF provides a very comprehensive range of precision hybrid angular contact ball bearings for machine tool spindles. The internal design differs in many ways from that of a standard bearing. They reflect the latest state of the art in the field.

The design has been optimised for outstanding speed capability in combination with the highest possible stiffness.

SKF hybrid bearings are designed to meet the most demanding requirements in terms of high precision and productivity. They are identified by the suffix HC, for example 71906 ACD/HC.

Where demands for high precision and productivity are exceptionally high
Innovative internal geometry features have been developed to sustain fully reliable behaviour under very high speed operation. Therefore, the outstanding dynamic performance of the hybrid bearings offers remarkable advantages, including:

- very low friction,
- very low stresses,
- minimised contact angle difference between the outer and inner ring raceway contacts,
- very low heat generation, and
- excellent cage stability.



Series 719 CE bearings are specially designed for applications where the highest possible stiffness is required and speeds are high. These bearings have a low cross section to allow a large spindle diameter. They also have considerably thicker rings compared with other designs. Therefore, bearings of series 719 CE are less sensitive to form errors of a shaft or a housing bore.

SKF provides an exceptionally wide range of high precision hybrid bearings for machine tool spindles. Three bearing dimension series and four designs cover most of the needs of any spindle designer

Wide product range

Single row angular contact ball bearings can carry axial loads in one direction only. Therefore, they are usually mounted with a second bearing to take axial loads acting in the opposite direction. The bearings may be used either singly or in groups of 2, 3 or 4 bearings.

To meet the requirements of modern machine tool applications as fully as possible the SKF high precision hybrid angular contact ball bearings are made in several dimension series and designs (➔ **table** 1). The bearings are non-separable.

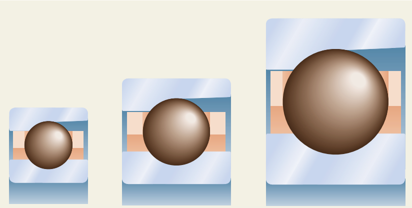
The bearings are delivered individually, but also as “matched bearing sets” (➔ **page 8**) or as “universally paired bearings” (➔ **page 10**). They are specially manufactured so that when mounted in pairs, or sets of three or four a predetermined value of preload is attained.

The bearing sets are used when the load carrying capacity of a single bearing is inadequate, or if axial loads acting in both directions have to be accommodated.

Lightweight cages

All SKF high precision hybrid angular contact ball bearings are fitted with an outer ring centred cage of fabric reinforced phenolic resin. The cages are of a particularly lightweight design in order to keep centrifugal force to a minimum. They are designed to allow free passage of lubricant to the contacts between the balls and the raceways.

Fig 1



A comparison of the cross section clearly shows the differences between the three dimension series

Three bearing series

To meet the requirements of modern machine tool applications as fully as possible the bearings are produced in three dimension series: 719, 70 and 72 (➔ **fig** 1). Each dimension series has its typical characteristics, which make it suitable for particular applications.

The light series 719 and 70 are designed for applications where there is little radial space available. They are also recommended for very high speed applications.

Where spindle stiffness is most important, the ultra-light series 719 allows for larger spindle diameters. Because the cross section is small these bearings incorporate relatively larger numbers of balls than the other dimension series although the balls are small. However, bearing stiffness increases with an increasing number of balls more than it decreases with decreasing ball size. These two factors contribute to high spindle system stiffness as this increases with increasing spindle diameter. The bearing stiffness is more strongly influenced by the number than by the size of the balls.

Range of hybrid bearings

Table 1

ISO Dimension Series	**SKF series designation**	**Contact angle**	**Shaft diameter range** (inclusive)
–	–	degrees	mm
19	719 ACD/HC	25	10 to 140
	719 CD/HC	15	10 to 140
	719 CE/HC	15	60 to 120
10	70 ACD/HC	25	8 to 100
	70 CD/HC	15	8 to 100
	70 CE/HC	15	60 to 100
	70 CC/HC	12	8 to 40
02	72 ACD/HC	25	10 to 60
	72 CD/HC	15	10 to 60

Dimensions

The boundary dimensions of the hybrid bearings are the same as those of the corresponding all-steel bearings. This means that they can replace all-steel bearings in existing applications without any modifications being required. The boundary dimensions conform to ISO 15-1981 and the chamfer dimension limits conform to ISO 582-1979. The chamfer dimensions for the non-thrust side of the outer rings are according to ISO 12044.

Four designs

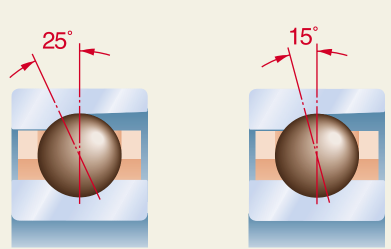
Each dimension series is available in different designs: ACD,CD (➔ **fig** 2), CC and CE (➔ **fig** 3).

The CE design bearings have a larger number of smaller diameter balls compared with the standard CD and ACD designs. Centrifugal forces acting in the contact between the balls and the outer ring raceway are therefore further reduced, as is contact pressure.

Because of the smaller diameter balls of the CE design they occupy less of the bearing cross section. The rings are therefore correspondingly thicker. This means that any form errors of a shaft or a housing bore have less influence on the roundness of the bearing rings. As a result the running accuracy is enhanced.

Bearings having the larger contact angle are recommended for applications where high axial stiffness and high axial load carrying capacity are required.

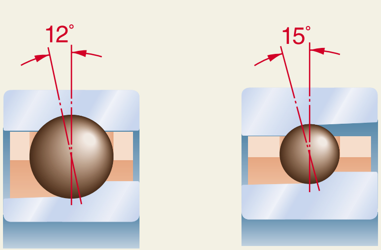
Fig 2



Design ACD with 25° contact angle and ceramic balls of standard size

Design CD with 15° contact angle and ceramic balls of standard size

Fig 3



Design CC with 12° contact angle and ceramic balls of standard size

Design CE with 15° contact angle and small ceramic balls

Matched bearing sets for superior performance

The SKF hybrid high precision angular contact ball bearings are also supplied as complete sets of two, three or four bearings. They are matched in manufacture so that when the bearings are mounted immediately next to each other, the predetermined value of the preload will be obtained, or the load will be evenly distributed. The bore and outside diameters do not differ by more than one third of the permissible diameter tolerance. There is even less difference be-tween the diameters of matched bearings to tolerance class PA9A.

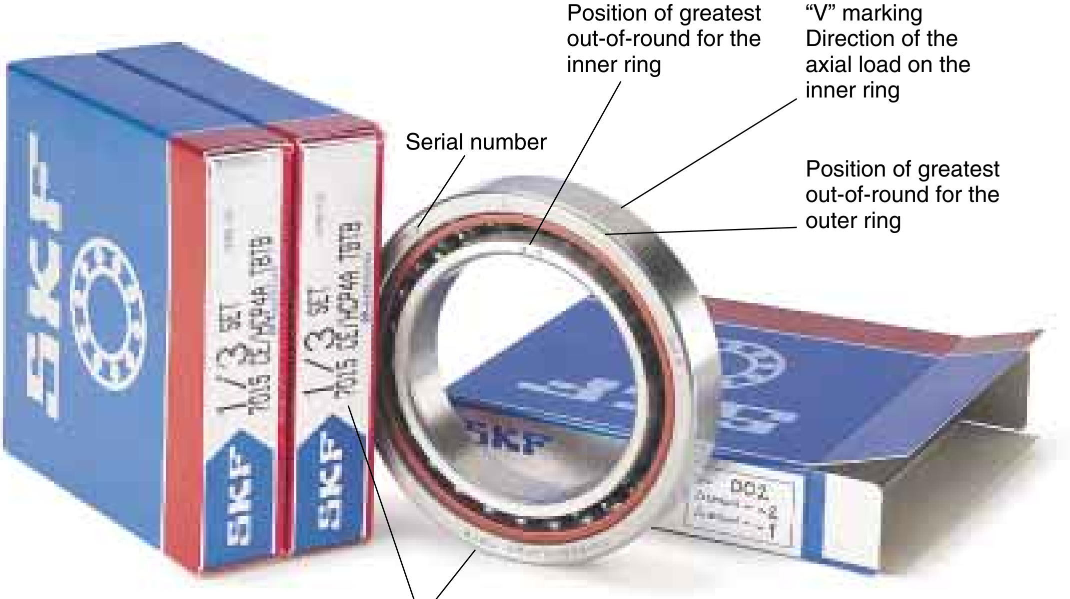
Marking of bearing sets
The bearing rings carry several markings. These are for identification purposes and to indicate how the bearings of a matched set should be correctly mounted.

A "V"-shaped marking is to be found on the outside diameter of the bearings. The bearings should be mounted in the order shown by this marking to obtain correct preload. It also serves to show how the set should be mounted compared with the axial load. The point of the "V" gives the direction in which the axial load should act on the inner ring(s). Where axial loads act in both directions, the "V" point gives the direction of the greater axial load.

Each bearing of a matched set is marked with the complete designation of the bearing set. The same serial number is shown on the face of the outer ring.

An asterisk marks the position of the greatest out-of-round on the inner and outer ring faces. This is where the greatest wall thickness between the base of the raceway groove and the bore or the outside diameter surface has been found. In addition, the "V" marking on the outer ring is always applied at this position. The actual values of the mean deviations from the nominal bore and outside diameters, Δ_{dm} and Δ_{Dm} respectively, are given on the rings and on the package. All deviations are expressed in µm.

The bearing sets are supplied in packaged units in which each bearing is individually packed



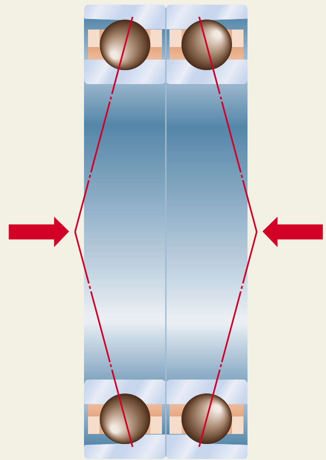
Back-to-back arrangement DB
The load lines of bearings arranged back-to-back diverge towards the bearing axis (➔ **fig** 4). Axial loads can be accommodated in both directions, although only by one bearing (or bearings in tandem) at a time. The back-to-back arrangement is relatively stiff and can also take up tilting moments.

Tandem arrangement DT
In a tandem arrangement, the load lines of the bearings are in parallel (➔ **fig** 5). Radial and axial loads are equally distributed over the bearings, but axial loads can only be carried in one direction. A set of bearings in a tandem arrangement is therefore generally adjusted against another bearing which can take the axial loads acting in the opposite direction.

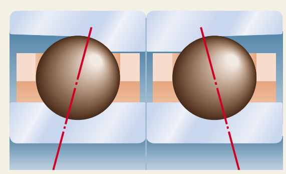
Other tandem arrangements
Combinations of tandem and back-to-back (➔ **fig** 6) are normally used when the design makes it impossible to adjust a further bearing or bearing set against the tandem set.

More combinations on request
The various bearing combinations shown (➔ **figs** 4 **to** 6) are the most commonly used. However, SKF can also provide face-to-face and/or tandem combinations of two to four bearings on request.

Fig 4

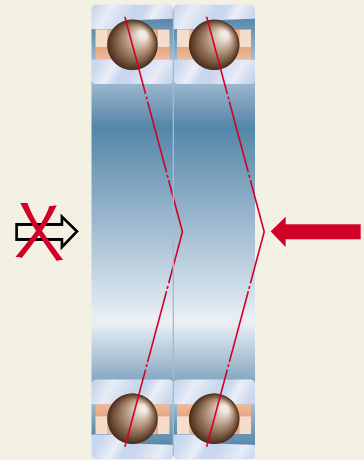


Back-to-back arrangement
for axial load in both directions

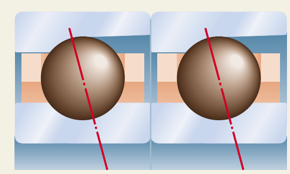


Back-to-back arrangement
Designation suffix DB

Fig 5

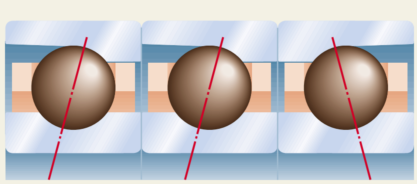


Tandem arrangement
for axial load in one directions

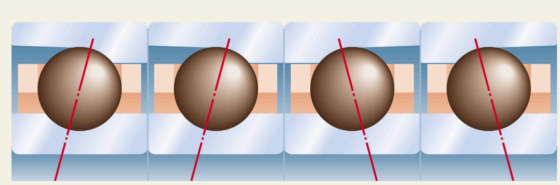


Tandem arrangement
Designation suffix DB

Fig 6



Combination of tandem and back-to-back arrangement
Designation suffix TBT



Back-to-back arrangement
Designation suffix QBC

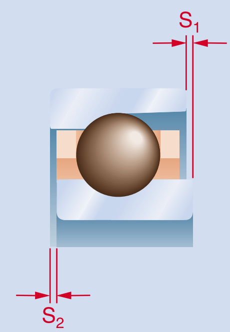
Universal bearings for paired mounting

A special version of the precision bearings is intended for paired mounting. They are named “universal bearings” and are adjusted during manufacture so that they may be mounted immediately next to each other in a back-to-back, face-to-face or tandem arrangement as desired (➔ **figs 7, 8 and 9**).

Predetermined preload
When arranged back-to-back (➔ **fig 7**) or face-to-face (➔ **fig 8**) the bearings will have a light or medium preload, depending on requirements. Single bearings of universal design are identified by the designation suffix G. The suffix is followed by the letter A or B showing the degree of preload, e.g. 71912 CEGA/HCP4A.

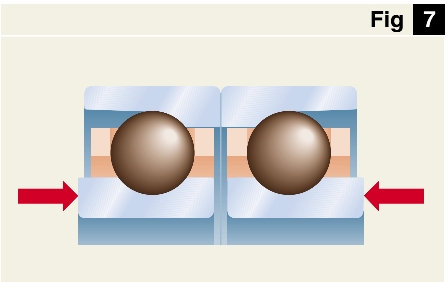
Ordering
When ordering universal bearings for paired mounting it is important that the number of single bearings required is stated, not the number of bearing pairs. There are two classes of preload, A and B, which is stated as a suffix in the bearing designation, for example 71912 CEGA/HCP4A. The class B preload is the heavier of the two.

Pairs of universal design bearings can also be ordered with matched bores and outside diameters. Depending on the preload, the bearings carry the suffix DGA or DGB, e.g. 71912 CE/HCP4ADGA. When ordering these bearings the procedure is different. In this case the number of bearing pairs required should be ordered, not the number of single bearings.



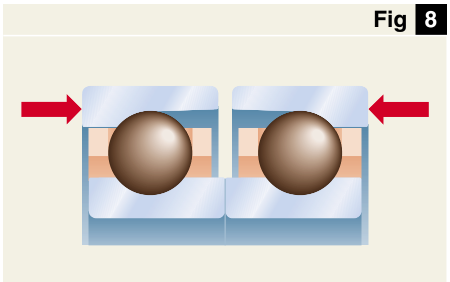
It is the manufacturing precision that determines the accuracy of the preload. The outer and inner rings are ground to the same width but with the raceways somewhat displaced in relation to each other. In the illustration this is represented by the distances $S_1 = S_2$. The correct preload is automatically obtained when $S_1 = S_2$ during mounting is reduced to zero. (Please observe, the dimensions S_1 and S_2 are not to scale.)

Fig 7



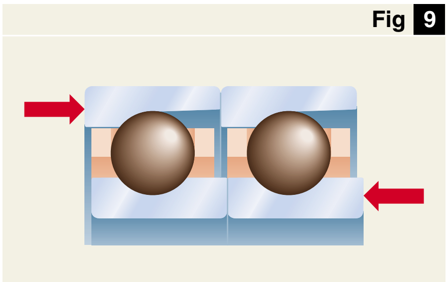
In a back-to-back arrangement the outer rings are in contact before mounting is completed. The preload is set by driving the inner rings towards each other

Fig 8



In a face-to-face arrangement the inner rings are in contact before mounting is completed. The preload is set by driving the outer rings towards each other

Fig 9



In a tandem arrangement both the rings are in contact from the beginning. The preload is achieved by calibrated springs

Designations of SKF hybrid bearings

Each SKF bearing of standard metric design is given a basic designation, in this case four or five figures and supplementary designations.

The complete designation of a single hybrid high precision angular contact ball bearing identifies the series, bore diameter, contact angle and design. It includes the suffix /HC, which identifies the hybrid bearing, and suffixes showing the tolerance class, e.g. 71912 CE/HCP4A. The designation of a bearing set also in-cludes suffixes showing the number of bearings in a set and the type of arrangement. A more detailed presentation will be found in the illustration on this page where individual suffixes are explained.

Use the complete designation when ordering bearings. If the suffix /HC does not appear in the designation the bearing will be an allsteel bearing. This will ensure that a bearing of the right type and size is delivered.

719 | 14 | CE / HC | P4A | D | B | A

Bearing series

719	single row angular contact ball bearing, ISO Dimension Series 19
70	single row angular contact ball bearing, ISO Dimension Series 10
72	single row angular contact ball bearing, ISO Dimension Series 02

Bore diameter

8	8 mm bore diameter
9	9 mm bore diameter
00	10 mm bore diameter
01	12 mm bore diameter
02	15 mm bore diameter
03	17 mm bore diameter
04 (×5)	20 mm bore diameter
.	
.	
28 (×5)	140 mm bore diameter

Contact angle and internal design

ACD	25°
CD	15°
CC	12°, special high speed design
CE	15°, small balls

Rolling element material

HC	silicon nitride

Tolerance class

P4A	dimensional accuracy to ISO Class 4, running accuracy better than ISO Class 4
PA9A	accuracy to ABMA class ABEC 9
PA9B	accuracy to ABMA class ABEC 9 but with reduced radial runout of the inner ring

Number of bearings in set

D	2 bearings
T	3 bearings
Q	4 bearings

Bearing arrangement in matched set

B	back-to-back (two bearings)
F	face-to-face (two bearings)
T	tandem
BT	back-to-back and tandem (three bearings)
FT	face-to-face and tandem (three bearings)
BC	pairs in tandem back-to-back (four bearings)
FC	pairs in tandem face-to-face (four bearings)
G	for universal matching

Preload

A	light preload
B	medium preload
G..	special preload, value in daN, e.g. G240

The ceramic ball makes the big difference

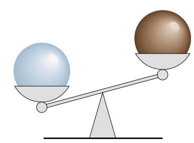
Ceramic balls provide the optimum combination of strength, hardness, durability and low density for high precision bearings. They are made of silicon nitride – hot isostatic pressed silicon nitride, Si_3N_4. It is a carefully chosen material which has the best combination of properties for use in bearings.

The ceramic balls have a very smooth surface and high dimensional accuracy. The coefficient of friction is only 20 % compared with a similar steel ball. But ceramic balls also possess other qualities.

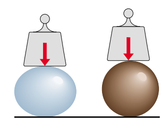
The modulus of elasticity is some 50 % higher than for a steel ball. This means that a ceramic ball under load does not distort to the same extent. In turn, this means that the contact between ball and rings is smaller. So there is less friction!

Compared with a steel ball of the same size, the ceramic ball has 60 % lower density. Therefore, it is subject to significantly reduced centrifugal force. Consequently, the forces between the ball and the outer ring are considerably reduced and there will be less change in the angle of contact. The smaller the change of the contact angle, the better the dynamic accuracy of the bearing arrangement. Because of the lower mass the friction is also reduced.

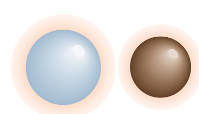
As an additional advantage, the thermal expansion is less than 30 % of that of steel. This implies on one hand that a ceramic ball is less sensitive to the heat differences between the rings, on the other that it does not transfer heat in the same way as steel. Moreover, the degree of expansion is insignificant. In principle this means a smaller initial preload for cold bearings. But also that the preload does not increase due to volume increase during operation when the bearing temperature rises. The increase in friction is small or non-existent. Thus the friction is far less than for bearings with steel balls.



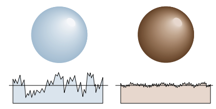
The almost 60 % lower density compared with steel balls has the effect of significantly reducing the stresses caused by centrifugal forces



The 50 % higher modulus of elasticity makes the bearing much stiffer, up to 25 % stiffer at high speeds



Ceramic balls are less sensitive to thermal expansion, only 29 % of similar steel balls, minimising any uncontrolled increase in preload



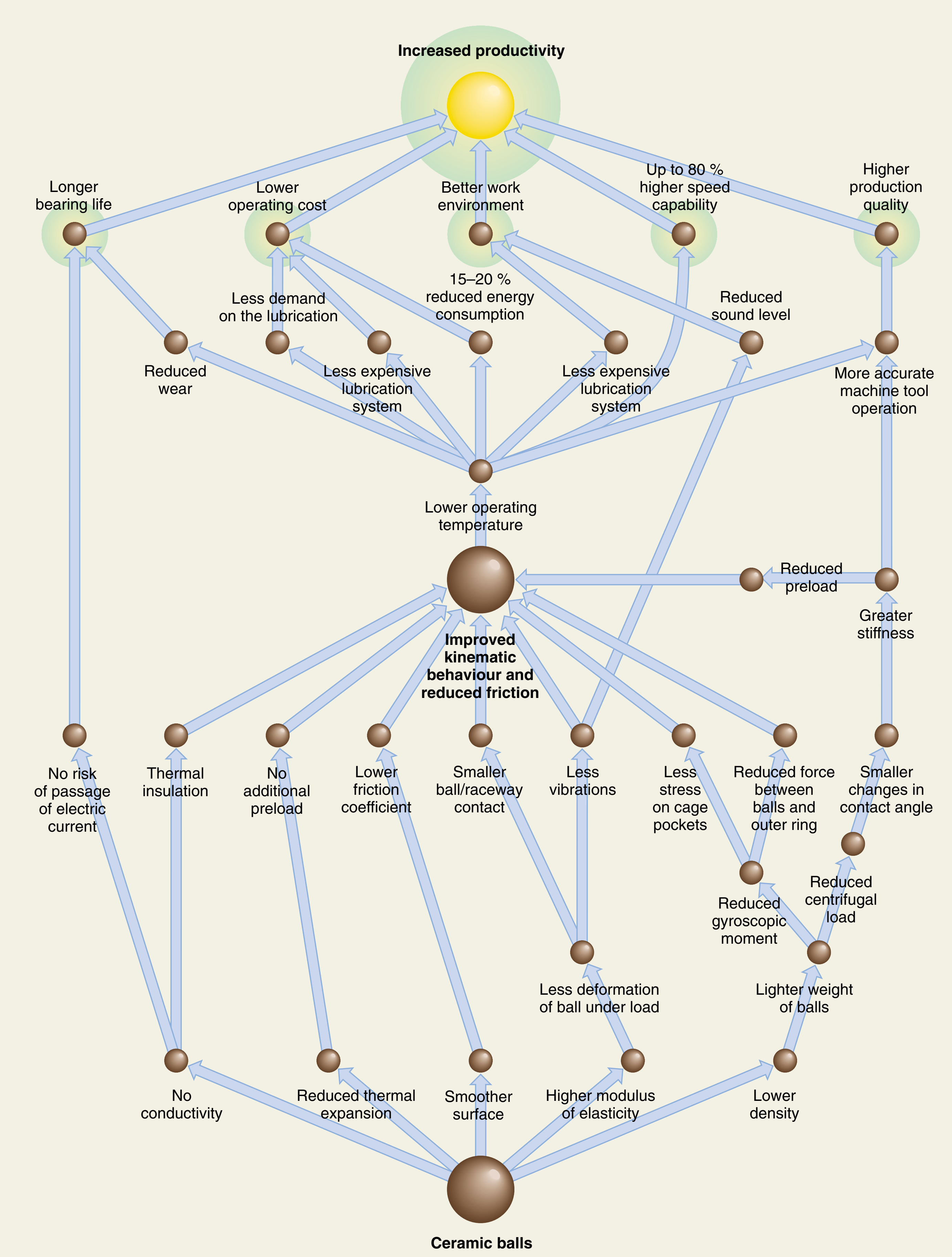
The very low friction enhances wear resistance and enables bearings to run cooler even when they are poorly lubricated

Stages in net-shape forming of ceramic ball blanks

Ceramic balls

Page 17

Page 34



Better than steel

The failure mode for silicon nitride is very similar to that of bearing steel, i.e. fatigue, which manifests itself as flaking or spalling. But the fatigue life of the ceramic material itself is much longer than that of steel (➔ **diagram 8, page 16**).

It is hard and tough. It has good strength. These properties in combination lead to better surface finish and resistance to damage from particles and impurities forcing their way into the bearing (➔ **table 2**)

SKF has studied this material for bearing purposes since the early sixties, establishing rules and methods covering manufacturing, finishing and quality aspects. Today all SKF ceramic balls are produced in-house in facilities devoted to the production of bearings for aerospace industry.

A comparison of the physical properties between bearing steel and silicon nitride is shown in **table 3**.

Micro-structurally uniform and free from defects
The ceramic balls used for high precision bearings must be micro-structurally uniform and free of defects. Otherwise they would not be capable of accommodating dynamic and static loads and yet provide resistance to both wear and fatigue failure. Silicon nitride has a low coefficient of thermal expansion and an impressive resistance to fracture by thermal shock. It has a tensile strength of 700 N/mm² which remains constant up to 1 000 °C. The material is virtually inert and, therefore, has an excellent resistance to corrosion even in the most hostile environments.

Although silicon nitride is neither the hardest nor the toughest of engineering ceramics, it is considered to have the best combination of mechanical and physical properties for use in high performance bearing applications. Various types of rolling contact fatigue tests and bearing tests have shown that fully dense and homogeneous silicon nitride has good fatigue resistance.

But, unlike steels, there are no material or composition specifications for ceramics, nor are there any standard methods for assessment of the important properties. It is estimated that worldwide there are more than 150 different types and grades of ceramic material differing in composition, processing and properties. In view of this situation it has been necessary to develop in-house specifications for bearing ceramic materials and special inspection techniques to ensure that the highest quality is achieved (➔ **fig 10, page 16**).

Table 2

Grade	Roughness R_a Steel balls
3	0,012 µm
5	0,020 µm
10	0,025 µm

Maximum surface roughness for steel balls of ISO Grade
ISO 3290 specification for surface roughness of steel balls. The roughness of ceramic balls is as good (or better) than that of the highest grade

Properties of silicon nitride and bearing steel

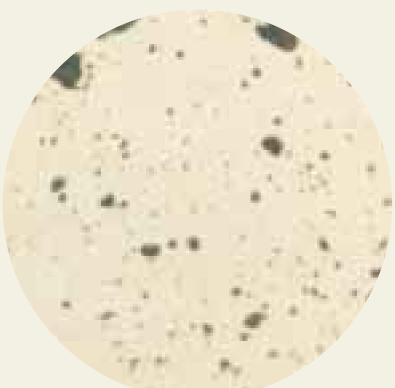
Table 3

Property[1]	Unit	Silicon nitride HIPSN	Bearing steel, hardened
Density, ρ	g/cm³	3,21	7,85
Coefficient of thermal expansion	1/°C		
20 – 1 000 °C		$3{,}2 \times 10^{-6}$	
20 – 300 °C			$11{,}5 \times 10^{-6}$
Modulus of elasticity, E	N/mm²	315 000	206 000
Poisson's ratio	–	0,26	0,30
Hardness HV10	–	1 700	700
Tensile strength	N/mm²		
20 °C		700	2 400
1 000 °C		700	0
Fracture toughness, K_{IC}	MPa · $m^{1/2}$	7	25
Thermal conductivity	W/mK	30 – 40	40 – 50
Specific electrical resistance	Ω · mm²/m	$10^{17} – 10^{18}$	$10^{-1} – 1$

[1] Valid at 20 °C if not otherwise stated

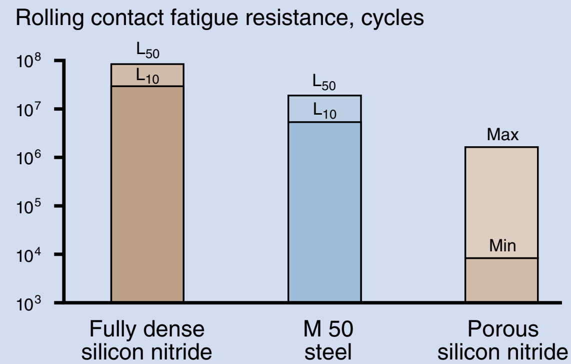
Fig 10

Highest grade material in terms of structure and properties. This is the material of which the balls for SKF hybrid bearings are made.



Low grade material not used for bearings.

Diagram 8



The basic rating bearing life – L_{10}

The life of a bearing is the number of revolutions (or operating hours, L_{10h}) which the bearing can run before the first sign of fatigue (spalling or flaking) occurs on one of its rings or rolling elements.

Laboratory tests and practical experience, however, show that seemingly identical bearings operating under the same conditions have different lives. Therefore all information from SKF on dynamic load ratings is based on the “basic rating life” according to ISO. The basic rating life, i.e. L_{10} in millions of revolutions, is the life 90 % of a sufficiently large group of apparently identical bearings can be expected to attain or exceed under identical operating conditions.

The median bearing life – L_{50}

This is the median bearing life, the life which will be attained or exceed by fifty percent of the bearings. The median life is approximately five times the calculated basic rating life. The dispersion in life for SKF hybrid bearings is very wide, which is characteristic for a first-class material.

Other bearing lives

There are several other “bearing lives,” including “service life” and “specification life”.

“Service life” is the actual life achieved by a specific bearing before it becomes unserviceable. Failure is not generally initiated by fatigue, but by wear, corrosion, contamination, seal failure etc. The “service life” of a bearing depends to a large extent on operating conditions. But also on the procedures used to mount and maintain it.

“Specification life” is the life specified by the equipment builder and is based on hypothetical load and speed data supplied by the builder.

For more information about bearing life, please refer to the SKF General Catalogue.

Quality assurance

To make sure that each SKF bearing has the desired quality several tests and inspections are carried out. The dimensional quality of silicon nitride balls is assessed in the same way as for steel balls. But also various methods for non-destructive evaluation are used including fluorescent dye penetrants and light microscopy.

Design support

The general recommendations given in the SKF General catalogue and the SKF catalogue "Precision bearings" regarding application of bearings also apply to hybrid precision bearings. As the leading manufacturer of rolling bearings worldwide, SKF can provide a comprehensive range of hybrid precision bearings, as well as qualified assistance including spindle design and bearing calculations.

We offer qualified engineering expertise for all machine tool applications. Specialised SKF application engineers are ready to offer assistance, making use of SKF's unparalleled fund of high precision application experience.

Backing this, our Engineering and Research Centre (ERC) provides the deeper know-how allowing SKF to stay in the forefront of bearing technology. The resources and test facilities at the Centre cover all areas of bearing technology and are unequalled in the bearing industry.

The right bearing for the job
The selection of the most suitable bearing for a given application should be based on the required performance (➔ **table 1**, **page 18**), particularly with regard to speeds and stiffness or a combination of these.

The SKF range of hybrid angular contact ball bearings (➔ **pages 34 to 42**) covers in principle all demands from the spindle designer for extra machine tool productivity in terms of high speed and stiffness.

Cooperation with the spindle bearing specialists within SKF gives access to all important information which determines the bearing selection, as well as computer programs for complex bearing performance calculations specially developed by SKF.

Selection of bearing series and design

There are three dimension series and four designs at your disposal. When designing a bearing arrangement certain factors should be taken into consideration, such as

- available space,
- loads,
- stiffness,
- accommodation of axial displacements,
- speed, and
- heat generation.

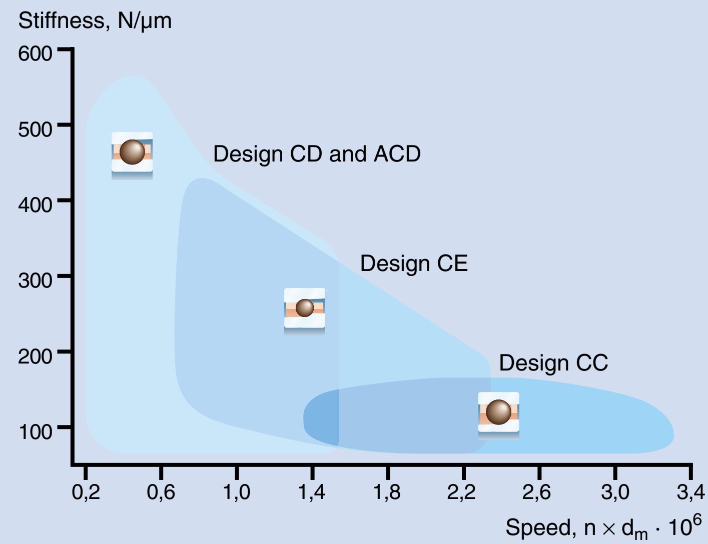
Which bearing to choose for a specific arrangement is a question of which of the above factors will have a dominant influence.

For detailed information, please refer to the bearing tables which start on **page 34** and the catalogue "Precision bearings". However, some guidelines will be given.

Available space

Precision bearing arrangements generally call for bearings with low cross section. They enable relatively large diameter spindles to be used for a given housing bore diameter. These berings generally have a large number of balls. Therefore, they have a high stiffness and ensure the running accuracy of the spindle bearing arrangement.

Diagram 1



Hybrid bearing selection guideline
This diagram should be regarded as a rough guideline for the selection of the most popular hybrid bearings. It is based on theoretical radial stiffness and speed

The most common bearings used for machine tools are from dimension series 70. For bearing arrangements with less radial space available the lighter series 719 bearings are the ideal choice. Series 72 bearings offer high load rating.

Loads

Angular contact ball bearings can support combined radial and axial loads. However, it is often criteria such as stiffness, the size of spindle bore, machining speeds and accuracy rather than loads which determine the size of the bearing (**➔ "Load carrying capacity", page 22**).

Machine tool types and typical performance requirements

Table 1

	Lathes and milling machines	**Machine centres and high speed milling machines**	**Surface grinders**	**High speed internal grinders**
Typical customer requirements				
Spindle diameter, mm	50 – 250	40 – 120	40 – 150	8 – 40
Spindle runout, µm	2 – 4	1 – 3	1 – 3	0,5 – 1
Max. speed, r/min	< 10 000	5 000 – 40 000	500 – 3 000	20 000 – 200 000
Required stiffness, N/µm	100 – 600	100 – 500	50 – 800	5 – 40
Temperature rise, °C	< 20	< 20	< 15	< 20
SKF solutions using all-steel bearings				
Option 1				
Front side	NN 30 K + BTA .. B	70 CE/P4AQBC	719 ACD/P4AQBC	70 CC/PA9BDT
Drive side	NN 30 K	70 CD/P4ADB	NNU 49 BK	70 CC/PA9BDT
Option 2				
Front side	NN 30 K + 2344(00)	70 CE/P4AQBC	NN 30 K + 2344(00)	70 CD/PA9ADT
Drive side	NN 30 K	N 10 K	NN 30 K	70 CD/PA9ADT
Option 3				
Front side	70 ACD/P4ATBT	70 CD/P4ADB	NN 30 K + BTA .. B	
Drive side	NN 30 K	70 CD/P4ADB	NN 30 K	

Stiffness

The stiffness of a hybrid angular contact ball bearing depends of the number and size of the balls and the contact angle. The number of balls has a greater influence on the bearing stiffness than the size. Bearing stiffness is also influenced by the fits on the shaft and in the housing. However, too high a degree of interference increases the preload, whilst too loose a fit means that the preload value will not be attained.

Where high radial stiffness is required, bearings having the smallest possible angle of contact should be used.

Where high axial stiffness is called for, the contact angle should be as large as possible (➔ **diagram 1**).

Accommodation of axial displacement

To prevent the angular contact ball bearings being subjected to extra stress as a result of changes in shaft length caused by thermal expansion, the spindle should be supported in locating and non-locating bearings. A non-locating bearing can be displaced axially. Generally, the non-rotating outer ring is given a loose fit in the housing at one end of the spindle.

Speed

Heat generation is a limiting factor for high speed. A hybrid bearing with low friction and thus low heat generation in the bearing itself is therefore the most suitable for high speed operation.

Heat generation

The method of lubrication and the quantity of lubricant play an important part with respect to the actual heat generation in hybrid bearings. Grease lubrication has therefore become increasingly popular because there is little heat generation when a small amount of lubricant is used. Also, the oil spot method is suitable for keeping the operating temperature at a constantly low level.

Preload

By preloading bearings it is possible not only to increase the bearing stiffness, but also the running accuracy of a bearing arrangement. Preload is obtained first after mounting and depends on how the bearing is adjusted. A single row angular contact bearing is adjusted against a second bearing which can take the axial loads acting in the opposite direction. Preload is applied to bearing groups in two ways: by a “constant load arrangement” or a “constant position arrangement”.

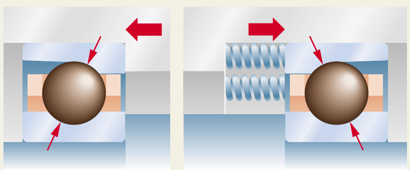
The preload values quoted in **tables 2, 3 and 4** apply to the bearing sets before mounting. After mounting, preload usually increases, depending on the fits used and the stiffness of the shaft and housing.

Series 719:
Preload in bearing pairs arranged back-to-back or face-to-face

Table 2

Bearing Bore diameter	Size	**Axial preload Series 719 CD/HC** Class A	B	**Series 719 CE/HC** Class A	B	**Series 719 ACD/HC** Class A	B
mm	–	N					
10	00	10	20	–	–	15	30
12	01	10	20	–	–	15	30
15	02	15	30	–	–	25	50
17	03	15	30	–	–	25	50
20	04	25	50	–	–	35	70
25	05	25	50	–	–	40	80
30	06	25	50	–	–	40	80
35	07	35	70	–	–	60	120
40	08	45	90	–	–	70	140
45	09	50	100	–	–	80	160
50	10	50	100	–	–	80	160
55	11	70	140	–	–	120	240
60	12	70	140	100	200	120	240
65	13	80	160	110	220	120	240
70	14	130	260	150	300	200	400
75	15	130	260	150	300	210	420
80	16	140	280	160	320	220	440
85	17	170	340	210	420	270	540
90	18	180	360	220	440	280	560
95	19	190	380	220	440	290	580
100	20	230	460	280	560	360	720
105	21	230	460	290	580	360	720
110	22	230	460	290	580	370	740
120	24	290	580	370	740	450	900
130	26	350	700	–	–	540	1 080
140	28	360	720	–	–	560	1 120

Fig 1



For an application where extremely high speed is required and a moderate stiffness is acceptable, sufficient preload should be achieved by calibrated springs acting against a bearing ring

Constant load arrangement
An axial load may be imposed through elastic elements, appropriately placed between bearing rings and the housing shoulder (➔ **fig** 1). Usually calibrated springs are used for this. In such a case axial preload is considered as being applied by means of a linear spring. It is not then influenced by any kinematic phenomenon occurring within the bearings themselves. Practically, this is a “speed independent” preload remaining almost constant over the whole speed range. This kind of arrangement is usually known as a “constant load arrangement”.

The method is mainly used for high speed arrangements. It is to be regarded as a norm for internal grinding spindle applications, and is not as stiff as the constant position arrangement.

Table 3
Series 70:
Preload in bearing pairs arranged back-to-back or face-to-face

Table 4
Series 72:
Preload in bearing pairs arranged back-to-back or face-to-face

Table 3

Bearing Bore diameter	Size	**Axial preload Series 70 CD/HC** Class A	B	**Series 70 CE/HC** Class A	B	**Series 70 ACD/HC** Class A	B
mm	–	N					
8	8	10	20	–	–	20	40
9	9	10	20	–	–	20	40
10	00	15	30	–	–	25	50
12	01	15	30	–	–	25	50
15	02	20	40	–	–	30	60
17	03	25	50	–	–	40	80
20	04	35	70	–	–	50	100
25	05	35	70	–	–	60	120
30	06	50	100	–	–	90	180
35	07	60	120	–	–	90	180
40	08	60	120	–	–	100	200
45	09	110	220	–	–	170	340
50	10	110	220	–	–	180	360
55	11	150	300	–	–	230	460
60	12	150	300	140	280	240	480
65	13	160	320	150	300	240	480
70	14	200	400	200	400	300	600
75	15	200	400	200	400	310	620
80	16	240	480	260	520	390	780
85	17	250	500	260	520	400	800
90	18	300	600	330	660	460	920
95	19	310	620	340	680	480	960
100	20	310	620	350	700	500	1 000

Table 4

Bearing Bore diameter	Size	**Axial preload Series 72 CD/HC** Class A	B	**Series 72 ACD/HC** Class A	B
mm	–	N			
10	00	20	40	35	70
12	01	20	40	35	70
15	02	30	60	45	90
17	03	35	70	60	120
20	04	45	90	70	140
25	05	50	100	80	160
30	06	90	180	150	300
35	07	120	240	190	380
40	08	150	300	240	480
45	09	160	320	260	520
50	10	170	340	260	520
55	11	210	420	330	660
60	12	250	500	400	800

Constant position arrangement
When designing machining centre and milling spindles, or lathe and boring machine spindles no springs are used because they make the arrangements less stiff.

Consequently, arrangements where preload is obtained by adjusting the bearings against each other (i.e. matched sets), are preferred (➔ **fig 2**). This solution, usually known as the “constant position arrangement”, offers considerable advantages in terms of system stiffness. However, since the bearings are tightened against each other through a rigid element (lock nut or stepped sleeve), preload becomes speed dependent.

SKF laboratories have measured the preload variation as a function of rotating speed by means of strain gauged spacers. A drastic increase of preload when approaching very high speeds was found. The increase is mostly due to the centrifugal load affecting the position of the rolling elements. Thus, the adoption of ceramic balls allows much higher speeds of rotation whilst maintaining low heat generation as well as adequate stiffness.

Two classes of preload
Based on these studies only two classes of preload, A and B, have been established for normal applications. When designing for extreme speed and stiffness it is necessary to consider different preload values and the SKF spindle bearing specialists should be consulted.

The **tables 2, 3 and 4** show preload values for bearing pairs arranged either back-to-back or face-to-face. Matched sets involving three or four bearings have higher preload values than pairs. The actual values are obtained by multiplying the values in the tables by the following factors:

1,35 for TBT and TFT sets
1,60 for QBT and QFT sets
2,00 for QBC and QFC sets

Bearing sets with special preload will be supplied on request. The preload values for single bearings of G design for universal pairing are the same as for the matched bearing sets.

Series 70 CC
Series 70 CC bearings have been specially designed for high speed operation and are normally preloaded by springs. No general recommendations are given for this series, therefore SKF should be consulted for an individual analysis.

Speed ratings

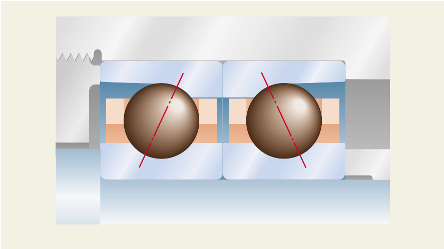
The speed ratings quoted in the bearing tables are guideline values only. They are valid if the bearings are lightly loaded (P < 0,06 C) and lightly preloaded by means of springs, always assuming that the transport of heat away from the bearing position is good. The ratings given in the bearing tables (➔ **pages 34 to 44**) under oil spot lubrication should be reduced for certain other oil lubrication methods (➔ **table 5, page 22**).

The ratings for grease lubrication are maximum values which can be attained using a good quality grease of soft consistency.

The speed ratings in the tables must also be reduced when two or more bearings are adjusted against each other and are mounted immediately adjacent to each other. Appropriate reduction factors for the various conditions are given in **table 6, page 22**.

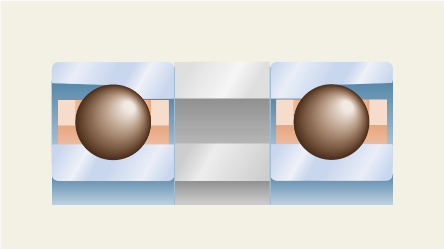
The speed ratings quoted in the bearing tables should be multiplied by these factors as appropriate. When the speed ratings obtained from the above for matched bearing sets are inadequate, a simple design change – the inclusion of intermediate rings between the bearings – will allow appreciable increases to be made (➔ **fig 3**). For sets of three bearings, for example, it should then be possible to run at the speed ratings quoted for paired bearings. Preloading the bearings by springs may be beneficial. This method of applying preload is generally used for high speed operation to obtain an even preload over the whole operating speed range of the machine.

Fig 2



For an application where there is a demand for high stiffness, the preload is preferably obtained by adjusting the bearings against each other and using matched sets

Fig 3



It is possible to increase the speed ratings by using intermediate rings between the bearings. The two rings have to be face ground together

Load carrying capacity and life

The size of a bearing required for a given bearing arrangement is generally determined by the load carrying capacity. The selection is made in relation to the actual loads but also to the desired life and operational reliability.

For machine tool spindles, bearing size is nearly always determined by criteria such as stiffness of the system, or by fixed dimensions for the tool holder, or by the spindle bore. The bearings selected according to such criteria give arrangements which are often required to have a very long life.

The determination of the loads to which a bearing is subjected is particularly complex for precision bearings considering all influencing factors. Therefore, SKF has developed special computer programs for the calculation of indeterminate spindle bearing systems. Please contact SKF for assist-ance in determining the bearing loads and designing an optimum bearing arrangement.

The factor a_{HC}

Under the same external load, the stress in the contact area between a hybrid bearing ball and each raceway will be higher than in an all-steel bearing. This is due to the higher hardness and stiffness of the ceramic material compared with steel. As ISO does not give guidance in calculating basic load ratings for hybrid bearings, it has been decided to quote the same load rating values for hybrid bearings as for all-steel bearings. By introducing a factor a_{HC} into the life equations the higher contact stress is considered.

$$L_{10\ (hybrid)} = a_{HC}\ (C/P)^p$$

$$L_{na\ (hybrid)} = a_1\ a_{23}\ a_{HC}\ (C/P)^p$$

$$L_{naa\ (hybrid)} = a_1\ a_{SKF}\ a_{HC}\ (C/P)^p$$

The value of a_{HC} for ball bearings is 0,3144. It should be remembered that the equations give a fatigue life. Generally, experience shows that the service life of hybrid bearings is longer or even much longer than that of all-steel bearings under the conditions normally encountered in machine tool operations.

Hybrid bearings are much less susceptible to wear and lubrication conditions are generally superior to those in an all-steel bearing.

The same basic static load ratings as for all-steel bearings are valid if they are compensated by the different values of the static safety factor s_0, where $s_0 = C_0/P_0$ (➔ **table 7**).

For more detailed information of life calculations please consult the SKF General Catalogue.

Load carrying capacity of bearing sets

The values given in the bearing tables for the basic dynamic and static load ratings apply to single bearings. The basic dynamic load rating for sets of bearings arranged back-to-back, face-to-face or in tandem is obtained by multiplying the C value for a single bearing by

1,62 for sets comprising two bearings
2,16 for sets comprising three bearings
2,64 for sets comprising four bearings.

Where the basic static load rating is concerned, values for bearing sets can be obtained by multiplying the single bearing value by the number of bearings in the set, viz. by 2, 3, or 4.

Guidelines for speed rating reduction factors due to oil lubrication method

Table 5

Lubrication method	Reduction factor
Oil bath	0,3 – 0,4
Oil mist	0,95
Oil jet	Depends on oil type, oil supply rate, oil inlet temperature, oil drainage efficiency etc. Please consult SKF giving details of specific application

Speed reduction factors for preloaded arrangements

Table 6

Bearing arrangement	Reduction factors for preloaded arrangements, preload to class A	B
Sets of two bearings arranged in tandem	0,9	0,7
Sets of two bearings arranged back-to-back	0,75	0,6
Sets of three bearings	0,65	0,4
Sets of four bearings	0,55	0,3

Equivalent bearing loads
Generally, angular contact ball bearings are subjected to combined loads, i.e. radial and axial loads acting simultaneously. The preload forces are included in the axial load (➔ **"Calculation of preloaded bearings", page 24)**. In all such cases, it is necessary to calculate an equivalent bearing load which will have the same influence on bearing life, or produce the same permanent deformation in the bearing, as the actual load. The equivalent bearing loads can be obtained from

$$P = XF_r + YF_a$$

and

$$P_0 = X_0F_r + Y_0F_a$$

where
P = equivalent dynamic bearing load, N
P_0 = equivalent static bearing load, N
F_r = radial component of bearing load, N
F_a = axial component of bearing load, N
X, X_0 = radial load factors
Y, Y_0 = axial load factors

All necessary information to calculate the equivalent bearing loads for single bearings and sets of two bearings is given in the following. The information does not apply to sets of three or four bearings as it cannot be assumed that the load is evenly distributed over the bearings, and the reaction forces caused by spindle deflection cannot be neglected. Special SKF computer programs can be used to calculate the equivalent loads of such a bearing arrangement as well as other parameters, e.g. spindle deflection. Further information will be supplied on request.

Equivalent dynamic bearing load
For bearings arranged singly or paired in tandem

$$P = F_r \quad \text{when } F_a/F_r \le e$$
$$P = XF_r + YF_a \quad \text{when } F_a/F_r > e$$

For bearings paired back-to-back or face-to-face

$$P = F_r + Y_1F_a \quad \text{when } F_a/F_r \le e$$
$$P = XF_r + Y_2F_a \quad \text{when } F_a/F_r > e$$

Values of the factors are given in **tables 8 and 9, page 24**. When calculating bearing pairs, F_r and F_a represent the forces acting on the bearing pair.

Equivalent static bearing load
For bearings arranged singly or paired in tandem

$$P_0 = 0,5\,F_r + Y_0F_a$$

When $P_0 < F_r$, $P_0 = F_r$ should be used.

For bearings paired back-to-back or face-to-face

$$P_0 = F_r + Y_0F_a$$

The value of factor Y_0 depends on the contact angle and can be obtained from **tables 8 and 9, page 24**. When calculating bearing pairs, F_r and F_a are the forces acting on the bearing pair.

Guideline values for static safety factor s_0 for hybrid ball bearings

Table 7

Type of operation	Rotating bearings Requirements regarding quiet running unimportant	normal	high	Non-rotating bearings
Smooth, vibration-free	0,75	1,5	3	0,6
Normal	0,75	1,5	3	0,75
Pronounced shock loads	≥ 2,25	≥ 2,25	≥ 3	≥ 1,5

Vibration from other machinery, from traffic or during transportation may cause damage to the bearings. In such cases, bearing life is not limited by the material fatigue. Instead it is the permanent deformation produced in the contact between balls and raceways which shorten the bearing life. A ball may be driven into the surface of the rings by the applied load.

The same may happen for bearings which have to sustain heavy shock loads during a fraction of a revolution.

As the demands for running properties and life are very high, permanent deformation of the bearing parts should be avoided at all costs. The maximum load should not, therefore, exceed the equivalent static load obtained from the equation

$$P_0 = C_0/s_0$$

where
P_0 = equivalent static bearing load, N
C_0 = basic static load rating, N
s_0 = static safety factor (➔ **table 7**)

2

Calculation of preloaded bearings
When calculating the equivalent bearing load for preloaded bearings, it is necessary, as mentioned above, to take the preload into account. The axial component of the load F_a is needed for the equivalent load calculation. It is obtained by the following equations when the actual operating conditions are considered (the values obtained will be approximate).

For bearing pairs under radial load and axially secured

$F_a = G_m$

For bearing pairs under radial load and preloaded by springs

$F_a = G_{A,\,B}$

For bearing pairs under axial load and axially secured

$F_a = G_m + 0{,}67\ K_a$ when $K_a \leq 3\ G_m$
$F_a = K_a$ when $K_a > 3\ G_m$

For bearing pairs under axial load and preloaded by springs

$F_a = G_{A,\,B} + K_a$

where
F_a = axial component of a bearing load, N
$G_{A,\,B}$ = preload of a bearing pair, N (➔ **tables 2, 3 and 4, pages 19 and 20**)
G_m = preload on a mounted bearing pair, N (➔ **page 33**)
K_a = external axial force acting on single bearing, N

Calculation factors for single bearings and bearings paired in tandem

Table 8

$f_0\ F_a/C_0$[1)]	e	X	Y	Y_0
Contact angle 12° (suffix CC)				
≤0,0176	0,33	0,46	1,72	0,47
0,354	0,35	0,46	1,59	0,47
0,706	0,39	0,46	1,43	0,47
1,06	0,41	0,46	1,34	0,47
1,41	0,43	0,46	1,28	0,47
2,12	0,46	0,46	1,19	0,47
3,53	0,51	0,46	1,07	0,47
5,29	0,55	0,46	1,01	0,47
≥7,06	0,55	0,46	1,00	0,47
Contact angle 15° (suffix CD, CE)				
≤0,178	0,38	0,44	1,47	0,46
0,357	0,40	0,44	1,40	0,46
0,714	0,43	0,44	1,30	0,46
1,07	0,46	0,44	1,23	0,46
1,43	0,47	0,44	1,19	0,46
2,14	0,50	0,44	1,12	0,46
3,57	0,55	0,44	1,02	0,46
5,35	0,56	0,44	1,00	0,46
≥7,14	0,56	0,44	1,00	0,46
Contact angle 25° (suffix ACD)				
–	0,68	0,41	0,87	0,38

1) Values of f_0 are given in the bearing table

Calculation factors for bearings paired back-to-back and face-to-face

Table 9

$2\ f_0\ F_a/C_0$[1)]	e	X	Y_1	Y_2	Y_0
Contact angle 12° (suffix CC)					
≤0,0176	0,33	0,74	1,97	2,79	0,94
0,354	0,35	0,74	1,82	2,58	0,94
0,706	0,39	0,74	1,56	2,33	0,94
1,06	0,41	0,74	1,53	2,17	0,94
1,41	0,43	0,74	1,47	2,08	0,94
2,12	0,46	0,74	1,36	1,93	0,94
3,53	0,51	0,74	1,22	1,74	0,94
5,29	0,55	0,74	1,15	1,64	0,94
≥7,06	0,55	0,74	1,14	1,63	0,94
Contact angle 15° (suffix CD, CE)					
≤0,178	0,38	0,72	1,65	2,39	0,92
0,357	0,40	0,72	1,57	2,28	0,92
0,714	0,43	0,72	1,46	2,11	0,92
1,07	0,46	0,72	1,38	2,00	0,92
1,43	0,47	0,72	1,34	1,93	0,92
2,14	0,50	0,72	1,26	1,82	0,92
3,57	0,55	0,72	1,14	1,66	0,92
5,35	0,56	0,72	1,12	1,63	0,92
≥7,14	0,56	0,72	1,12	1,63	0,92
Contact angle 25° (suffix ACD)					
–	0,68	0,67	0,47	1,41	0,76

1) Values of f_0 are given in the bearing table

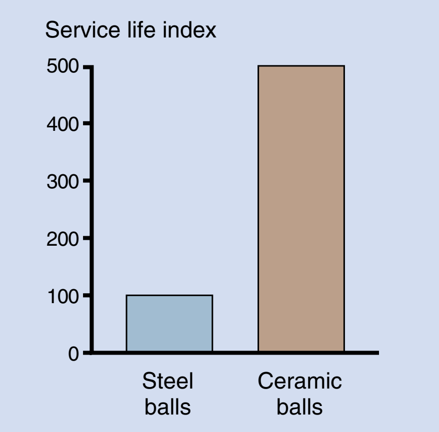
Examples of proven benefits

The results achieved when changing from all-steel bearings to hybrid bearings are clearly expressed in practical results. Irrespective of the fact that an application is of a new design, or an all-steel bearing application already in use it benefits from the superior properties of hybrid bearings.

Four fairly common cases will show how the hybrid bearings can add increased life and speed to a standard application. But there are also other benefits to be achieved through a change to the hybrid bearing technology: cooler running, product quality improvements, less preload, higher spindle stiffness and other improvements of a similar kind.

As the boundary dimensions are the same for all-steel and hybrid bearings of the same series and design they are fully interchangeable. This means that an all-steel bearing spindle having, for example, reached its ultimate speed limit can be used for even higher speeds when fitted with the corresponding hybrid bearings, without having to make any other design changes.

When designing for high productivity machine tool spindles, hybrid bearings can be used to achieve hitherto unattainable performance.



Fourfold life increase and enhanced product quality

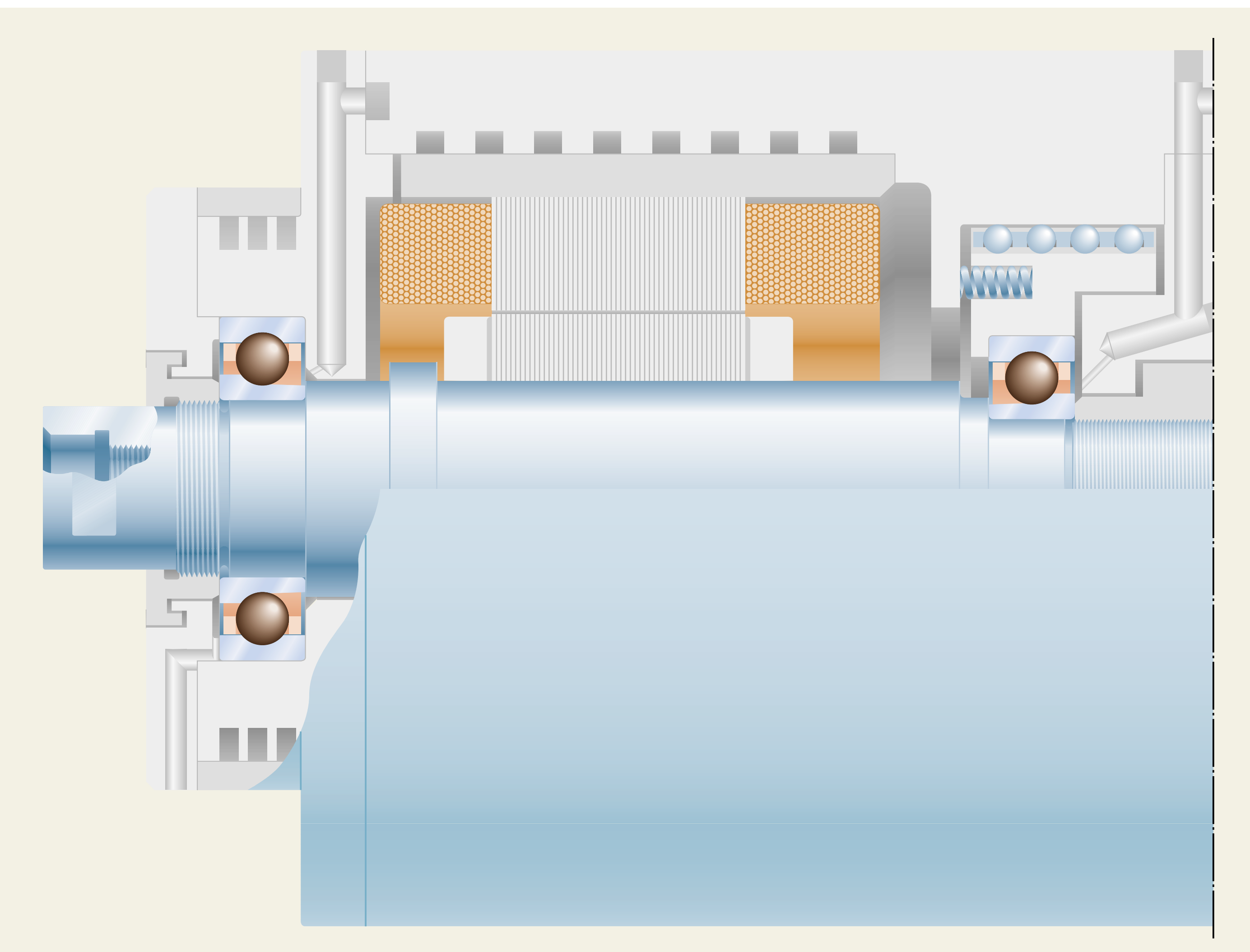
An internal grinding spindle used in a manufacturing unit was originally fitted with conventional all-steel high precision angular contact ball bearings. The spindle was operated at a speed corresponding to an $n \times d_m$ value of 2 108 000. This application is lubricated by oil spot lubrication.

Occasionally this spindle was subjected to significant shock loads acting in the axial direction.

The requirement was to extend spindle life, i.e. bearing life. This had to be achieved whilst maintaining the same operating conditions in all other respects.

By fitting hybrid bearings of the ultra high speed, high precision series 70 CC/HCPA9B with ceramic balls, the life obtained was found to be four times as long.

This was not the only benefit gained by using the hybrid bearings, however. The shock loads were found to exert a much less negative influence on bearing performance and in addition the quality of the machined products was enhanced.



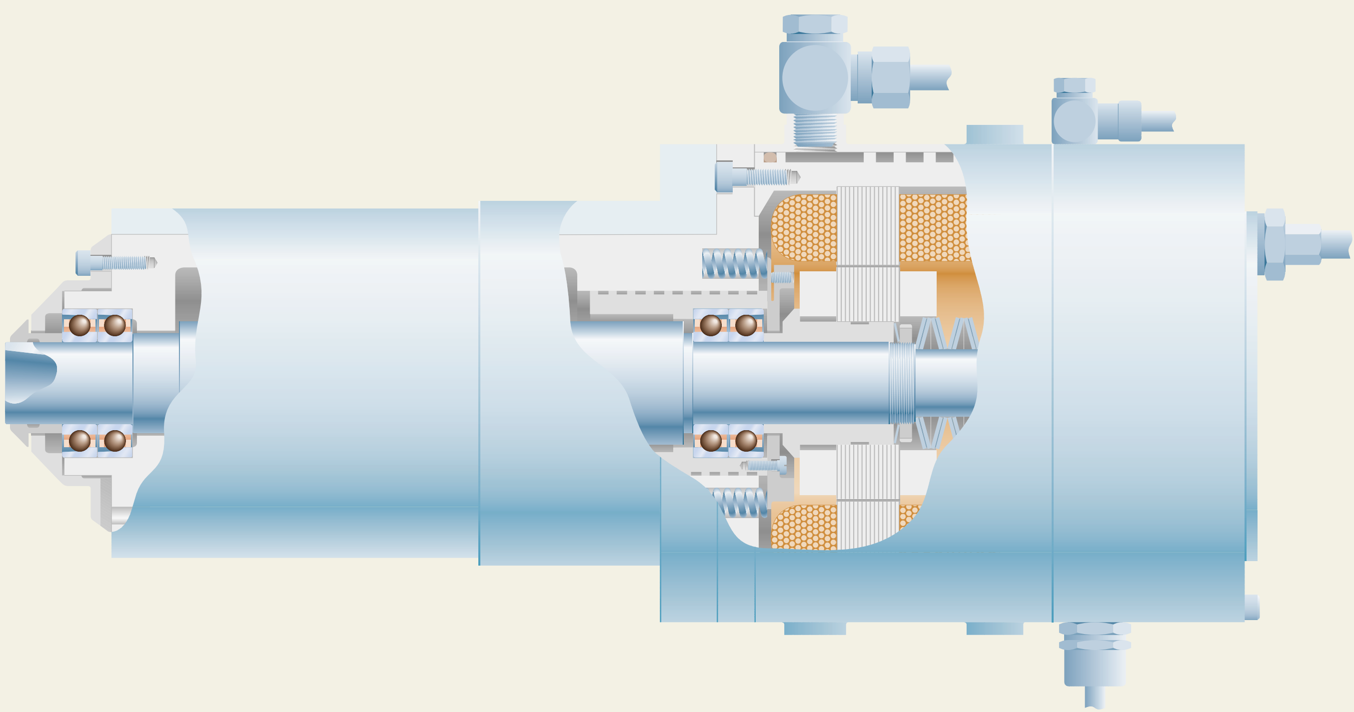
Higher speed and extended service life for a high speed milling spindle

Developments in high speed milling, used for example in the aerospace industry to machine aluminium and other light alloy materials, have led to demands for bearings able to operate at very high speeds.

For a high-frequency milling spindle (MF30, produced by Posalux S.A., Bienne) it was desired to increase the maximum speed from 30 000 to 40 000 r/min and to extend the service life from between 800 and 1 000 to 5 000 hours without changing the method of lubrication. The spindle was fitted with grease lubricated all-steel bearings 71903 CD/P4ADT.

The bearings were arranged as a matched set of two bearings in tandem at the work side and another (opposing) set of two bearings arranged in tandem at the drive side. Both sets were spring loaded.

Computer calculations were performed by SKF, and hybrid bearings of the same size and design, e.g. 71903 CD/HCP4ADT, were proposed as replacements for the all-steel bearings. As a result, the hybrid bearings did not only enable the customer requirements for higher speed and longer life to be met, but the spindle stiffness was also enhanced.



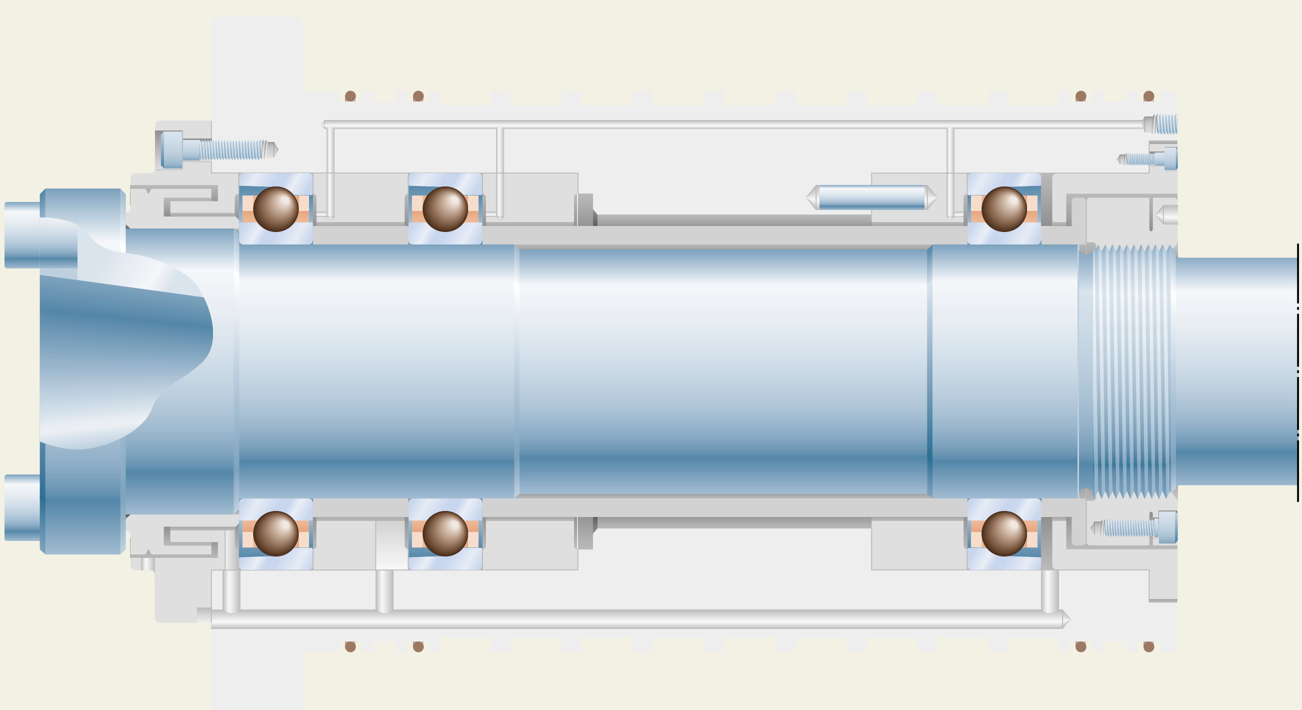
High speed machining centre spindle

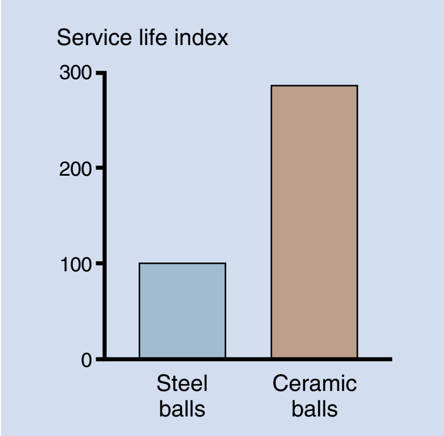
A new horizontal machining centre (RAM Horizontal Machining Centre) has been designed by the largest USA machine tool manufacturer (Gidding & Lewis). It is intended for high speed machining. To achieve the higher speed performance hybrid bearings are used. For the spindle, three universally matchable preloaded high precision hybrid angular contact ball bearings 7018 ACDGA/HCP4A are used. The motor runs on a pair of high precision hybrid angular contact ball bearings 71917 CD/HCP4ADGA.

The maximum spindle speed is 12 000 r/min corresponding to an $n \times d_m$ value of 1 280 000. Thanks to the lower friction of the hybrid bearings, and by using oil mist lubrication, it has been possible to keep the operating temperature as low as 35 °C, i.e. a temperature rise of approximately 15 °C.

An even better result has been achieved by changing the bearings supporting the motor.

The manufacturer had problems with the motor bearings before the hybrid bearings were installed. The motor generated too much heat for the all-steel bearings resulting in premature fatigue. When the hybrid bearings were installed the heat generation was not a problem for the bearings any longer. The motor was then operating with the same efficiency as before the speed was increased and the desired speed could easily be reached. This depends on the fact that hybrid bearings have a lower thermal expansion, the balls will not increase in size or transfer the heat to the outer ring. Which in turn enables a reduction of the additional preload rise caused by the heat generation in an operating bearing.





Increased life and cooler running for a grinding spindle

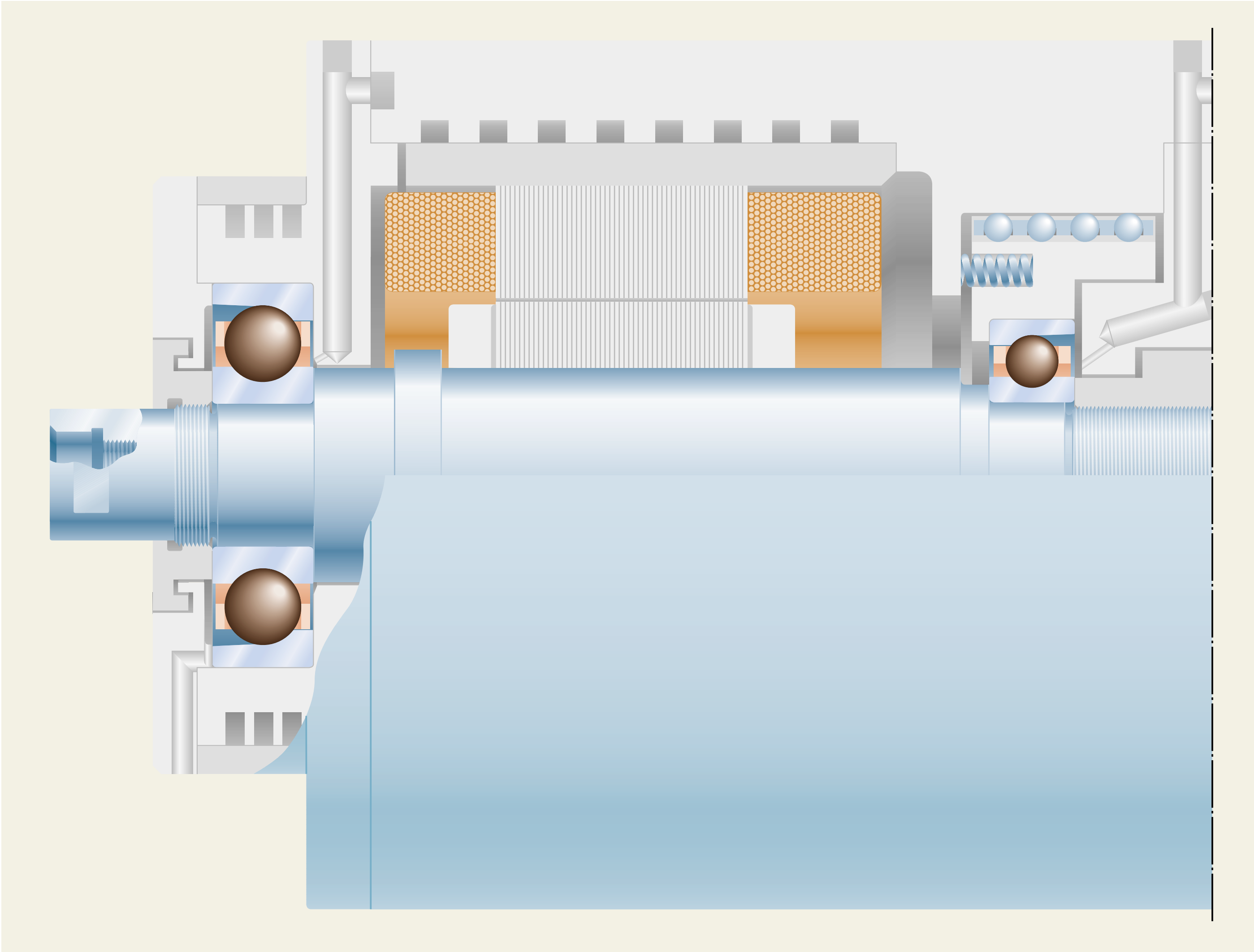
A grinding spindle operated at a speed corresponding to an $n \times d_m$ value of 1 500 000. The spindle was fitted with oil lubricated precision all-steel angular contact ball bearings. The bearings were preloaded to a certain degree because of the required spindle stiffness.

As for the case above an increase in service life was desirable. This was preferably to be achieved without any change of lubricating system or lowering of product quality.

Following elaborate computer analysis of the application, hybrid bearings of the same size and design as the previous all-steel bearings were installed, Consequently bearings of series 72 CD/HCPA9A at the work side and a series 70 CD/HCPA9A bearing at the rear were installed.

The benefit of the change to hybrid bearings was that the bearing life was more than trebled.

Because of the better kinematic behaviour of the hybrid bearings it was possible to dramatically reduce the applied preload without sacrificing stiffness; furthermore, cooler running was obtained. These two factors also contribute to a longer bearing life.



Lubrication and mounting

Bearings should be protected from dirt and moisture, correctly lubricated and mounted for achieving maximum service life. SKF is able to supply both the right grease and relevant mounting tools as well as proven methods for lubrication and mounting. Contact SKF for advice or your special application, if in doubt.

Hybrid bearings are less sensitive to poor lubrication than all-steel bearings. They can, for example, operate at up to 20 % higher speed under the same lubrication conditions compared with all-steel bearings of the same size.

Most hybrid bearing applications can be lubricated by grease. Where speeds are very high the bearings should be lubricated with oil as the service life of the grease is too short under such conditions. Consequently, the high speed bearings of series 70 CC should always be oil lubricated.

It is very important that the lubricant used is clean, i.e. free from contamination of all kinds. Any contaminant particle, even soft, will dramatically shorten the life of the bearing.

Grease lubrication

To use grease lubrication means that the bearing arrangement design can be relatively simple because grease is more easily retained at the bearing position than oil. Grease also contributes to sealing from contaminants and moisture.

Bear in mind that the grease applied should always be free from contaminants.

In most cases a lithium grease with a mineral oil base is suitable for precision bearings. Where demands are high in respect of speed, temperature and service life, the use of bearing greases based on synthetic oils, e.g. the SKF grease LGLT 2 which has a diester oil base, has proved beneficial.

The quantity should never be greater than 30 % of the free space in the bearing. In high speed applications, however, the grease quantity usually should be lower than 30 % (➔ **table 10**).

Please consult the SKF Precision Bearing Catalogue, the SKF General Catalogue and the SKF Bearing Maintenance Handbook for further information.

Running in

Freshly greased bearings should be run at low speed during a running-in phase. This should be done to make sure that the grease is evenly distributed within the bearing and that excess grease can be ejected. If the running-in phase is neglected, there is a risk of temperature peaking which can lead to bearing failure.

Relubrication intervals
The relubrication intervals should be at least as long as those between planned inspections of the machine, since replenishment of grease is not recommended for high speed precision bearings. There is a risk of over-lubrication and hot running.

When relubricating, all the grease should be removed and it should be replaced by the right quantity of fresh grease.

Spindle bearings in general do not operate at constant speeds. In cases where it is important to establish accurate relubrication intervals it is advisable to consult SKF.

Grease charge

Table 10

Bearing bore diameter	Grease charge Bearing series 719 CD 719 ACD	 70 CD 70 ACD	 72 CD 72 ACD	 719 CE	 70 CE
mm	cm^3				
8	–	0,05	–	–	–
9	–	0,06	–	–	–
10	0,04	0,08	0,12	–	–
12	0,04	0,09	0,15	–	–
15	0,07	0,13	0,22	–	–
17	0,08	0,18	0,30	–	–
20	0,15	0,30	0,46	–	–
25	0,18	0,34	0,57	–	–
30	0,21	0,53	0,83	–	–
35	0,31	0,66	1,2	–	–
40	0,48	0,80	1,5	–	–
45	0,54	1,1	1,8	–	–
50	0,58	1,2	2,1	–	–
55	0,83	1,7	2,6	–	–
60	0,90	1,8	3,3	0,87	1,6
65	0,95	1,9	–	0,93	1,7
70	1,5	2,7	–	1,5	2,5
75	1,7	2,8	–	1,6	2,6
80	1,7	3,7	–	1,7	3,6
85	2,4	3,9	–	2,5	3,8
90	2,5	5,0	–	2,6	5,0
95	2,6	5,2	–	2,7	5,1
100	3,5	5,4	–	3,7	5,4
105	3,7	–	–	3,9	–
110	3,8	–	–	4,0	–
120	5,1	–	–	5,5	–
130	6,8	–	–	–	–
140	7,2	–	–	–	–

Oil lubrication

Oil is preferred to grease in those situations where grease is technically or economically unsuitable. Oil lubrication is the choice when the grease lubrication intervals would be too short, or when heat has to be removed from the bearing position.There are several methods of oil lubrication available; oil bath lubrication, circulating oil lubrication, oil drop lubrication, oil jet lubrication, oil mist lubrication and oil spot lubrication. For spindle bearing arrangements, the high operating speeds and requisite low operating temperatures generally require the use of circulating oil lubrication with oil cooling, or the oil spot method.

Like grease, the oil used for hybrid bearings should have a good resistance to oxidation, resist evaporation and should also prevent corrosion. The viscosity of the oil can be determined following recommendations in the SKF General Catalogue.

Oil replacement intervals
Always change a contaminated oil even if it has been recently changed.

Where oil drop, oil mist or oil spot lubrication is used, the oil is lost, i.e. it is only supplied once.

With oil-bath lubrication, it is generally sufficient to change the oil once a year. This is if the bearing temperature is regularly lower than 50 °C. At higher temperatures the oil should be changed more frequently.

With oil circulation, the oil change interval should be determined by inspecting the oil and changing when necessary.

Mounting

The primary rule of bearing maintenance is to keep bearings clean before and during mounting. A variety of factors – faulty mounting techniques or methods, dirty hands or tools, contaminated grease or oil – will most certainly cause bearing damage. Regardless of the quality of the bearings and seals, these factors can quickly lead to bearing failure.

It is easier to prevent bearings from becoming dirty or rusty in the first place than to clean them effectively after they have been contaminated. Single row angular contact ball bearings should be adjusted against one another according to the relevant drawings or to the preload tables on **pages 19 and 20**.

There are several mounting methods which ensure the performance of the high precision hybrid bearings. SKF can supply most of the tools needed to make the mounting safe and fast. There is separate product literature available describing suitable mounting tools. Please contact SKF for discussions about the best methods and tools for your specific purpose.

Mounting the bearing sets

As already mentioned, the bearing should be mounted in the order indicated by the “V” marking. The direction of the axial load should act in the direction the “V” is pointing. Therefore, the set should be turned so that the opening of the “V” faces the direction from which the predominant axial load is being applied to the inner ring.

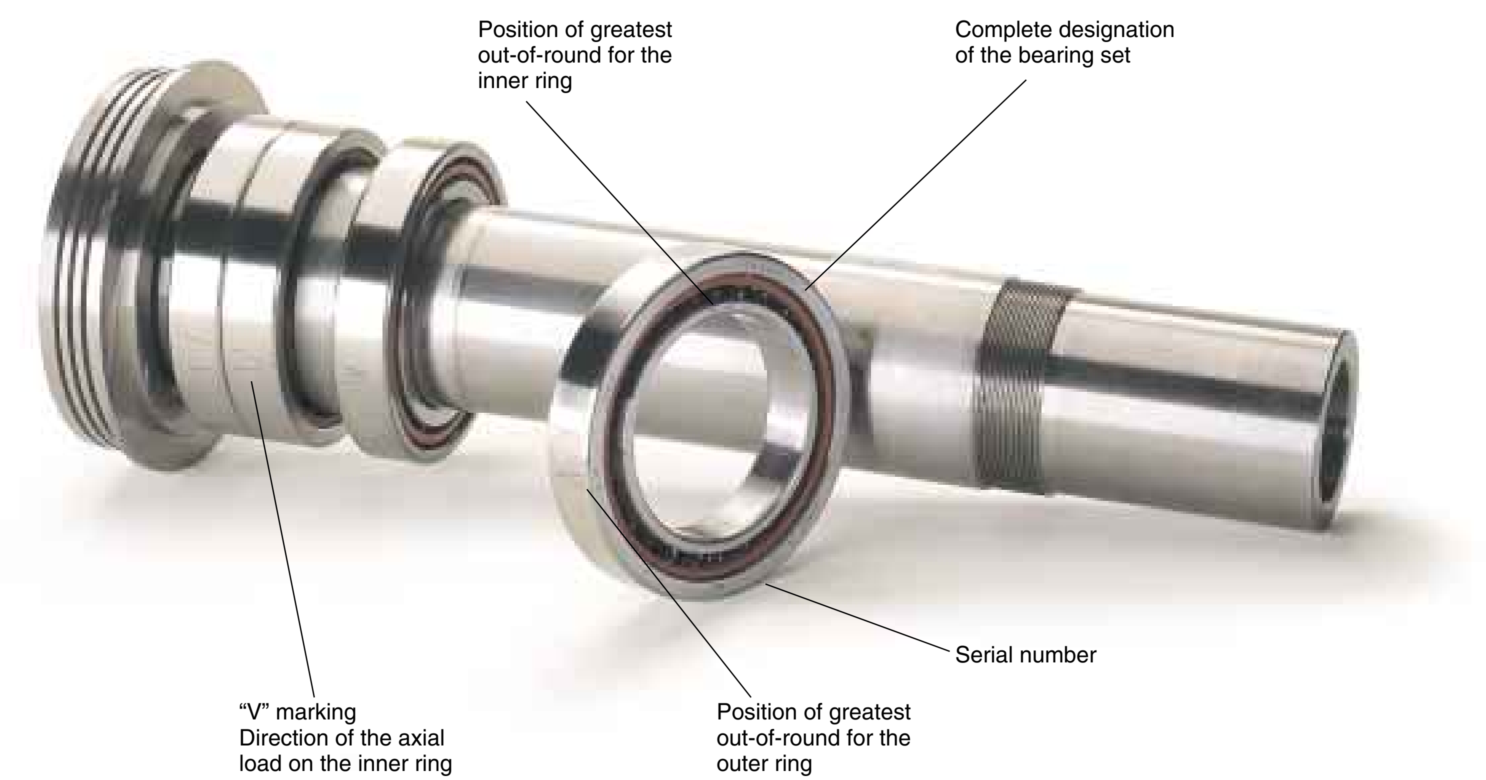
Bearings in sets should be mounted so that the positions of the greatest out-of-round on the inner and outer rings are lined up. Bearing arrangements with particularly high running accuracy are obtained when the bearings are mounted so that the position of greatest out-of-round of the inner ring is opposite to the position of greatest out-of-round of the shaft.

In arrangements where the bearing outer rings rotate, the greatest out-of-round of the outer ring should be diametrically opposed to that of the housing bore.

When spacer sleeves are mounted between the bearings of a matched set, sufficient accuracy is obtained if the sleeves between the inner and outer rings have the same width and flat, parallel faces. This is achieved by machining the sleeves together, for example on a lapping machine.

Of course the order of the bearings shown by the “V” should be maintained even when spacer sleeves are used.

The bearings should be mounted so that a “V” is created. The point of the “V” marking also shows in which direction the axial should act on the inner ring



Preload of bearings in sets after mounting

The preload values quoted in the tables on **pages 19 and 20** apply to the bearing sets before mounting. After mounting, preload usually increases, depending on the fits used and the stiffness of the shaft and housing. However, there is less influence from the internal clearance reduction for the CE design, because of the greater thicknesses of the rings. This is shown in the diagram below (➔ **diagram 2**). It shows the differences in the bearing factor f, which is dependent on ring stiffness and is used to calculate the increase in preload after mounting.

When the bearings are mounted with normal interference fits (shaft eating to tolerance js4 and housing seating to JS5) on a steel shaft and in a steel or cast iron housing with a sufficiently thick wall, the preload of the mounted bearing sets can be calculated with reasonable accuracy from

$$G_m = f\ f_1\ f_2\ G_{A,B}$$

where

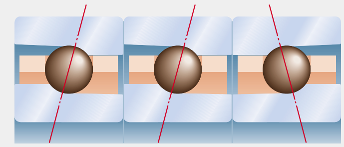
G_m = preload of the mounted bearing sets, N

$G_{A,B}$ = preload of bearing sets before mounting, N (corresponding to the tables on **pages 19 and 20**)

f = bearing factor (➔ **diagram 2**)

f_1 = correction factor depending on the angle of contact (➔ **table 11**)

f_2 = correction factor depending on preload class (➔ **table 11**)



Example

What will be the preload of the bearing set 71920 CE/HCP4ATBTB when mounted?

This is a set of three low section bearings mounted in a combination of back-to-back and tandem arrangement (TBT). The preload is to class B, the last letter in the suffix TBTB.

The value of the bearing factor f = 2,05 from **diagram 2**. The correction factors obtained from **table 11** are f_1 = 1,1 and f_2 for preload class B = 1,07.

From **table 2, page 19,** the preload value G_B is found to be 560 N for a set of two bearings. As there are more than two bearings this factor should be multiplied by factor 1,35 for TBT and TFT (➔ **page 21**). So, for the TBT set $G_B = 560 \times 1{,}35 = 756$ N. Therefore:

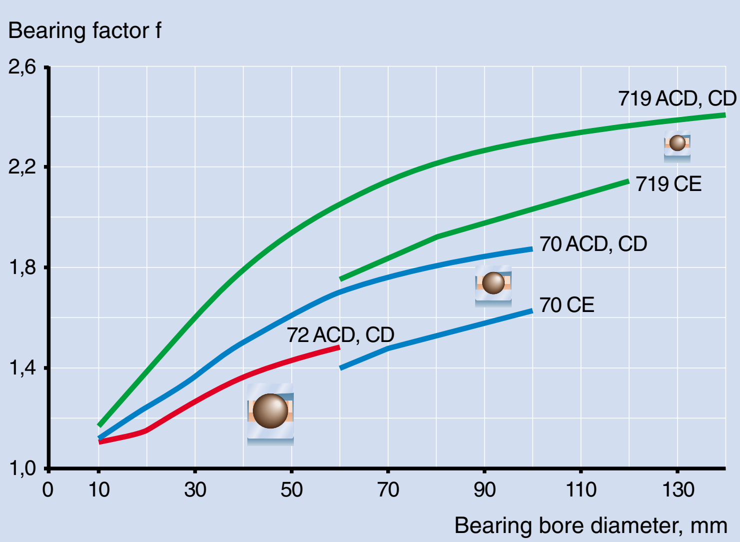
$$G_m = f\ f_1\ f_2\ G_B$$

$$G_m = 2{,}05 \times 1{,}1 \times 1{,}07 \times 756$$

$$= 1\ 824\ \text{N}$$

Bearing factor f

Diagram 2

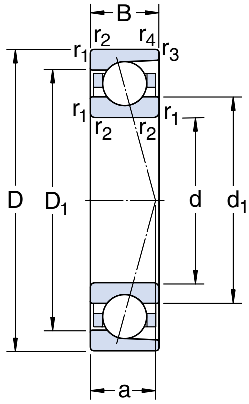


Correction factors f_1 and f_2

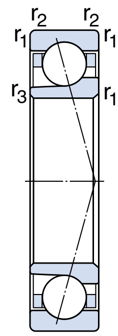
Table 11

Bearing series	Factors f_1	f_2 Preload class A	B
719 ACD/HC	1	0,92	1
719 CD/HC	1,1	0,92	1
719 CE/HC	1,1	1	1,07
70 ACD/HC	1	0,92	1
70 CD/HC	1,07	0,92	1
70 CE/HC	1,07	1	1,07
72 ACD/HC	1	0,92	1
72 CD/HC	1,07	0,92	1

High precision hybrid angular contact ball bearings
d **8 – 17** mm

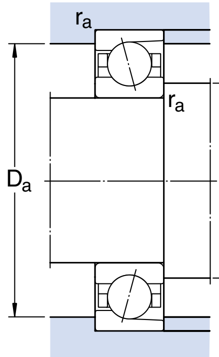


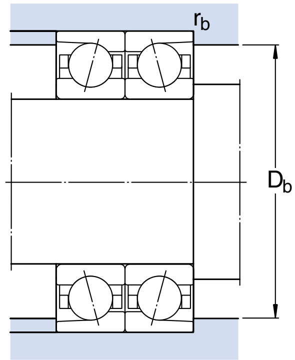
ACD, CD

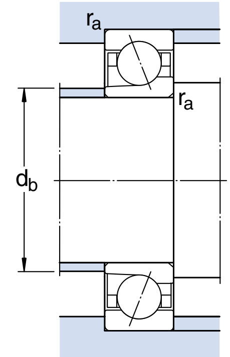


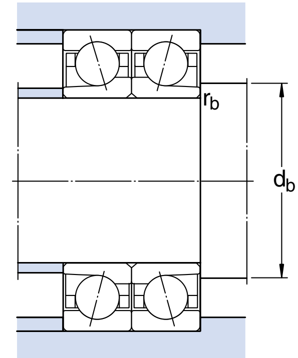
CC

Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Calcu-lation factor	Speed ratings Lubrication grease	oil spot	Mass	Designation
d	D	B	C	C_0	P_u	f_0				
mm			N		N	–	r/min		kg	–
8	22	7	2 960	1 160	49	8,4	80 000	120 000	0,010	**708 CD/HC**
	22	7	2 910	1 120	48	–	75 000	110 000	0,010	**708 ACD/HC**
	22	7	2 550	900	38	6,5	–	170 000	0,011	**708 CC/HC**
9	24	7	3 250	1 340	57	8,8	80 000	120 000	0,012	**709 CD/HC**
	24	7	3 120	1 290	54	–	75 000	110 000	0,012	**709 ACD/HC**
	24	7	2 810	1 040	44	6,8	–	160 000	0,012	**709 CC/HC**
10	22	6	2 510	1 100	48	9,5	80 000	120 000	0,0080	**71900 CD/HC**
	22	6	2 420	1 060	45	–	75 000	110 000	0,0080	**71900 ACD/HC**
	26	8	4 100	1 660	71	8,3	75 000	110 000	0,016	**7000 CD/HC**
	26	8	3 970	1 600	67	–	70 000	100 000	0,016	**7000 ACD/HC**
	26	8	3 510	1 270	54	6,4	–	150 000	0,016	**7000 CC/HC**
	30	9	5 400	2 200	93	8,2	70 000	100 000	0,025	**7200 CD/HC**
	30	9	5 200	2 120	90	–	67 000	95 000	0,025	**7200 ACD/HC**
12	24	6	2 650	1 250	53	9,8	75 000	110 000	0,0090	**71901 CD/HC**
	24	6	2 550	1 180	50	–	70 000	100 000	0,0090	**71901 ACD/HC**
	28	8	4 490	1 900	80	8,7	70 000	100 000	0,017	**7001 CD/HC**
	28	8	4 360	1 830	78	–	67 000	95 000	0,017	**7001 ACD/HC**
	28	8	3 900	1 500	63	6,7	–	140 000	0,017	**7001 CC/HC**
	32	10	5 850	2 550	108	8,5	67 000	95 000	0,032	**7201 CD/HC**
	32	10	5 720	2 450	104	–	60 000	85 000	0,032	**7201 ACD/HC**
15	28	7	3 970	1 900	80	9,6	67 000	95 000	0,013	**71902 CD/HC**
	28	7	3 770	1 800	78	–	63 000	90 000	0,013	**71902 ACD/HC**
	32	9	5 200	2 450	104	9,3	63 000	90 000	0,025	**7002 CD/HC**
	32	9	4 940	2 320	98	–	56 000	80 000	0,025	**7002 ACD/HC**
	32	9	4 420	1 900	80	7,1	–	120 000	0,026	**7002 CC/HC**
	35	11	7 410	3 350	140	8,5	60 000	85 000	0,037	**7202 CD/HC**
	35	11	7 150	3 200	134	–	53 000	75 000	0,037	**7202 ACD/HC**
17	30	7	4 160	2 080	88	9,8	63 000	90 000	0,015	**71903 CD/HC**
	30	7	3 970	2 000	85	–	56 000	80 000	0,015	**71903 ACD/HC**
	35	10	6 760	3 250	137	9,1	56 000	80 000	0,032	**7003 CD/HC**
	35	10	6 500	3 100	132	–	53 000	75 000	0,032	**7003 ACD/HC**
	35	10	5 850	2 550	108	7,0	–	110 000	0,032	**7003 CC/HC**
	40	12	9 230	4 150	176	8,5	53 000	75 000	0,053	**7203 CD/HC**
	40	12	8 840	4 000	170	–	48 000	67 000	0,053	**7203 ACD/HC**



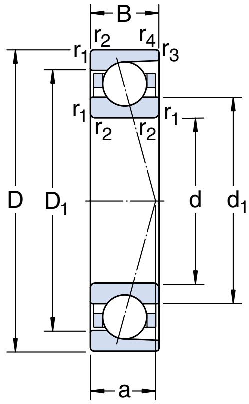




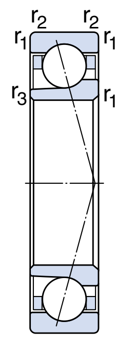


Dimensions						**Abutment and fillet dimensions**					
d	d_1 ≈	D_1 ≈	$r_{1,2}$ min	$r_{3,4}$ min	a	d_a min	d_b min	D_a max	D_b max	r_a max	r_b max
mm						mm					
8	12,6	17,7	0,3	0,1	6	10	–	20	20,4	0,3	0,1
	12,6	17,5	0,3	0,1	7	10	–	20	20,4	0,3	0,1
	12,6	17,4	0,3	0,1	5	10	9,6	20	–	0,3	0,1
9	13,9	19,5	0,3	0,1	6	11	–	22	22,4	0,3	0,1
	13,9	19,2	0,3	0,1	7	11	–	22	22,4	0,3	0,1
	14,1	18,9	0,3	0,1	5,2	11	10,6	22	–	0,3	0,1
10	13,9	18,1	0,3	0,1	5	12	–	20	20,8	0,3	0,1
	13,9	18,1	0,3	0,1	7	12	–	20	20,8	0,3	0,1
	15,1	21,3	0,3	0,1	6	12	–	24	24,4	0,3	0,1
	15,1	21	0,3	0,1	8	12	–	24	24,4	0,3	0,1
	15,1	20,9	0,3	0,1	5,9	12	11,6	24	–	0,3	0,1
	16,8	23,3	0,6	0,3	7	15	–	25	28	0,6	0,3
	16,8	23,3	0,6	0,3	9	15	–	25	28	0,6	0,3
12	15,9	20,1	0,3	0,1	5	14	–	22	22,8	0,3	0,1
	15,9	20,1	0,3	0,1	7	14	–	22	22,8	0,3	0,1
	17,1	23,3	0,3	0,1	7	14	–	26	26,4	0,3	0,1
	17,1	23	0,3	0,1	9	14	–	26	26,4	0,3	0,1
	17,1	22,9	0,3	0,1	6,1	14	13,6	26	–	0,3	0,1
	18,2	25,8	0,6	0,3	8	17	–	27	30	0,6	0,3
	18,2	25,8	0,6	0,3	10	17	–	27	30	0,6	0,3
15	19,1	23,9	0,3	0,1	6	17	–	26	26,8	0,3	0,1
	19,1	23,9	0,3	0,1	9	17	–	26	26,8	0,3	0,1
	20,6	26,8	0,3	0,1	8	17	–	30	30,4	0,3	0,1
	20,6	26,5	0,3	0,1	10	17	–	30	30,4	0,3	0,1
	20,6	26,4	0,3	0,1	7	17	16,6	30	–	0,3	0,1
	21,5	29,1	0,6	0,3	9	20	–	30	33	0,6	0,3
	21,5	29,1	0,6	0,3	12	20	–	30	33	0,6	0,3
17	21,1	25,9	0,3	0,1	7	19	–	28	28,8	0,3	0,1
	21,1	25,9	0,3	0,1	9	19	–	28	28,8	0,3	0,1
	22,9	29,6	0,3	0,1	9	19	–	33	33,4	0,3	0,1
	22,9	29,2	0,3	0,1	11	19	–	33	33,4	0,3	0,1
	22,6	29,3	0,3	0,1	7,7	19	18,6	33	–	0,3	0,1
	24,2	32,8	0,6	0,3	10	22	–	35	38	0,6	0,3
	24,2	32,8	0,6	0,3	13	22	–	35	38	0,6	0,3

High precision hybrid angular contact ball bearings
d **20 – 40** mm

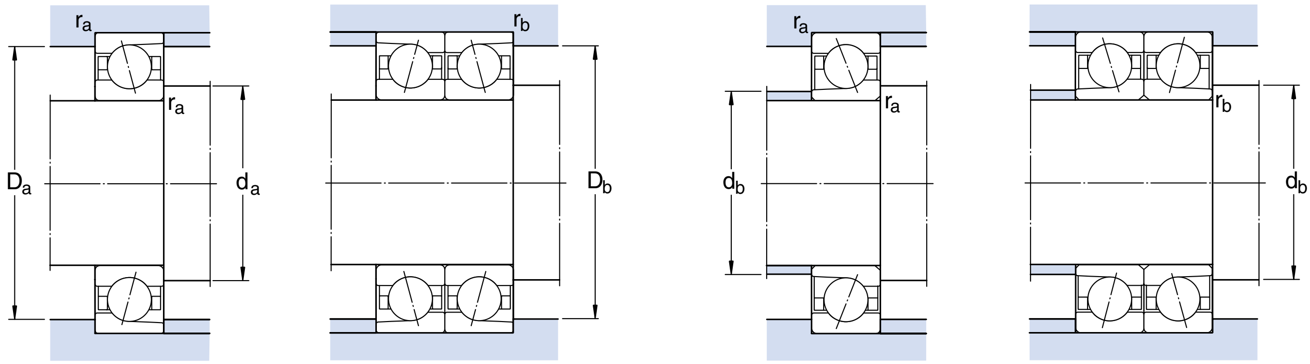


ACD, CD



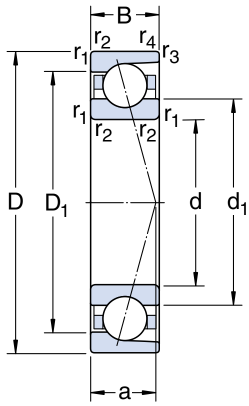
CC

Principal dimensions			**Basic load ratings** dynamic	static	**Fatigue load limit**	**Calcu-lation factor**	**Speed ratings** Lubrication grease	oil spot	**Mass**	**Designation**
d	D	B	C	C_0	P_u	f_0				
mm			N		N	–	r/min		kg	–
20	37	9	6 050	3 200	137	9,8	53 000	75 000	0,031	**71904 CD/HC**
	37	9	5 720	3 050	129	–	48 000	67 000	0,031	**71904 ACD/HC**
	42	12	8 710	4 300	180	9,2	48 000	67 000	0,058	**7004 CD/HC**
	42	12	8 320	4 150	173	–	43 000	60 000	0,058	**7004 ACD/HC**
	42	12	7 410	3 350	143	7,1	–	95 000	0,059	**7004 CC/HC**
	47	14	11 900	5 850	245	8,7	43 000	60 000	0,089	**7204 CD/HC**
	47	14	11 400	5 600	236	–	40 000	56 000	0,089	**7204 ACD/HC**
25	42	9	6 760	4 000	170	10	45 000	63 000	0,037	**71905 CD/HC**
	42	9	6 370	3 800	160	–	40 000	56 000	0,037	**71905 ACD/HC**
	47	12	9 560	5 200	220	9,6	40 000	56 000	0,066	**7005 CD/HC**
	47	12	9 230	5 000	212	–	38 000	53 000	0,066	**7005 ACD/HC**
	47	12	8 190	4 050	173	7,4	–	80 000	0,067	**7005 CC/HC**
	52	15	13 500	7 200	305	9,1	38 000	53 000	0,12	**7205 CD/HC**
	52	15	13 000	6 950	290	–	34 000	48 000	0,12	**7205 ACD/HC**
30	47	9	7 150	4 550	193	10	38 000	53 000	0,043	**71906 CD/HC**
	47	9	6 760	4 300	183	–	34 000	48 000	0,043	**71906 ACD/HC**
	55	13	14 300	8 000	345	9,4	34 000	48 000	0,094	**7006 CD/HC**
	55	13	13 800	7 650	325	–	32 000	45 000	0,094	**7006 ACD/HC**
	55	13	12 400	6 300	265	7,3	–	67 000	0,094	**7006 CC/HC**
	62	16	24 200	16 000	670	14	32 000	45 000	0,17	**7206 CD/HC**
	62	16	23 400	15 300	640	–	28 000	40 000	0,17	**7206 ACD/HC**
35	55	10	9 750	6 550	275	10	32 000	45 000	0,065	**71907 CD/HC**
	55	10	9 230	6 200	260	–	30 000	43 000	0,065	**71907 ACD/HC**
	62	14	15 600	9 500	400	9,7	30 000	43 000	0,13	**7007 CD/HC**
	62	14	14 800	9 000	380	–	26 000	38 000	0,13	**7007 ACD/HC**
	62	14	13 500	7 500	315	7,6	–	60 000	0,13	**7007 CC/HC**
	72	17	31 900	21 600	915	14	26 000	38 000	0,24	**7207 CD/HC**
	72	17	30 700	20 800	880	–	22 000	34 000	0,24	**7207 ACD/HC**
40	62	12	12 400	8 500	360	10	28 000	40 000	0,096	**71908 CD/HC**
	62	12	11 700	8 000	340	–	24 000	36 000	0,096	**71908 ACD/HC**
	68	15	16 800	11 000	465	10	26 000	38 000	0,16	**7008 CD/HC**
	68	15	15 900	10 400	440	–	22 000	34 000	0,16	**7008 ACD/HC**
	68	15	14 600	8 650	365	7,8	–	53 000	0,16	**7008 CC/HC**
	80	18	41 000	28 000	1 180	14	22 000	34 000	0,30	**7208 CD/HC**
	80	18	39 000	27 000	1 140	–	20 000	32 000	0,30	**7208 ACD/HC**

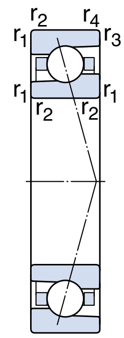


Dimensions						Abutment and fillet dimensions					
d	d_1 ≈	D_1 ≈	$r_{1,2}$ min	$r_{3,4}$ min	a	d_a min	d_b min	D_a max	D_b max	r_a max	r_b max
mm						mm					
20	25,4	31,6	0,3	0,15	8	22	–	35	35,8	0,3	0,1
	25,4	31,6	0,3	0,15	11	22	–	35	35,8	0,3	0,1
	26,9	35,1	0,6	0,3	10	25	–	37	40	0,6	0,3
	26,9	35,1	0,6	0,3	13	25	–	37	40	0,6	0,3
	27,1	34,8	0,6	0,3	9,2	25	22	37	–	0,6	0,3
	29,1	38,7	1	0,3	12	26	–	41	45	1	0,3
	29,1	38,7	1	0,3	15	26	–	41	45	1	0,3
25	30,4	36,6	0,3	0,15	9	27	–	40	40,8	0,3	0,1
	30,4	36,6	0,3	0,15	12	27	–	40	40,8	0,3	0,1
	31,9	40,1	0,6	0,3	11	30	–	42	45	0,6	0,3
	31,9	40,1	0,6	0,3	15	30	–	42	45	0,6	0,3
	32,1	39,9	0,6	0,3	9,8	30	27	42	–	0,6	0,3
	34,1	43,7	1	0,3	13	31	–	46	50	1	0,3
	34,1	43,7	1	0,3	17	31	–	46	50	1	0,3
30	35,4	41,6	0,3	0,15	10	32	–	45	45,8	0,3	0,1
	35,4	41,6	0,3	0,15	14	32	–	45	45,8	0,3	0,1
	38,1	46,9	1	0,3	12	36	–	49	53	1	0,3
	38,1	46,9	1	0,3	17	36	–	49	53	1	0,3
	37,7	47,3	1	0,3	11	36	32	49	–	1	0,3
	40,3	51,7	1	0,3	14	36	–	56	60	1	0,3
	40,3	51,7	1	0,3	19	36	–	56	60	1	0,3
35	41,2	48,8	0,6	0,15	11	40	–	50	53,8	0,6	0,1
	41,2	48,8	0,6	0,15	16	40	–	50	53,8	0,6	0,1
	43,7	53,3	1	0,3	14	41	–	56	60	1	0,3
	43,7	53,3	1	0,3	19	41	–	56	60	1	0,3
	43,7	53,3	1	0,3	12	41	37	56	–	1	0,3
	47	60	1,1	0,3	16	42	–	65	70	1	0,3
	47	60	1,1	0,3	21	42	–	65	70	1	0,3
40	46,7	55,3	0,6	0,15	13	45	–	57	60,8	0,6	0,1
	46,7	55,3	0,6	0,15	18	45	–	57	60,8	0,6	0,1
	49,2	58,8	1	0,3	15	46	–	62	66	1	0,3
	49,2	58,8	1	0,3	20	46	–	62	66	1	0,3
	49,2	58,8	1	0,3	13	46	42	62	–	1	0,3
	53	67	1,1	0,6	17	47	–	73	75	1	0,6
	53	67	1,1	0,6	23	47	–	73	75	1	0,6

High precision hybrid angular contact ball bearings
d **45 – 65** mm

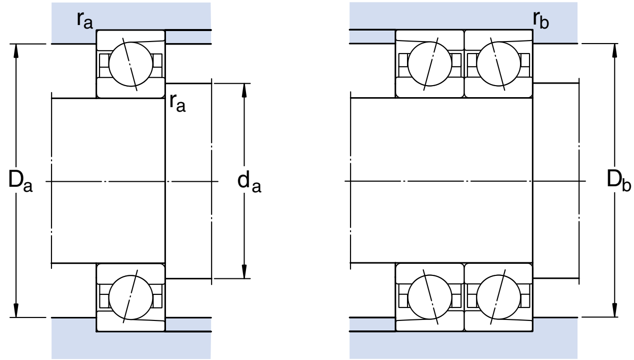


ACD, CD



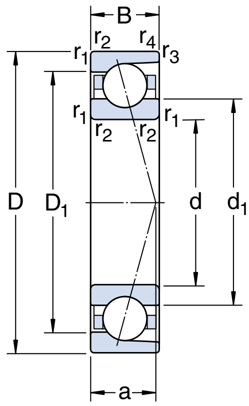
CE

Principal dimensions			**Basic load ratings** dynamic	static	**Fatigue load limit**	**Calcu-lation factor**	**Speed ratings** Lubrication grease	oil spot	**Mass**	**Designation**
d	D	B	C	C_0	P_u	f_0				
mm			N		N	–	r/min		kg	–
45	68	12	13 000	9 500	400	11	24 000	36 000	0,11	**71909 CD/HC**
	68	12	12 400	9 000	380	–	22 000	34 000	0,11	**71909 ACD/HC**
	75	16	28 600	22 400	950	15	22 000	34 000	0,20	**7009 CD/HC**
	75	16	27 600	21 600	900	–	20 000	32 000	0,20	**7009 ACD/HC**
	85	19	42 300	31 000	1 320	14	20 000	32 000	0,34	**7209 CD/HC**
	85	19	41 000	30 000	1 250	–	18 000	28 000	0,34	**7209 ACD/HC**
50	72	12	13 500	10 400	440	11	22 000	34 000	0,11	**71910 CD/HC**
	72	12	12 700	9 800	415	–	19 000	30 000	0,11	**71910 ACD/HC**
	80	16	29 600	24 000	1 020	15	20 000	32 000	0,21	**7010 CD/HC**
	80	16	28 100	23 200	980	–	18 000	28 000	0,21	**7010 ACD/HC**
	90	20	44 900	34 000	1 430	15	19 000	30 000	0,38	**7210 CD/HC**
	90	20	42 300	32 500	1 390	–	17 000	26 000	0,38	**7210 ACD/HC**
55	80	13	19 500	14 600	620	10	19 000	30 000	0,15	**71911 CD/HC**
	80	13	18 200	13 700	585	–	18 000	28 000	0,15	**71911 ACD/HC**
	90	18	39 700	32 500	1 370	15	18 000	28 000	0,31	**7011 CD/HC**
	90	18	37 100	31 000	1 320	–	17 000	26 000	0,31	**7011 ACD/HC**
	100	21	55 300	43 000	1 800	14	17 000	26 000	0,51	**7211 CD/HC**
	100	21	52 700	40 500	1 730	–	16 000	24 000	0,51	**7211 ACD/HC**
60	85	13	19 900	15 300	655	11	18 000	28 000	0,16	**71912 CD/HC**
	85	13	18 600	14 600	620	–	17 000	26 000	0,16	**71912 ACD/HC**
	85	13	13 500	12 200	520	11	24 000	36 000	0,17	**71912 CE/HC**
	95	18	40 300	34 500	1 500	15	17 000	26 000	0,34	**7012 CD/HC**
	95	18	39 000	33 500	1 400	–	16 000	24 000	0,34	**7012 ACD/HC**
	95	18	19 000	16 300	680	11	20 000	32 000	0,36	**7012 CE/HC**
	110	22	67 600	53 000	2 240	14	16 000	24 000	0,65	**7212 CD/HC**
	110	22	63 700	50 000	2 120	–	15 000	22 000	0,65	**7212 ACD/HC**
65	90	13	20 800	17 000	710	11	17 000	26 000	0,17	**71913 CD/HC**
	90	13	19 500	16 000	680	–	16 000	24 000	0,17	**71913 ACD/HC**
	90	13	14 000	13 295	560	11	20 000	32 000	0,18	**71913 CE/HC**
	100	18	41 600	37 500	1 600	16	16 000	24 000	0,36	**7013 CD/HC**
	100	18	39 000	35 500	1 500	–	15 000	22 000	0,36	**7013 ACD/HC**
	100	18	19 900	17 600	750	11	19 000	30 000	0,36	**7013 CE/HC**

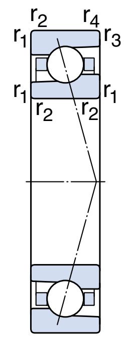


Dimensions						**Abutment and fillet dimensions**				
d	d_1 ≈	D_1 ≈	$r_{1,2}$ min	$r_{3,4}$ min	a	d_a min	D_a max	D_b max	r_a max	r_b max
mm						mm				
45	52,2	60,8	0,6	0,15	14	50	63	66,8	0,6	0,1
	52,2	60,8	0,6	0,15	19	50	63	66,8	0,6	0,1
	54,7	65,3	1	0,3	16	51	69	73	1	0,3
	54,7	65,3	1	0,3	22	51	69	73	1	0,3
	57,5	72,5	1,1	0,6	18	52	78	80	1	0,6
	57,5	72,5	1,1	0,6	25	52	78	80	1	0,6
50	56,7	65,3	0,6	0,15	14	55	67	70,8	0,6	0,1
	56,7	65,3	0,6	0,15	20	55	67	70,8	0,6	0,1
	59,7	70,3	1	0,3	17	56	74	78	1	0,3
	59,7	70,3	1	0,3	23	56	74	78	1	0,3
	62,5	77,5	1,1	0,6	20	57	83	85	1	0,6
	62,5	77,5	1,1	0,6	27	57	83	85	1	0,6
55	62,7	72,3	1	0,3	16	61	74	78	1	0,3
	62,7	72,3	1	0,3	22	61	74	78	1	0,3
	66,3	78,7	1,1	0,6	19	62	83	86	1	0,6
	66,3	78,7	1,1	0,6	26	62	83	86	1	0,6
	69	85,9	1,5	0,6	21	64	91	95	1,5	0,6
	69	85,9	1,5	0,6	29	64	91	95	1,5	0,6
60	67,7	77,3	1	0,3	16	66	79	83	1	0,3
	67,7	77,3	1	0,3	23	66	79	83	1	0,3
	68,6	76,4	1	0,3	16	66	79	83	1	0,3
	71,3	83,7	1,1	0,6	20	67	88	91	1	0,6
	71,3	83,7	1,1	0,6	27	67	88	91	1	0,6
	72,7	82,3	1,1	0,6	19	67	88	91	1	0,6
	75,6	94,4	1,5	0,6	23	69	101	105	1,5	0,6
	75,6	94,4	1,5	0,6	31	69	101	105	1,5	0,6
65	72,7	82,3	1	0,3	17	71	84	88	1	0,3
	72,7	82,3	1	0,3	25	71	84	88	1	0,3
	73,6	81,4	1	0,3	16	71	84	88	1	0,3
	76,3	88,7	1,1	0,6	20	72	93	96	1	0,6
	76,3	88,7	1,1	0,6	28	72	93	96	1	0,6
	77,7	87,3	1,1	0,6	20	72	93	96	1	0,6

High precision hybrid angular contact ball bearings
d **70 – 95** mm

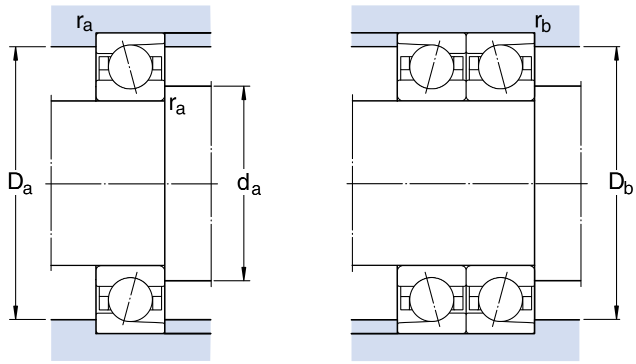


ACD, CD



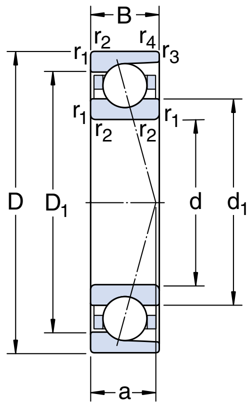
CE

Principal dimensions d	D	B	**Basic load ratings** dynamic C	static C_0	**Fatigue load limit** P_u	**Calcu-lation factor** f_0	**Speed ratings** Lubrication grease	oil spot	**Mass**	**Designation**
mm			N		N	–	r/min		kg	–
70	100	16	34 500	34 000	1 430	16	16 000	24 000	0,28	**71914 CD/HC**
	100	16	32 500	32 500	1 370	–	15 000	22 000	0,28	**71914 ACD/HC**
	100	16	20 300	18 300	780	11	19 000	30 000	0,29	**71914 CE/HC**
	110	20	52 000	45 500	1 930	15	15 000	22 000	0,49	**7014 CD/HC**
	110	20	48 800	44 000	1 860	–	14 000	20 000	0,49	**7014 ACD/HC**
	110	20	27 000	23 600	1 000	11	18 000	28 000	0,53	**7014 CE/HC**
75	105	16	35 800	37 500	1 560	16	15 000	22 000	0,30	**71915 CD/HC**
	105	16	33 800	35 500	1 500	–	14 000	20 000	0,30	**71915 ACD/HC**
	105	16	20 300	19 300	815	11	18 000	28 000	0,30	**71915 CE/HC**
	115	20	52 700	49 000	2 080	16	15 000	22 000	0,52	**7015 CD/HC**
	115	20	49 400	46 500	1 960	–	13 000	19 000	0,52	**7015 ACD/HC**
	115	20	27 000	24 500	1 040	11	17 000	26 000	0,56	**7015 CE/HC**
80	110	16	36 400	39 000	1 660	16	15 000	22 000	0,31	**71916 CD/HC**
	110	16	34 500	36 500	1 560	–	13 000	19 000	0,31	**71916 ACD/HC**
	110	16	21 200	20 800	880	11	17 000	26 000	0,32	**71916 CE/HC**
	125	22	65 000	61 000	2 550	16	14 000	20 000	0,71	**7016 CD/HC**
	125	22	62 400	58 500	2 450	–	12 000	18 000	0,71	**7016 ACD/HC**
	125	22	34 500	30 500	1 270	11	16 000	24 000	0,74	**7016 CE/HC**
85	120	18	46 200	48 000	2 040	16	14 000	20 000	0,44	**71917 CD/HC**
	120	18	43 600	45 500	1 930	–	12 000	18 000	0,44	**71917 ACD/HC**
	120	18	28 100	27 000	1 120	11	16 000	24 000	0,45	**71917 CE/HC**
	130	20	67 600	65 500	2 650	16	13 000	19 000	0,74	**7017 CD/HC**
	130	20	63 700	62 000	2 500	–	11 000	17 000	0,74	**7017 ACD/HC**
	130	20	35 100	32 000	1 320	11	16 000	24 000	0,77	**7017 CE/HC**
90	125	18	47 500	51 000	2 080	16	13 000	19 000	0,47	**71918 CD/HC**
	125	18	44 200	48 000	1 960	–	11 000	17 000	0,47	**71918 ACD/HC**
	125	18	29 100	29 000	1 180	11	16 000	24 000	0,47	**71918 CE/HC**
	140	24	79 300	76 500	3 000	16	12 000	18 000	0,95	**7018 CD/HC**
	140	24	74 100	72 000	2 850	–	10 000	16 000	0,95	**7018 ACD/HC**
	140	24	44 200	40 000	1 560	11	15 000	22 000	0,95	**7018 CE/HC**
95	130	18	49 400	55 000	2 200	16	12 000	18 000	0,49	**71919 CD/HC**
	130	18	46 200	52 000	2 080	–	10 000	16 000	0,49	**71919 ACD/HC**
	130	18	29 600	30 000	1 200	11	15 000	22 000	0,49	**71919 CE/HC**
	145	24	81 900	80 000	3 100	16	11 000	17 000	1,00	**7019 CD/HC**
	145	24	76 100	76 500	2 900	–	9 500	15 000	1,00	**7019 ACD/HC**
	145	24	44 900	41 500	1 600	11	14 000	20 000	1,03	**7019 CE/HC**

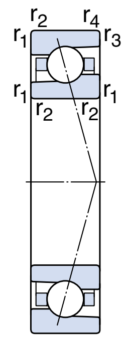


Dimensions						Abutment and fillet dimensions				
d	d_1 ≈	D_1 ≈	$r_{1,2}$ min	$r_{3,4}$ min	a	d_a min	D_a max	D_b max	r_a max	r_b max
mm						mm				
70	79,3	90,7	1	0,3	19	76	94	98	1	0,3
	79,3	90,7	1	0,3	28	76	94	98	1	0,3
	80,2	89,8	1	0,3	19	76	94	98	1	0,3
	82,9	97,1	1,1	0,6	22	77	103	106	1	0,6
	82,9	97,1	1,1	0,6	31	77	103	106	1	0,6
	84,2	95,8	1,1	0,6	22	77	103	106	1	0,6
75	84,3	95,7	1	0,3	20	81	99	103	1	0,3
	84,3	95,7	1	0,3	29	81	99	103	1	0,3
	85,2	94,8	1	0,3	20	81	99	103	1	0,3
	87,9	103	1,1	0,6	23	82	108	111	1	0,6
	87,9	103	1,1	0,6	32	82	108	111	1	0,6
	89,2	100,8	1,1	0,6	23	82	108	111	1	0,6
80	89,3	101	1	0,3	21	86	104	108	1	0,3
	89,3	101	1	0,3	30	86	104	108	1	0,3
	90,2	99,8	1	0,3	21	86	104	108	1	0,3
	94,4	111	1,1	0,6	25	87	118	121	1	0,6
	94,4	111	1,1	0,6	35	87	118	121	1	0,6
	95,8	109,2	1,1	0,6	25	87	118	121	1	0,6
85	95,8	110	1,1	0,6	23	92	113	115	1	0,6
	95,8	110	1,1	0,6	33	92	113	115	1	0,6
	96,7	108,3	1,1	0,6	22	92	113	115	1	0,6
	99,4	116	1,1	0,6	26	92	123	126	1	0,6
	99,4	116	1,1	0,6	36	92	123	126	1	0,6
	100,8	114,2	1,1	0,6	25	92	123	126	1	0,6
90	100	115	1,1	0,6	23	97	118	120	1	0,6
	100	115	1,1	0,6	34	97	118	120	1	0,6
	101,7	113,3	1,1	0,6	24	97	118	120	1	0,6
	106	124	1,5	0,6	28	99	131	136	1,5	0,6
	106	124	1,5	0,6	39	99	131	136	1,5	0,6
	107,3	122,7	1,5	0,6	28	99	131	136	1,5	0,6
95	105	120	1,1	0,6	24	102	123	125	1	0,6
	105	120	1,1	0,6	35	102	123	125	1	0,6
	106,7	118,3	1,1	0,6	24	102	123	125	1	0,6
	111	129	1,5	0,6	28	104	136	140	1,5	0,6
	111	129	1,5	0,6	40	104	136	140	1,5	0,6
	112,3	127,7	1,5	0,6	28	104	136	140	1,5	0,6

High precision hybrid angular contact ball bearings
d **100 – 140** mm

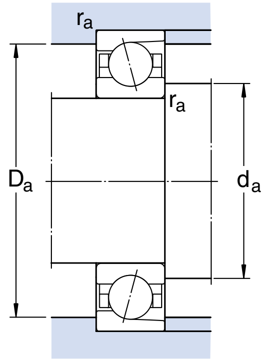


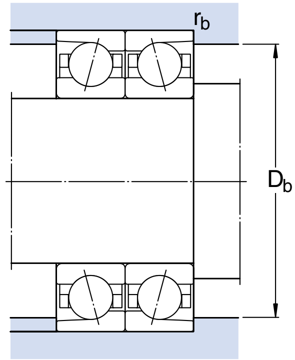
ACD, CD



CE

Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Calcu-lation factor	Speed ratings Lubrication grease	oil spot	Mass	Designation
d	D	B	C	C_0	P_u	f_0				
mm			N		N	–	r/min		kg	–
100	140	20	60 500	65 500	2 550	16	11 000	17 000	0,66	**71920 CD/HC**
	140	20	57 200	63 000	2 400	–	9 500	15 000	0,66	**71920 ACD/HC**
	140	20	37 100	36 500	1 400	11	14 000	20 000	0,66	**71920 CE/HC**
	150	24	83 200	85 000	3 200	16	10 000	16 000	1,05	**7020 CD/HC**
	150	24	79 300	80 000	3 050	–	9 500	15 000	1,05	**7020 ACD/HC**
	150	24	46 200	43 000	1 630	11	14 000	20 000	1,10	**7020 CE/HC**
105	145	20	61 800	69 500	2 600	16	10 000	16 000	0,69	**71921 CD/HC**
	145	20	57 200	65 500	2 500	–	9 500	15 000	0,69	**71921 ACD/HC**
	145	20	39 000	39 000	1 500	11	14 000	20 000	0,69	**71921 CE/HC**
110	150	20	62 400	72 000	2 700	17	10 000	16 000	0,72	**71922 CD/HC**
	150	20	58 500	68 000	2 550	–	9 000	14 000	0,72	**71922 ACD/HC**
	150	20	39 000	40 500	1 500	11	13 000	19 000	0,72	**71922 CE/HC**
120	165	22	78 000	91 500	3 250	16	9 000	14 000	0,97	**71924 CD/HC**
	165	22	72 800	86 500	3 050	–	8 500	13 000	0,97	**71924 ACD/HC**
	165	22	48 800	51 000	1 800	11	11 000	17 000	0,97	**71924 CE/HC**
130	180	24	92 300	108 000	3 650	16	8 500	13 000	1,30	**71926 CD/HC**
	180	24	87 100	102 000	3 450	–	8 000	12 000	1,30	**71926 ACD/HC**
140	190	24	95 600	116 000	3 900	17	8 000	12 000	1,35	**71928 CD/HC**
	190	24	90 400	110 000	3 650	–	7 500	11 000	1,35	**71928 ACD/HC**





Dimensions						Abutment and fillet dimensions				
d	d_1 ≈	D_1 ≈	$r_{1,2}$ min	$r_{3,4}$ min	a	d_a min	D_a max	D_b max	r_a max	r_b max
mm						mm				
100	112	128	1,1	0,6	26	107	133	135	1	0,6
	112	128	1,1	0,6	38	107	133	135	1	0,6
	113,3	126,7	1,1	0,6	26	107	133	135	1	0,6
	116	134	1,5	0,6	29	109	141	145	1,5	0,6
	116	134	1,5	0,6	41	109	141	145	1,5	0,6
	117,3	132,7	1,5	0,6	29	109	141	145	1,5	0,6
105	117	133	1,1	0,6	27	112	138	140	1	0,6
	117	133	1,1	0,6	39	112	138	140	1	0,6
	118,3	131,7	1,1	0,6	26	112	138	140	1	0,6
110	122	138	1,1	0,6	27	117	143	145	1	0,6
	122	138	1,1	0,6	40	117	143	145	1	0,6
	123,3	136,7	1,1	0,6	28	117	143	145	1	0,6
120	133	152	1,1	0,6	30	127	158	160	1	0,6
	133	152	1,1	0,6	44	127	158	160	1	0,6
	134,8	150,2	1,1	0,6	30	127	158	160	1	0,6
130	145	165	1,5	0,6	34	139	171	175	1,5	0,6
	145	165	1,5	0,6	49	139	171	175	1,5	0,6
140	155	175	1,5	0,6	33	149	181	185	1,5	0,6
	155	175	1,5	0,6	48	149	181	185	1,5	0,6

The SKF group – a worldwide corporation

SKF is an international industrial Group operating in some 130 countries and is world leader in bearings.

The company was founded in 1907 following the invention of the self-aligning ball bearing by Sven Wingquist and, after only a few years, SKF began to expand all over the world.

Today, SKF has some 44 000 employees and more than 70 manufacturing facilities spread throughout the world. An international sales network includes a large number of sales companies and over 20 000 distributors and retailers. Worldwide availability of SKF products is supported by a comprehensive technical advisory service.

The key to success has been a consistent emphasis on maintaining the highest quality of its products and services. Continuous investment in research and development has also played a vital role, resulting in many examples of epoch-making innovations.

The business of the Group consists of bearings, seals, special steel and a comprehensive range of other high-tech industrial components. The experience gained in these various fields provides SKF with the essential knowledge and expertise required in order to provide the customers with the most advanced engineering products and efficient service.

The SKF house colours are blue and red, but the thinking is green. The latest example is the new factory in Malaysia, where the bearing component cleaning process conforms to the strictest ecological standards. Instead of trichloroethylene, a water-based cleaning fluid is used in a closed system. The cleaning fluid is recycled in the factory's own treatment plant.

The SKF Engineering & Research Centre is situated just outside Utrecht in The Netherlands. In an area of 17 000 square metres (185 000 sq.ft) some 150 scientists, engineers and support staff are engaged in the further improvement of bearing performance. They are developing technologies aimed at achieving better materials, better designs, better lubricants and better seals – together leading to an even better understanding of the operation of a bearing in its application. This is also where the SKF New Life Theory was evolved, enabling the design of bearings which are even more compact and offer even longer operational life.

SKF has developed the Channel concept in factories all over the world. This drastically reduces the lead time from raw material to end product as well as work in progress and finished goods in stock. The concept enables faster and smoother information flow, eliminates bottlenecks and bypasses unnecessary steps in production. The Channel team members have the knowledge and commitment needed to share the responsibility for fulfilling objectives in areas such as quality, delivery time, production flow etc.

SKF manufactures ball bearings, roller bearings and plain bearings. The smallest are just a few millimetres (a fraction of an inch) in diameter, the largest several metres. In order to protect the bearings effectively against the ingress of contamination and the escape of lubricant, SKF also manufactures oil and bearing seals. SKF's subsidiaries CR and RFT S.p.A. are among the world's largest producers of seals.

Publication **Dd 7817/II E**

Printed in Sweden on environmentally friendly paper by Halls Offset AB