## Bearing retention and clearances

Bearing retention ..... 90

- Radial retention ..... 90
- Axial retention ..... 91
Positioning of single bearing assemblies ..... 91
Positioning of two bearing assemblies ..... 92
- Axial retention processes ..... 93
Bearing seats ..... 96
- Bearing tolerances ..... 96
$\square$ Shaft and housing seat tolerances ..... 97
$\square$ Recommended fits ..... 98
- Value of tolerances and fits ..... 100
Geometry and surface conditions of shaft and housing seats ..... 106
Radial clearance of radial contact bearings ..... 109
$\square$ Residual radial clearance : definition, calculation ..... 109
Ratio of interference effect on clearance ..... 109
Residual clearance after fitting: $J_{r m}$ ..... 110
Choice of internal clearance as a function of shaft and housing fits ..... 112
Calculation of residual clearance in operation ..... 112
Axial clearance of angular contact bearings ..... 115
Axial preload ..... 115
Axial penetration and prelaod ..... 115
Determining the preload ..... 116
Adjustment ..... 117
$\square$ Theoretical calculation of the variation in the axial clearance of an assembly ..... 117
Modification of clearance on assembly ..... 117
Theorical calculation of the variation in the axial clearance of an assembly ..... 118


## Bearing retention

## Radial retention

The bearing rings must be assembled with the mounting elements (shaft and housing) such that they become an integral part of them. The means of connection must prevent any relative movement of the rings on their seat under the radial and axial loads, while maintaining the precision of the bearing, its operating clearance, its limit loads, speed, temperature, etc.

Under the action of the radial load, one of the two rings of a rotating bearing is "rolled" between the rolling elements and its seat, and tends to turn on it. This relative displacement must be prevented to avoid wearing of the seat (bearing hardness: 62 HRC).

## General rule

The ring that rotates with respect to the load direction must be press fitted on its seat.

|  | Analysis of rotation (cases frequency) |  | Retention principle |
| :---: | :---: | :---: | :---: |
| Load stationary with respect to the outer ring | Stationary housing and load (95\%) <br> Rotating inner ring | Rotating housing and load (0.05 \%) <br> Stationary inner ring | Inner ring interference-fitted on shaft |
| Load stationary with respect to the inner ring | Stationary shaft and load (3\%) <br> Outer ring rotating | Rotating shaft and load <br> Outer ring stationary | Outer ring interference-fitted in the housing |

The bearing rings are usually retained with an interference fit. Other methods of retention do exist as: adapter sleeves (see page 139), eccentric locking collars or set screw on inner ring, gluing, etc. The seat fits are chosen from Standard ISO 286 according to the bearing operating criteria.

The bearings secure the axial positioning of the rotating part of a component with respect to the stationary part.

## Positioning of single bearing assemblies

Retention of bearing assemblies requires one bearing to float axially to prevent stresses due to thermal expansion


Stationary bearing F

Floating bearing L

Floating bearing L1

D the bearing must be positioned by the axial retention of the inner ring and the outer ring

D possible bearing types


D only the tight fitted ring is axially held, the other is loose D possible bearing types


Dith cylindrical roller bearings type N or NU , in which axial mobility is ensured by the bearing itself, the two bearing rings are retained

D possible bearing types


## Fixed assembly with two bearings

The fixed assembly may be made up of two associated bearings, depending on the assembly specifications.

## Bearing retention (continued)

$\Rightarrow$ Positioning of two bearing assemblies
$\square$ The principle of this assembly is to have one assembly limiting axial displacement of the shaft in one axial direction, while the other assembly limits it in the opposite direction.

This implies that one of the bearing rings must be free to move axially on its seat to permit assembly. The operating axial displacement then depends on the axial adjustment of the relative position of the inner rings with respect to the outer rings.

| Types |
| :---: |
| of bearings |


| Predominant radial interference |
| :---: |
| on inner ring | | Predominant radial interference |
| :---: |
| on outer ring |

## Radial contact bearings

This type of assembly can be used with the various types of radial contact bearings: ball bearings, cylindrical roller bearings, self-aligning and spherical bearings. A minimum axial displacement must apply, which varies according to the types of assembly.


## Angular contact bearings

Angular contact bearings get their rigidity through their fitting. They have to be adjusted to secure the relative positioning and the operating clearance.

Two types of assembly are possible:

Face-to-face assembly (0): the points of load application are located outside the bearings.


Back-to-back assembly (X): the points of load application are located between the bearings.


## Axial retention processes

Inner ring
Nut and washer


Cylindrical seat. Tight fit against shoulder.


Tapered seat, therefore bearing with tapered bore.
Preferential direction of axial thrust ( $\rightarrow$ ).


Easy and fast to fit, occupies little space.


A thrust washer must be installed between the inner ring and the snap ring if axial load is high.

## Bearing retention (continued)

## Adjusting ring

Reserved for shaft ends.


Press fit ring
Preferential direction of axial thrust $(\boldsymbol{\rightarrow})$.
The ring has to be destroyed to remove the bearing.


## Sleeve

Preferential direction of axial thrust ( $\boldsymbol{\rightarrow}$ ).
Does not need precise machining of the shaft.
Above all used for spherical roller bearings.


Outer ring

## Cap

Necessary gap between cap and face of casing.


Snap ring


Easy and quick to mount, occupies little space.


A thrust washer must be installed between the outer ring and the snap ring if axial load is high.

Note : the snap ring (with or without a thrust washer) can replace a shoulder.

Snap ring built in the bearing (type NR bearing)


Necessary gap between the cap and the face of the housing.


In the particular case where the housing is in two parts, the ring can be installed between the two parts.

## Bearing seats

## Bearing tolerances

Under the action of the radial load, one of the two rings of a rotating bearing tends to turn. To avoid wearing the seat, this relative displacement must be prevented by having an appropriate fit. The fit of the other ring will allow axial displacement on the seat (adjustment, thermal expansion).

Standard precision bearing tolerances

## Inner ring

Deviation with respect to the nominal bore


Other precision classes, see page 23.

## Outer ring

Deviation with respect to the nominal diameter


Or.

## Shaft and housing seat tolerances

The shafts are generally machined in tolerances of quality 6 or sometimes 5 . The housings, which are more difficult to machine, are usually in quality 7 or sometimes 6 tolerances.

- Fundamental tolerance values (taken from Standard ISO 286).

| Diameter <br> mm | Quality |  |  |
| :---: | ---: | :---: | :---: |
|  | 5 | 6 | 7 |
| $>3$ to 6 | 5 | 8 | 12 |
| $>6$ to 10 | 6 | 9 | 15 |
| $>10$ to 18 | 8 | 11 | 18 |
| $>18$ to 30 | 9 | 13 | 21 |
| $>30$ to 50 | 11 | 16 | 25 |
| $>50$ to 80 | 13 | 19 | 30 |
| $>80$ to 120 | 15 | 22 | 35 |
| $>120$ to 180 | 18 | 25 | 40 |
| $>180$ to 250 | 20 | 29 | 46 |
| $>250$ to 315 | 23 | 32 | 52 |
| $>315$ to 400 | 25 | 36 | 57 |
| $>400$ to 500 | 27 | 40 | 63 |

In certain cases, the shape and taper defects in the chosen tolerance interval are unacceptable because they are detrimental to correct bearing operation. In such cases a smaller tolerance interval must be adopted.

## Bearing seats (continued)

Recommended fits

| Analysis of rotation | Retention principle |  | Shaft |  |  | Housing |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Applications | Recommended fits | Examples | Applications | Recommended fits | Examples |
| The load turns with respect to the outer ring | Inner <br> ring <br> press <br> fitted <br> on shaft | Normal loads $P<C / 5$ | j6 / k6 | Electric <br> motors <br> Machine tool <br> spindles <br> Pumps <br> Fans <br> Speed <br> reducers | General case | H7 / J7 | Electric <br> motors of <br> moderate <br> power <br> Pulleys <br> Machine-tool <br> spindles <br> Transmissions |
|  |  | High loads P>C/5 | m6/p6 | Traction motors Large speed reducer, compressors | Ring floats on its seat | G7 / H7 | Axial displacement required (expansion or adjustment) |
|  |  |  |  |  | Cylindrical <br> and tapered <br> roller <br> bearings | M7 / P7 |  |
| The load turns with respect to the inner ring | Outer <br> ring <br> press <br> fitted in <br> housing | General case | g6 / h6 | Idler pulleys Tensioners Wheels | Normal loads $P<C / 5$ | M7 / N7 | Idler pulleys Tensioners Wheels |
|  |  | Ring floats on its seat | f6 / g6 | Axial <br> displacement <br> required <br> (expansion <br> or <br> adjustment) | Very high loads <br> High loads with impacts $P>C / 5$ | N7 / P7 | Railway equipment Heavy-duty roller bearings |
| Other cases |  | Purely axial loads | h6 / j6 | Bearings and thrust bearings | Purely axial loads | G7 / H7 | Bearings and thrust bearings |
|  |  | Adapter sleeves | h9 | Transmissions Agricultural Equipment |  |  |  |

Different choices can be made to take into account various construction and operating factors: for example, if an assembly is subject to vibration and impact, tighter fits must be considered. Moreover, the type of mounting and the installation procedure can demand different fits. For example, the fit adopted for light alloy housings is usually tighter than those normally specified, to compensate for the differential thermal expansion.

The following tables illustrate the fits used most frequently in the mounting of bearings.
Example for an SNR 6305 ball bearing ( $25 \times 62 \times 17$ )

Bearing/housing fit


Shaft/bearing fit


SNR. Bearing retention and clearances

## Bearing seats (continued)

## Value of tolerances and fits

The tables on the following pages indicate:

- the tolerance (in $\mu \mathrm{m}$ ) on the bore or outside diameter of the bearing (Standard ISO 492)
- the tolerance (in $\mu \mathrm{m}$ ) on the seat diameter according to the chosen fit. (Standard ISO 286)
- the differences (in $\mu \mathrm{m}$ ) between the respective diameters of the bearing and its seat:
- Theoretical values calculated from the extreme bearing and seat tolerance values
- Mean values
- Probable values calculated using the Gauss distribution law. (with a probability of 99.7\%) from the formula:

Probable toll. $=\left[(\text { Bearing toll. })^{2}+(\text { Seat toll. })^{2}\right]^{1 / 2}$

These tables concern all types of bearings except tapered roller bearings. For tapered roller bearings, use the same calculation procedure but with their specific tolerances.

In practice, one generally only considers the probable tolerance (the risks of error being limited to $0.3 \%$ ) to determine a realistic value for the probable clearance tolerance of a bearing after fitting.

## Example

SNR 6305 bearing ( 25 mm bore).
Fit on shaft k5.

| Tolerance | Mean | Molerance |  |
| :--- | :---: | :---: | :---: | :---: |
|  | maxi | value | interval |$|$

$$
\begin{aligned}
& \text { - theoretical mean interference }=- \text { (shaft mean val. }- \text { bearing mean val.) }=-[6,5-(-5)]=-11,5 \\
& \text { - theoretical max. interference }=- \text { (shaft max. val. - bearing min. val.) }=-[11-(-10)]=-21 \\
& \text { - theoretical min. interference }=- \text { (shaft min. val. }- \text { bearing max. val.) }=-(2-0)=-2 \\
& \text { - probable tolerance } \quad=\quad\left[(\text { bearing tol. interval })^{2}+(\text { shaft tol. interval })^{2}\right]^{1 / 2}=\left(10^{2}+9^{2}\right)^{1 / 2}=13 \\
& \text { - probable max. interference }=\text { theoretical mean interference - probable tolerance } / 2 \\
& =-11,5-6,5=-18 \\
& \text { - probable min. interference }=\text { theoretical mean interference }+ \text { probable tolerance } / 2 \\
& =-11,5+6,5=-5
\end{aligned}
$$

## Fits on shaft for normal class bearings (all bearings except tapered roller bearings)

| SHAFT |  | $\nabla$ |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Nominal diameer of shaft (mm) | Bearing <br> bore tolerance <br> $(\mathrm{mm})$ | Fits | 55 | f6 | g5 | g6 | h5 | h6 | 55 | [6 |
| $3<d \leq 6$ | -8 0 | Shaft tolerances in $\mu \mathrm{m}$ | -15 15 | -18 -10 | -9 -4 | -12 -4 | -5 0 | -8 0 | $1+4$ | -1 +7 |
|  |  | Mean Probable difference in diameters | $+13^{+8.5}+4$ | $\begin{gathered} +10 \\ +15.5+4.5 \end{gathered}$ | $+7^{-2.5}-2$ | $+9.5^{+4}-1.5$ | $+3^{-1.5}-6$ | $\begin{gathered} 0 \\ \hline+5.5 \quad-5.5 \\ \hline \end{gathered}$ | $\begin{array}{\|c} \hline-5.5 \\ -1 \\ \hline \end{array}$ | $\begin{array}{ll}  & -7 \\ -1.5 & -12.5 \end{array}$ |
| 6 <ds 10 | -8 | Shaft tolerances in $\mu \mathrm{m}$ | -19 -13 | $\begin{array}{ll}-22 & -13\end{array}$ | -11 -5 | -14 -5 | -6 0 | -9 0 | -2 +4 | $\begin{array}{ll}-2 & +7\end{array}$ |
|  |  | Mean <br> Probable difference in diameters | $+17^{+12}+7$ | $\begin{gathered} +13.5 \\ +19.5+7.5 \end{gathered}$ | $+9^{+4}-1$ | $\begin{gathered} +5.5 \\ +11.5-0.5 \end{gathered}$ | $+4^{-1}-6$ | ${ }_{+6.5}^{+0.5}-5.5$ | $0^{-5} \quad-10$ | $\begin{array}{ll} -6.5 \\ -0.5 & -12.5 \\ \hline \end{array}$ |
| $10<d \leq 18$ | -8 | Shaft tolerances in $\mu \mathrm{m}$ | -24-16 | -27 -16 | -14 -6 | -17 -6 | -8 0 | -11 0 | -3 +5 | $\begin{array}{ll}-3 & +8\end{array}$ |
|  |  | Mean <br> Probable difference in diameters | $\begin{gathered} +16 \\ +21.5+10.5 \end{gathered}$ | $\begin{gathered} +17.5 \\ +24.5+10.5 \end{gathered}$ | $\begin{gathered} +6 \\ +11.5+0.5 \end{gathered}$ | $\begin{gathered} +7.5 \\ +14.5+0.5 \end{gathered}$ | $\begin{gathered} 0 \\ +5.5 \quad-5.5 \end{gathered}$ | ${ }_{+8.5}^{+1.5}-5.5$ | $\begin{gathered} -5 \\ +0.5 \quad-10.5 \end{gathered}$ | $\begin{array}{cc} -6.5 \\ +0.5 & -13.5 \end{array}$ |
| 18 <ds 30 | -10 | Shaft tolerances in $\mu \mathrm{m}$ | -29 -20 | -33 -20 | $-16$ | $-20 \quad-7$ | -9 0 | -13 0 | $-4+5$ | -4 +9 |
|  |  | Mean <br> Probable difference in diameters | $$ | $+3 \begin{gathered} +21.5 \\ +30^{2} \end{gathered}$ | $+13^{+6.5} 0$ | $+17^{+8.5} 0$ | $+6{ }^{-0.5}$ | $+10^{+1.5}-7$ | $+1^{-5.5}-12$ | $\begin{gathered} \\ +11^{-7.5} \\ -16 \end{gathered}$ |
| $30<d \leq 50$ | -12 | Shaft tolerances in $\mu \mathrm{m}$ | -36-25 | -41-25 | -20 $\quad-9$ | -25 $\quad-9$ | $-110$ | -16 0 | $-5+6$ | -5 +11 |
|  |  | Mean <br> Probable difference in diameters | $\begin{gathered} +24.5 \\ +32.5+16.5 \end{gathered}$ | $+37^{+27}+17$ | $\begin{gathered} +8.5 \\ +16.5+0.5 \end{gathered}$ | $+21^{+11}+1$ | $+7.5^{-0.5}-8.5$ | $+12^{+2}-8$ | $\begin{array}{\|c} -6.5 \\ +1.5 \quad-14.5 \end{array}$ | $\begin{array}{ll} -9 & -19 \end{array}$ |
| $50<d \leq 65$ | -15 | Shaft tolerances in $\mu \mathrm{m}$ | $\begin{array}{ll}-43 & -30\end{array}$ | $\begin{array}{ll}-49 & -30\end{array}$ | $\begin{array}{ll}-23 & -10\end{array}$ | $\begin{array}{ll}-29 & -10\end{array}$ | $-130$ | -19 0 | -7 | $\begin{array}{ll}-7 & +12\end{array}$ |
|  |  | Mean <br> Probable difference in diameters | $+39^{+29}+19$ | $\begin{gathered} +32 \\ +44 \\ +20 \end{gathered}$ | $+{ }^{+9} \quad-1$ | $+24^{+12} 0$ | $+9^{-1}-11$ | $+14^{+2}-10$ | $+3^{-7} \quad-17$ | $+2^{-10}-22$ |
| 65 <ds 80 | -15 | Shaft tolerances in $\mu \mathrm{m}$ | -43 $\quad-30$ | $\begin{array}{ll}-49 & -30\end{array}$ | $\begin{array}{ll}-23 & -10\end{array}$ | $\begin{array}{ll}-29 & -10\end{array}$ | $-130$ | -19 0 | $-7 \quad+6$ | $\begin{array}{ll}-7 & +12\end{array}$ |
|  |  | Mean Probable difference in diameters | $+39^{+29}+19$ | $+44^{+32}+20$ | $+19^{+9}-1$ | $+24^{+12} 0$ | $+9^{-1}-11$ | $+14^{+2}-10$ | $+3^{-7}-17$ | $+2^{-10}-22$ |
| $80<d \leq 100$ | -20 | Shaft tolerances in $\mu \mathrm{m}$ | $\begin{array}{ll}-51 & -36\end{array}$ | $\begin{array}{ll}-58 & -36\end{array}$ | $\begin{array}{ll}-27 & -12\end{array}$ | $\begin{array}{ll}-34 & -12\end{array}$ | -15 0 | -22 0 | $-9+6$ | -9 |
|  |  | Mean <br> Probable difference in diameters | $\begin{gathered} +33.5 \\ +46 \quad+21 \end{gathered}$ | $+52^{+37}+22$ | $+22^{+9.5}-3$ | $+28^{+13}-2$ | $+10^{-2.5}-15$ | $+16^{+1}-14$ | $+4^{-8.5}-21$ | $+3^{-12}-27$ |
| $100<d \leq 120$ | -20 | Shaft tolerances in $\mu \mathrm{m}$ | $\begin{array}{ll}-51 & -36\end{array}$ | $\begin{array}{ll}-58 & -36\end{array}$ | $\begin{array}{ll}-27 & -12\end{array}$ | $\begin{array}{ll}-34 & -12\end{array}$ | $-150$ | -22 0 | -9 +6 | $\begin{array}{ll}-9 & +13\end{array}$ |
|  |  | Mean <br> Probable difference in diameters | $\begin{array}{cc} +33.5 \\ +46 & +21 \end{array}$ | $+52^{+37}+22$ |  | $+28^{+13}-2$ | $+10^{-2.5}-15$ | $+{ }^{+1} \quad-14$ | $+4^{-8.5}-21$ | $+3^{-12}-27$ |
| $120<d \leq 140$ | -25 | Shaft tolerances in $\mu \mathrm{m}$ | -61 -43 | $\begin{array}{ll}-68 & -43\end{array}$ | $\begin{array}{ll}-32 & -14\end{array}$ | $\begin{array}{ll}-39 & -14\end{array}$ | -18 0 | -25 0 | -11 +7 | -11 +14 |
|  |  | Mean Probable difference in diameters | $\begin{gathered} \hline+39.5 \\ +55 \quad+24 \end{gathered}$ | $\begin{gathered} +43 \\ +60.5+25.5 \end{gathered}$ | $+26^{+10.5}-5$ | $\begin{gathered} +14 \\ +31.5-3.5 \end{gathered}$ | $+12^{-3.5}-19$ | $\begin{gathered} 0 \\ +17.5-17.5 \\ \hline \end{gathered}$ | $+5^{-10.5}-26$ | $+4^{-14}-32$ |
| $140<d \leq 160$ | -25 | Shaft tolerances in $\mu \mathrm{m}$ | -61 -43 | $\begin{array}{ll}-68 & -43\end{array}$ | $\begin{array}{ll}-32 & -14\end{array}$ | $\begin{array}{ll}-39 & -14\end{array}$ | -18 0 | -25 0 | $-11+7$ | -11 +14 |
|  |  | Mean Probable difference in diameters | ${ }^{+55^{+39.5}}+24$ | $\begin{gathered} +43 \\ +60.5+25.5 \end{gathered}$ | $+26^{+10.5}-5$ | $\begin{gathered} +14 \\ +31.5+3.5 \end{gathered}$ | $+12^{-3.5}-19$ | $\begin{gathered} 0 \\ +17.5-17.5 \end{gathered}$ | $+5^{-10.5}-26$ | $+4^{-14}-32$ |
| 160 <ds 180 | -25 | Shaft tolerances in $\mu \mathrm{m}$ | -61 -43 | -68 -43 | $\begin{array}{ll}-32 & -14\end{array}$ | $\begin{array}{ll}-39 & -14\end{array}$ | $-180$ | -25 0 | -11 +7 | -11 +14 |
|  |  | Mean Probable difference in diameters | ${ }^{2}+55^{+39.5}+24$ | $\begin{gathered} +43 \\ +60.5+25.5 \end{gathered}$ | $+26^{+10.5}-5$ | $\begin{gathered} +14 \\ +31.5-3.5 \end{gathered}$ | $+12^{-3.5}-19$ | $\begin{gathered} 0 \\ +17.5-17.5 \end{gathered}$ | $+5^{-10.5}-26$ | $+4^{-14}-32$ |
| $180<d \leq 200$ | -30 | Shaft tolerances in $\mu \mathrm{m}$ | -70 -50 | $\begin{array}{ll}-79 & -50\end{array}$ | $\begin{array}{ll}-35 & -15\end{array}$ | -44 -15 | $-20 \quad 0$ | -29 0 | $\begin{array}{ll}-13 & +7\end{array}$ | $-13+16$ |
|  |  | Mean Probable difference in diameters | $+63^{+45}+27$ | $\begin{gathered} +49.5 \\ +70.5+28.5 \\ \hline \end{gathered}$ | $+28^{+10}-8$ | $\begin{gathered} +14.5 \\ +35.5-6.5 \end{gathered}$ | $+13^{-5} \quad-23$ | $\begin{gathered} -0.5 \\ +20.5-21.5 \end{gathered}$ | $+6^{-12}-30$ | $\begin{gathered} -16.5 \\ +4.5 \quad-37.5 \end{gathered}$ |
| $200<d \leq 225$ | -30 | Shaft tolerances in $\mu \mathrm{m}$ | -70 -50 | $\begin{array}{ll}-79 & -50\end{array}$ | $\begin{array}{ll}-35 & -15\end{array}$ | -44 -15 | $-20 \quad 0$ | -29 0 | $\begin{array}{ll}-13 & +7\end{array}$ | $-13+16$ |
|  |  | Mean <br> Probable difference in diameters | $+63^{+45}+27$ | $\begin{gathered} +49.5 \\ +70.5+28.5 \end{gathered}$ | $+28^{+10}-8$ | $\begin{array}{r} +14.5 \\ +35.5-6.5 \end{array}$ | $+13^{-5}-23$ | $\begin{gathered} -0.5 \\ +20.5-21.5 \end{gathered}$ | $+6^{-12}-30$ | $\begin{gathered} -16.5 \\ +4.5 \quad-37.5 \end{gathered}$ |
| $225<d \leq 250$ | -30 | Shaft tolerances in $\mu \mathrm{m}$ | -70 -50 | $\begin{array}{ll}-79 & -50\end{array}$ | -35 -15 | -44 -15 | -20 0 | -29 0 | $\begin{array}{ll}-13 & +7\end{array}$ | $-13+16$ |
|  |  | Mean Probable difference in diameters | $+63^{+45}+27$ | $\begin{gathered} +49.5 \\ +70.5+28.5 \\ \hline \end{gathered}$ | $+28^{+10}-8$ | $\begin{gathered} +14.5 \\ +35.5-6.5 \end{gathered}$ | $+13^{-5} \quad-23$ | $\begin{gathered} -0.5 \\ +20.5-21.5 \end{gathered}$ | $+6^{-12}-30$ | $\begin{gathered} -16.5 \\ +4.5 \quad-37.5 \end{gathered}$ |
| $250<d \leq 280$ | -35 | Shaft tolerances in $\mu \mathrm{m}$ | $\begin{array}{ll}-79 & -56\end{array}$ | $\begin{array}{ll}-88 & -56\end{array}$ | $\begin{array}{ll}-40 & -17\end{array}$ | $\begin{array}{ll}-49 & -17\end{array}$ | $-23 \quad 0$ | -32 0 | $\begin{array}{ll}-16 & +7\end{array}$ | $-16+16$ |
|  |  | Mean Probable difference in diameters | $+71^{+50}+29$ | $\begin{gathered} +54.5 \\ +78 \quad+31 \end{gathered}$ | $+32^{+11}-10$ | $\begin{aligned} & +15.5 \\ & +39^{-8} \end{aligned}$ | $+15^{-6} \quad-27$ | $+22^{-1.5}-25$ | $+8^{-13} \quad-34$ | $+6^{-17.5}-41$ |
| $280<d \leq 315$ | -35 | Shaft tolerances in $\mu \mathrm{m}$ | $\begin{array}{ll}-79 & -56\end{array}$ | $\begin{array}{ll}-88 & -56\end{array}$ | $\begin{array}{ll}-40 & -17\end{array}$ | $\begin{array}{ll}-49 & -17\end{array}$ | $-23 \quad 0$ | -32 0 | $\begin{array}{ll}-16 & +7\end{array}$ | $-16+16$ |
|  |  | Mean Probable difference in diameters | ${ }^{+71^{+50}}+29$ | $\begin{gathered} +54.5 \\ +78 \quad+31 \end{gathered}$ | $+32^{+11}-10$ | $\begin{gathered} +15.5 \\ +39 \end{gathered}$ | $+15^{-6} \quad-27$ | $+22^{-1.5}-25$ | $+8^{-13}-34$ | $+6^{-17.5}-41$ |
| $315<d \leq 400$ | -40 | Shaft tolerances in $\mu \mathrm{m}$ | -87 -62 | $\begin{array}{ll}-98 & -62\end{array}$ | $\begin{array}{ll}-43 & -18\end{array}$ | $\begin{array}{ll}-54 & -18\end{array}$ | -25 0 | -36 0 | $\begin{array}{ll}-18 & +7\end{array}$ | -18 +18 |
|  |  | Mean Probable difference in diameters | ${ }^{+79} \quad+35$ | $\begin{gathered} \hline+62.5 \\ +88 \quad+37 \end{gathered}$ | $+35^{+13}-9$ | $\begin{gathered} +18.5 \\ +44 \end{gathered}$ | $+17^{-5} \quad-27$ | $+26^{-0.5} \quad-25$ | $+10^{-12} \quad-34$ | $+8{ }^{-17.5}-43$ |
| $400<d \leq 500$ | -45 | Shaft tolerances in $\mu \mathrm{m}$ | -95 -68 | $\begin{array}{ll}-108 & -68\end{array}$ | -47 -20 | $\begin{array}{ll}-60 & -20\end{array}$ | $-27 \quad 0$ | $-400$ | $-20 \quad+7$ | $-20 \quad+20$ |
|  |  | Mean Probable difference in diameters | $+86^{+64}+42$ | $+\begin{gathered} +70.5 \\ +97 \\ +44 \end{gathered}$ | $+38^{+16}-6$ | $\begin{gathered} +22.5 \\ +49 \end{gathered}$ | $+18^{-4}-26$ | $+29^{+2.5}-24$ | $+11^{-11} \quad-33$ | $+9{ }^{-17.5}-44$ |
| $500<d \leq 630$ | -50 | Shaft tolerances in $\mu \mathrm{m}$ |  | $\begin{array}{ll}-120 & -76\end{array}$ |  | -66-22 | -32 0 | -44 0 |  |  |
|  |  | Mean Probable difference in diameters |  | $\begin{gathered} +80.5 \\ +109+52 \end{gathered}$ |  | $+55^{+26.5}-2$ | $+22^{-1.5}-25$ | $+33^{+4.5}-24$ |  |  |
| $630<d \leq 800$ | -75 | Shaft tolerances in $\mu \mathrm{m}$ |  | -130 -80 |  | -74 -24 | -36 0 | -50 0 |  |  |
|  |  | Mean Probable difference in diameters |  | $\begin{gathered} +87.5 \\ +118 \end{gathered}$ |  | $+62^{+31.5}+1$ | $+26^{+0.5}-25$ | $+38^{+7.5}-23$ |  |  |

1. A negative value denotes an interference fit and a positive value a loose fit
2. The probable fit values are calculated on the assumption that the statistical distribution of the dimensions within the tolerances follows a "normal" law (Gauss distribution law)
3. Bearing tolerances and fits: values in microns ( $\mu \mathrm{m}$ )
4. $\boldsymbol{T}$ The most common fits

Fits on shaft for normal class bearings (all bearings except tapered roller bearings)

| SHAFT |  | $\nabla$ |  |  |  | $\nabla$ |  | n6 | p5 | p6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Nominal diameter of shaft $(\mathrm{mm})$ | Bearing bore tolerance ( mm ) | Fits | k5 | k6 | m5 | m6 | n5 |  |  |  |
| $3<d \leq 6$ | -8 | Shaft tolerances in $\mu \mathrm{m}$ | +1 +6 | +1 +9 | +4 +9 | +4 +12 | +8 +13 | +8 +16 | +12 +17 | +12 +20 |
|  |  | Mean <br> Probable difference in diameters | $-3^{-7.5}-12$ | $-{ }^{-9}-3.5-14.5$ | $6_{-6}^{-10.5}-15$ | $\begin{array}{c\|} \hline-12 \\ -6.5-17.5 \\ \hline \end{array}$ | $-10^{-14.5}-19$ | $\begin{array}{\|c\|} \hline-16 \\ -10.5-21.5 \end{array}$ | $-14^{-18.5}-23$ | $\begin{gathered} -20 \\ -14.5-25.5 \end{gathered}$ |
| $6<d \leq 10$ | -8 | Shaft tolerances in $\mu \mathrm{m}$ | +1 +7 | +1 +10 | +8 +12 | +6 +15 | $+10+16$ | +10 +19 | +15 +21 | +15 +24 |
|  |  | Mean <br> Probable difference in diameters | $-3^{-8} \quad-13$ | $\begin{gathered} -9.5 \\ -3.5-15.5 \end{gathered}$ | $-8^{-13} \quad-18$ | $\begin{array}{c\|} \hline-14.5 \\ -8.5-20.5 \\ \hline \end{array}$ | $-12^{-17}-22$ | $\begin{gathered} \hline-18.5 \\ -12.5-24.5 \end{gathered}$ | $-17^{-22}-27$ | $\begin{gathered} -23.5 \\ -17.5-29.5 \end{gathered}$ |
| $10<d \leq 18$ | -8 | Shaft tolerances in $\mu \mathrm{m}$ | +1 +9 | +1 +12 | +7 +15 | +7 +18 | +12 +20 | +12 +23 | +18 +26 | +18 +29 |
|  |  | Mean <br> Probable difference in diameters | $-\frac{-9}{-3.5-14.5}$ | $\begin{gathered} -10.5 \\ -3.5-17.5 \end{gathered}$ | $\begin{gathered} -15 \\ -9.5-20.5 \end{gathered}$ | $\begin{gathered} -16.5 \\ -9.5-23.5 \end{gathered}$ | $\begin{gathered} -20 \\ -14.5-25.5 \end{gathered}$ | $\begin{gathered} -21.5 \\ -14.5-28.5 \end{gathered}$ | $\begin{gathered} -26 \\ -20.5-31.5 \end{gathered}$ | $\begin{gathered} -27.5 \\ -20.5-34.5 \end{gathered}$ |
| 18 <ds 30 | -10 0 | Shaft tolerances in $\mu \mathrm{m}$ | +2 +11 | +2 +15 | +8 +17 | +8 +21 | +15 +24 | +15 +28 | +22 +31 | +22 +35 |
|  |  | Mean <br> Probable difference in diameters | $\begin{gathered} -11.5 \\ -5 \end{gathered}$ | $\begin{array}{\|l\|l\|} \hline & -13.5 \\ -5 & -22 \end{array}$ | $\begin{gathered} -17.5 \\ -11 \end{gathered}$ | $\begin{array}{\|c\|} \hline-19.5 \\ -11 \end{array}$ | $-18^{-24.5} \quad-31$ | $1-26.5$ | $\begin{aligned} & -31.5 \\ & -25 \\ & \hline \end{aligned}$ | $\begin{gathered} \hline-33.5 \\ -25^{-42} \end{gathered}$ |
| $30<d \leq 50$ | -12 | Shaft tolerances in $\mu \mathrm{m}$ | +2 +13 | +2 +18 | +9 +20 | +9 +25 | +17 +28 | +17 +33 | +26 +37 | +26 +42 |
|  |  | Mean <br> Probable difference in diameters | $\begin{gathered} -13.5 \\ -5.5-21.5 \end{gathered}$ | $-6^{-16}-26$ | $\begin{gathered} -20.5 \\ -12.5-28.5 \\ \hline \end{gathered}$ | $-13^{-23}-33$ | $\begin{aligned} & -28.5 \\ & -20.5-36.5 \\ & \hline \end{aligned}$ | $-21^{-31}-41$ | $\begin{gathered} -37.5 \\ -29.5-45.5 \end{gathered}$ | $-30^{-40}-50$ |
| $50<d \leq 65$ | -15 | Shaft tolerances in $\mu \mathrm{m}$ | +2 +15 | +2 +21 | +11 +24 | $+11+30$ | $+20+33$ | $+20+39$ | +32 +45 | +32 +51 |
|  |  | Mean <br> Probable difference in diameters | $-_{-6}^{-16} \quad-26$ | $.^{-19} \quad-31$ | $-15^{-25}-35$ | $-16^{-28}-40$ | $-24^{-34} \quad-44$ | $-25^{-37} \quad-49$ | $-36^{-46}-56$ | $\begin{aligned} & -49 \\ & -37^{-49}-61 \end{aligned}$ |
| 65 <ds 80 | -15 | Shaft tolerances in $\mu \mathrm{m}$ | +2 +15 | +2 +21 | +11 +24 | +11 +30 | $+20+33$ | $+20 \quad+39$ | +32 +45 | +32 +51 |
|  |  | Mean | -16 | -19 | -25 | -28 | -34 | -37 | -46 | -49 |
|  |  | Probable difference in diameters | -6 -26 | $\begin{array}{ll}-7 & -31\end{array}$ | $\begin{array}{ll}-15 & -35\end{array}$ | $\begin{array}{ll}-16 & -40\end{array}$ | -24 -44 | -25 -49 | $\begin{array}{ll}-36 & -56\end{array}$ | $\begin{array}{ll}-37 & -61\end{array}$ |
| 80 <ds 100 | -20 | Shaft tolerances in $\mu \mathrm{m}$ | +3 +18 | +3 +25 | +13 +28 | +13 +35 | +23 +38 | +23 +45 | +37 +52 | +37 +59 |
|  |  | Mean | -20.5 | -24 | -30.5 | -34 | -40.5 | -44 | -54.5 | -58 |
|  |  | Probable difference in diameters | -8 -33 | $\begin{array}{ll}-9 & -39\end{array}$ | -18 -43 | $\begin{array}{ll}-19 & -49\end{array}$ | $\begin{array}{ll}-28 & -53\end{array}$ | -29 $\quad-59$ | -42 -67 | $\begin{array}{ll}-43 & -73\end{array}$ |
| $100<d s 120$ | -20 | Shaft tolerances in $\mu \mathrm{m}$ | +3 +18 | +3 +25 | +13 +28 | +13 +35 | +23 +38 | +23 +45 | $+37 \quad+52$ | +37 +59 |
|  |  | Mean <br> Probable difference in diameters | $\begin{gathered} -20.5 \\ -83 \end{gathered}$ | $-9^{-24}-39$ | $\begin{gathered} -30.5 \\ -18^{-43} \end{gathered}$ | $-19^{-34}-49$ | $-28^{-40.5}-53$ | $-29^{-44}-59$ | $-42^{-54.5}-67$ | $-43^{-58}-73$ |
| $120<d s 140$ | -25 | Shaft tolerances in $\mu \mathrm{m}$ | +3 +21 | +3 +28 | +15 +33 | +15 +40 | +27 +45 | +27 +52 | +43 +61 | +43 +68 |
|  |  | Mean Probable difference in diameters | $-9^{-24.5}-40$ | $\begin{gathered} -28 \\ -10.5-45.5 \end{gathered}$ | $\begin{gathered} -36.5 \\ -21^{-52} \end{gathered}$ | $\begin{gathered} -40 \\ -22.5-57.5 \end{gathered}$ | $\begin{array}{\|c\|} \hline-48.5 \\ -33^{-64} \end{array}$ | $\begin{gathered} -52 \\ -34.5-69.5 \end{gathered}$ | $\begin{gathered} -64.5 \\ -49^{-60} \end{gathered}$ | $\begin{gathered} -68 \\ -50.5-85.5 \end{gathered}$ |
| $140<d \leq 160$ | -25 | Shaft tolerances in $\mu \mathrm{m}$ | +3 +21 | +3 +28 | +15 +33 | +15 +40 | +27 +45 | $+27+52$ | +43 +61 | +43 +68 |
|  |  | Mean <br> Probable difference in diameters | $\begin{aligned} & -24.5 \\ & -90 \end{aligned}$ | $\begin{gathered} \hline-28 \\ -10.5-45.5 \end{gathered}$ | $\begin{array}{\|c} \hline-36.5 \\ -21^{-52} \end{array}$ | $\begin{gathered} -40 \\ -22.5-57.5 \end{gathered}$ | $\begin{array}{\|c} \hline-48.5 \\ -33^{-64} \end{array}$ | $\begin{gathered} -52 \\ -34.5-69.5 \end{gathered}$ | $\begin{gathered} -64.5 \\ -49^{-60} \end{gathered}$ | $\begin{gathered} \hline-68 \\ -50.5-85.5 \end{gathered}$ |
| $160<d s 180$ | -25 | Shaft tolerances in $\mu \mathrm{m}$ | +3 +21 | +3 +28 | +15 +33 | +15 +40 | +27 +45 | $+27 \quad+52$ | +43 +61 | +43 +68 |
|  |  | Mean Probable difference in diameters | $-9^{-24.5}-40$ | $\begin{gathered} -28 \\ -10.5-45.5 \\ \hline \end{gathered}$ | $-21^{-36.5}-52$ | $\begin{gathered} -40 \\ -22.5-57.5 \end{gathered}$ | $-33^{-48.5}-64$ | $\begin{gathered} -52 \\ -34.5-69.5 \end{gathered}$ | $\begin{gathered} -64.5 \\ -49^{8} \\ \hline \end{gathered}$ | $\begin{gathered} -68 \\ -50.5-85.5 \end{gathered}$ |
| $180<d \leq 200$ | -30 | Shaft tolerances in $\mu \mathrm{m}$ | +4 +24 | +4 +33 | +17 +37 | +17 +46 | +31 +51 | +31 +60 | $+50+70$ | +50 +79 |
|  |  | Mean Probable difference in diameters | $-11^{-29}-47$ | $\begin{gathered} -33.5 \\ -12.5-54.5 \end{gathered}$ | $-24^{-42}-60$ | $\begin{array}{c\|} \hline-46.5 \\ -25.5-67.5 \end{array}$ | $-38^{-56} \quad-74$ | $\begin{gathered} \hline-60.5 \\ -39.5-81.5 \end{gathered}$ | $-57^{-75} \quad-93$ | $\begin{gathered} -79.5 \\ -58.5-100.5 \end{gathered}$ |
| $200<d \leq 225$ | -30 | Shaft tolerances in $\mu \mathrm{m}$ | +4 +24 | +4 +33 | $+17+37$ | $+17+46$ | +31 +51 | $+31+60$ | +50 +70 | +50 +79 |
|  |  | Mean Probable difference in diameters | $-11^{-29}-47$ | $-12.5^{-33.5}-54.5$ | $-24^{-42}-60$ | $\begin{array}{r} -46.5 \\ -25.5-67.5 \end{array}$ | $-38^{-56}-74$ | $\begin{gathered} -60.5 \\ 39.5-81.5 \end{gathered}$ | $-57^{-75} \quad-93$ | $\begin{gathered} -79.5 \\ 58.5-100.5 \end{gathered}$ |
| $225<$ ds 250 | -30 | Shaft tolerances in $\mu \mathrm{m}$ | +4 +24 | +4 +33 | +17 +37 | +17 +46 | +31 +51 | $+31+60$ | +50 +70 | +50 +79 |
|  |  | Mean Probable difference in diameters | $-11^{-29} \quad-47$ | $\begin{gathered} -33.5 \\ -12.5-54.5 \end{gathered}$ | $-24^{-42}-60$ | $\begin{gathered} -46.5 \\ -25.5-67.5 \end{gathered}$ | $-38^{-56} \quad-74$ | $\begin{array}{c\|} \hline-60.5 \\ -39.5-81.5 \end{array}$ | $-57^{-75} \quad-93$ | $\begin{gathered} -79.5 \\ -58.5-100.5 \end{gathered}$ |
| $250<d \leq 280$ | $-350$ | Shaft tolerances in $\mu \mathrm{m}$ | +4 +27 | +4 +36 | +20 +43 | +20 +52 | +34 +57 | +34 +66 | +56 +79 | +56 +88 |
|  |  | Mean Probable difference in diameters | $-12^{-33}-54$ | $-14^{-37.5}-61$ | $-28^{-49}-70$ | $-30^{-53.5}-77$ | $-42^{-63}-84$ | $-44^{-67.5}-91$ | $-64^{-85}-106$ | $\begin{gathered} -89.5 \\ -66^{-113} \end{gathered}$ |
| $280<d \leq 315$ | -35 | Shaft tolerances in $\mu \mathrm{m}$ | +4 +27 | +4 +36 | +20 +43 | +20 +52 | +34 +57 | +34 +66 | +56 +79 | +56 +88 |
|  |  | Mean | -33 | -37.5 | -49 | -53.5 | -63 | -67.5 | -85 | -89.5 |
|  |  | Probable difference in diameters | -12 $\quad-54$ | -14 61 | -28 -70 | -30 -77 | $\begin{array}{ll}-42 & -84\end{array}$ | -44 $\quad-91$ | -64-106 | $\begin{array}{lll}-66 & -113\end{array}$ |
| 315 <ds 400 | $-400$ | Shaft tolerances in $\mu \mathrm{m}$ | +4 +29 | +4 +40 | +21 +46 | +21 +57 | +37 +62 | +37 +73 | +62 +87 | +62 +98 |
|  |  | Mean | -34 | -39.5 | -51 | -56.5 | -67 | -72.5 | -92 | -97.5 |
|  |  | Probable difference in diameters | $\begin{array}{ll}-12 & -56\end{array}$ | -14 | -29 -73 | $\begin{array}{ll}-31 & -82\end{array}$ | $\begin{array}{ll}-45 & -89\end{array}$ | -47 -98 | -70 -114 | $\begin{array}{lll}-72 & -123\end{array}$ |
| $400<d \leq 500$ | -45 0 | Shaft tolerances in $\mu \mathrm{m}$ | +5 +32 | +5 +45 | $+23+50$ | $+23+63$ | +40 +67 | +40 +80 | +68 +95 | +68 +108 |
|  |  | Mean | -36 | -42.5 | -54 | -60.5 | -71 | -77.5 | -99 | -105.5 |
|  |  | Probable difference in diameters | -14 | $\begin{array}{ll}-16 & -69\end{array}$ | -32 -76 | $\begin{array}{ll}-34 & -87\end{array}$ | -49 | -51-104 | -77 -121 | $\begin{array}{lll}-79 & -132\end{array}$ |
| $500<d \leq 630$ | -50 0 | Shaft tolerances in $\mu \mathrm{m}$ |  | 0 +44 |  | +26 +70 |  | +44 +88 |  | +78 +122 |
|  |  | Mean Probable difference in diameters |  | $-11^{-39.5} \quad-68$ |  | $\begin{array}{\|c\|} \hline-65.5 \\ -37^{-94} \end{array}$ |  | $\begin{gathered} -83.5 \\ -55 \quad-112 \end{gathered}$ |  | $\begin{gathered} -117.5 \\ -89 \quad-146 \end{gathered}$ |
| $630<d \leq 800$ | -75 0 | Shaft tolerances in $\mu \mathrm{m}$ |  | $0 \quad+50$ |  | +30 +80 |  | $+50+100$ |  | +88 +138 |
|  |  | Mean Probable difference in diameters |  | $-12^{-42.5}-73$ |  | $\begin{array}{cc}  & -72.5 \\ -42 & -103 \end{array}$ |  | $\begin{gathered} -92.5 \\ -62 \quad-123 \end{gathered}$ |  | $\begin{gathered} -130.5 \\ -100-161 \end{gathered}$ |

1. A negative value denotes an interference fit and a positive value a loose fit
2. The probable fit values are calculated on the assumption that the statistical distribution of the dimensions within the tolerances follows a "normal" law (Gauss distribution law)
3. Bearing tolerances and fits: values in microns ( $\mu \mathrm{m}$ )
4. $\boldsymbol{\nabla}$ The most common fits

Fits in the housings for normal class bearings (all bearings except tapered roller bearings)


1. A negative value denotes an interference fit and a positive value a loose fit
2. The probable fit values are calculated on the assumption that the statistical distribution of the dimensions within the tolerances follows a "normal" law (Gauss distribution law)
3. Bearing tolerances and fits: values in microns ( $\mu \mathrm{m}$ )
4. $\boldsymbol{\nabla}$ The most common fits

Fits in the housings for normal class bearings (all bearings except tapered roller bearings)

\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|}
\hline HOUSING \& \& \multicolumn{4}{|c|}{\(\nabla\)} \& \multicolumn{5}{|c|}{\(\nabla\)} \\
\hline \begin{tabular}{l}
Nominal
diameter
of housing \\
(mm)
\end{tabular} \& Tolerance on outsiae ( pm ) \& Fits \& M6 \& M7 \& N6 \& N7 \& P6 \& P7 \& R6 \& R7 \\
\hline \multirow[t]{2}{*}{\(10<D \leq 18\)} \& \multirow[t]{2}{*}{-8} \& Housing tolerance \& -15 -4 \& -18 \& \(-20 \quad-9\) \& -23 -5 \& -26-15 \& -29 -11 \& -31-20 \& -34 -16 \\
\hline \& \& \begin{tabular}{l}
Mean \\
Probable difference in diameters
\end{tabular} \& \[
\begin{gathered}
-5.5 \\
+1.5-12.5
\end{gathered}
\] \& \[
+5^{-5} \quad-15
\] \& \[
\begin{gathered}
\hline-10.5 \\
-3.5 \quad-17.5
\end{gathered}
\] \& \[
0^{-10}-20
\] \& \[
\begin{gathered}
-16.5 \\
-9.5 \quad-23.5
\end{gathered}
\] \& \[
e^{-16} \quad-26
\] \& \[
\begin{gathered}
-21.5 \\
-14.5-28.5
\end{gathered}
\] \& \[
-11^{-21}-31
\] \\
\hline \multirow[t]{2}{*}{\(18<0 \leq 30\)} \& \multirow[t]{2}{*}{-9} \& Housing tolerance \& -17 -4 \& -21 \& \(\begin{array}{ll}-24 \& -11\end{array}\) \& \(\begin{array}{ll}-28 \& -7\end{array}\) \& \(\begin{array}{ll}-31 \& -18\end{array}\) \& \(\begin{array}{ll}-35 \& -14\end{array}\) \& \(\begin{array}{ll}-37 \& -24\end{array}\) \& -41-20 \\
\hline \& \& \begin{tabular}{l}
Mean \\
Probable difference in diameters
\end{tabular} \& \[
+2^{-6}-14
\] \& \[
\begin{gathered}
-6 \\
+5.5 \quad-17.5
\end{gathered}
\] \& \[
-5^{-13}-21
\] \& \[
-1.5^{-13}-24.5
\] \& \[
-12^{-20}-28
\] \& \[
-8.5^{-20}-31.5
\] \& \[
-18^{-26}-34
\] \& \[
\begin{gathered}
-26 \\
-14.5 \quad-37.5
\end{gathered}
\] \\
\hline \multirow[t]{2}{*}{\(30<0 \leq 50\)} \& \multirow[t]{2}{*}{\(-110\)} \& Housing tolerance \& \(-20 \quad-4\) \& -25 \& \(\begin{array}{ll}-28 \& -12\end{array}\) \& \(\begin{array}{ll}-33 \& -8\end{array}\) \& \(\begin{array}{ll}-37 \& -21\end{array}\) \& \(\begin{array}{ll}-42 \& -17\end{array}\) \& \(\begin{array}{ll}-45 \& -29\end{array}\) \& -50 -25 \\
\hline \& \& Mean
Probable difference in diameters \& \[
+3^{-6.5}-16
\] \& \[
\begin{gathered}
-7 \\
+6.5 \quad-20.5
\end{gathered}
\] \& \[
-5^{-14.5}-24
\] \& \[
-1.5^{-15}-28.5
\] \& \[
-14^{-23.5}-33
\] \& \[
\begin{gathered}
-24 \\
-10.5-37.5
\end{gathered}
\] \& \[
-22^{-31.5}-41
\] \& \[
\begin{gathered}
-32 \\
-18.5-45.5
\end{gathered}
\] \\
\hline \multirow[t]{2}{*}{\(50<D \leq 65\)} \& \multirow[t]{2}{*}{\(-13\)} \& Housing tolerance \& -24 -5 \& \(-30 \quad 0\) \& \(\begin{array}{ll}-33 \& -14\end{array}\) \& \(\begin{array}{ll}-39 \& -9\end{array}\) \& \(\begin{array}{ll}-45 \& -26\end{array}\) \& \(\begin{array}{ll}-51 \& -21\end{array}\) \& \(\begin{array}{ll}-54 \& -35\end{array}\) \& \(\begin{array}{ll}-60 \& -30\end{array}\) \\
\hline \& \& \begin{tabular}{l}
Mean \\
Probable difference in diameters
\end{tabular} \& \[
+3.5^{-8}-19.5
\] \& \[
+8^{-8.5}-25
\] \& \[
-5.5^{-17} \quad-28.5
\] \& \[
-1^{-17.5}-34
\] \& \[
\begin{gathered}
-29 \\
-17.5-40.5
\end{gathered}
\] \& \[
-13^{-29.5}-46
\] \& \[
-26.5-49.5
\] \& \[
-22^{-38.5}-55
\] \\
\hline \multirow[t]{2}{*}{\(65<D \leq 80\)} \& \multirow[t]{2}{*}{\(-13\)} \& Housing tolerance \& -24 \(\quad-5\) \& -30 \& \(\begin{array}{ll}-33 \& -14\end{array}\) \& \(\begin{array}{ll}-39 \& -9\end{array}\) \& \(\begin{array}{ll}-45 \& -26\end{array}\) \& \(\begin{array}{ll}-51 \& -21\end{array}\) \& \(\begin{array}{ll}-56 \& -37\end{array}\) \& -62 -32 \\
\hline \& \& Mean
Probable difference in diameters \& \[
\begin{gathered}
-8 \\
+3.5 \quad-19.5 \\
\hline
\end{gathered}
\] \& \[
+8^{-8.5} \quad-25
\] \& \[
-5.5^{-17} \quad-28.5
\] \& \[
-1^{-17.5} \quad-34
\] \& \[
\begin{gathered}
-29 \\
-17.5-40.5 \\
\hline
\end{gathered}
\] \& \[
-13^{-29.5}-46
\] \& \[
\begin{gathered}
-40 \\
-28.5-51.5 \\
\hline
\end{gathered}
\] \& \[
-24^{-40.5}-57
\] \\
\hline \multirow[t]{2}{*}{\(80<D \leq 100\)} \& \multirow[t]{2}{*}{-15} \& Housing tolerance \& -28 -6 \& -35 \& \(\begin{array}{ll}-38 \& -16\end{array}\) \& \(\begin{array}{ll}-45 \& -10\end{array}\) \& \(\begin{array}{ll}-52 \& -30\end{array}\) \& \(\begin{array}{ll}-59 \& -24\end{array}\) \& -66 -44 \& -73 -38 \\
\hline \& \& Mean
Probable difference in diameters \& \[
+4^{-9.5}-23
\] \& \[
+9^{-10}-29
\] \& \[
-6{ }^{-19.5}-33
\] \& \[
-1^{-20}-39
\] \& \[
-20^{-33.5}-47
\] \& \[
-15^{-34}-53
\] \& \[
-34^{-47.5}-61
\] \& \[
-29^{-48}-67
\] \\
\hline \multirow[t]{2}{*}{\(100<0 \leq 120\)} \& \multirow[t]{2}{*}{-15} \& Housing tolerance \& \(-28-6\) \& -35 \& \(\begin{array}{ll}-38 \& -16\end{array}\) \& -45 -10 \& \(\begin{array}{ll}-52 \& -30\end{array}\) \& \(\begin{array}{ll}-59 \& -24\end{array}\) \& \(\begin{array}{ll}-66 \& -47\end{array}\) \& \(\begin{array}{ll}-76 \& -41\end{array}\) \\
\hline \& \& Mean
Probable difference in diameters \& \[
+4^{-9.5}-23
\] \& \[
+9^{-10} \quad-29
\] \& \[
-6^{-19.5}-33
\] \& \[
-1^{-20} \quad-39
\] \& \[
-20^{-33.5}-47
\] \& \[
-15^{-34}-53
\] \& \[
-37^{-50.5} \quad-64
\] \& \[
-32^{-51}-70
\] \\
\hline \multirow[t]{3}{*}{\(120<D \leq 140\)} \& \multirow[t]{3}{*}{-18} \& Housing tolerance \& -33 \& -40 \& -45 -20 \& -52 \& -61-36 \& \(\begin{array}{ll}-68 \& -28\end{array}\) \& -81-56 \& -88 -48 \\
\hline \& \& Mean \& -11.5 \& -11 \& -23.5 \& -23 \& -39.5 \& -39 \& -59.5 \& -59 \\
\hline \& \& Probable difference in diameters \& +4 \(\quad-27\) \& +11 -33 \& \(\begin{array}{ll}-8 \& -39\end{array}\) \& \(\begin{array}{ll}-1 \& -45\end{array}\) \& \(\begin{array}{ll}-24 \& -55\end{array}\) \& \(\begin{array}{ll}-17 \& -61\end{array}\) \& \(\begin{array}{ll}-44 \& -75\end{array}\) \& \(\begin{array}{ll}-37 \& -81\end{array}\) \\
\hline \multirow[t]{2}{*}{\(140<0 \leq 150\)} \& \multirow[t]{2}{*}{-18} \& Housing tolerance \& -33 -8 \& -40 \& -45 -20 \& \(\begin{array}{ll}-52 \& -12\end{array}\) \& -61-36 \& \(\begin{array}{ll}-68 \& -28\end{array}\) \& \(\begin{array}{ll}-83 \& -58\end{array}\) \& \(\begin{array}{ll}-90 \& -50\end{array}\) \\
\hline \& \& Mean
Probable difference in diameters \& \[
+4^{-11.5}-27
\] \& \[
+11^{-11}-33
\] \& \[
-8^{-23.5}-39
\] \& \[
-1^{-23} \quad-45
\] \& \[
-24^{-39.5}-55
\] \& \[
-17^{-39} \quad-61
\] \& \[
\begin{aligned}
\& -61.5 \\
\& \hline-46
\end{aligned} \begin{aligned}
\& -77
\end{aligned}
\] \& \[
-39^{-61} \quad-83
\] \\
\hline \multirow[t]{2}{*}{\(150<D \leq 160\)} \& \multirow[t]{2}{*}{-25} \& Housing tolerance \& -33 \& -40 \& -45 -20 \& \(\begin{array}{ll}-52 \& -12\end{array}\) \& -61-36 \& \(\begin{array}{ll}-68 \& -28\end{array}\) \& \(\begin{array}{ll}-83 \& -58\end{array}\) \& \(\begin{array}{ll}-90 \& -50\end{array}\) \\
\hline \& \& Mean
Probable difference in diameters \& \[
+9.5^{-8}-25.5
\] \& \[
\begin{aligned}
\& -7.5 \\
\& +16^{-31}
\end{aligned}
\] \& \[
-2.5^{-20}-37.5
\] \& \[
+4^{-19.5}-43
\] \& \[
\begin{gathered}
-36 \\
-18.5-53.5
\end{gathered}
\] \& \[
-12^{-35.5}-59
\] \& \[
\begin{gathered}
-58 \\
-40.5-75.5
\end{gathered}
\] \& \[
-34^{-57.5}-81
\] \\
\hline \multirow[t]{2}{*}{\(160<D \leq 180\)} \& \multirow[t]{2}{*}{-25} \& Housing tolerance \& -33 \& -40 \& -45 -20 \& \(\begin{array}{ll}-52 \& -12\end{array}\) \& \(\begin{array}{ll}-61 \& -36\end{array}\) \& \(\begin{array}{ll}-68 \& -28\end{array}\) \& \(\begin{array}{ll}-86 \& -61\end{array}\) \& \(\begin{array}{ll}-93 \& -53\end{array}\) \\
\hline \& \& Mean
Probable difference in diameters \& \[
+9.5^{-8}-25.5
\] \& \[
+16^{-7.5}-31
\] \& \[
-2.5^{-20}-37.5
\] \& \[
+4^{-19.5}-43
\] \& \[
\begin{gathered}
-36 \\
-18.5-53.5
\end{gathered}
\] \& \[
-12^{-35.5} \quad-59
\] \& \[
-43.5-78.5
\] \& \[
-37^{-60.5} \quad-84
\] \\
\hline \multirow[t]{2}{*}{\(180<D \leq 200\)} \& \multirow[t]{2}{*}{-30} \& Housing tolerance \& \(\begin{array}{ll}-37 \& -8\end{array}\) \& \(-460\) \& -51 -22 \& -60 \(\quad-14\) \& \(\begin{array}{ll}-70 \& -41\end{array}\) \& \(\begin{array}{ll}-79 \& -33\end{array}\) \& \(\begin{array}{ll}-97 \& -68\end{array}\) \& -106 \(\quad-60\) \\
\hline \& \& Mean
Probable difference in diameters \& \[
\begin{gathered}
-7.5 \\
+13.5-28.5 \\
\hline
\end{gathered}
\] \& \[
\begin{gathered}
-8 \\
+19.5-35.5 \\
\hline
\end{gathered}
\] \& \[
\begin{gathered}
-21.5 \\
-0.5 \quad-42.5 \\
\hline
\end{gathered}
\] \& \[
\begin{gathered}
-22 \\
+5.5-49.5 \\
\hline
\end{gathered}
\] \& \[
\begin{gathered}
-40.5 \\
-19.5-61.5 \\
\hline
\end{gathered}
\] \& \[
\begin{gathered}
-41 \\
-13.5-68.5 \\
\hline
\end{gathered}
\] \& \[
\begin{gathered}
-67.5 \\
-46.5-88.5
\end{gathered}
\] \& \[
\begin{gathered}
-68 \\
-40.5-95.5
\end{gathered}
\] \\
\hline \multirow[t]{2}{*}{\(200<D \leq 225\)} \& \multirow[t]{2}{*}{-30} \& Housing tolerance \& \(\begin{array}{ll}-37 \& -8\end{array}\) \& \(-46 \quad 0\) \& -51-22 \& -60 \(\quad-14\) \& \(\begin{array}{ll}-70 \& -41\end{array}\) \& \(\begin{array}{ll}-79 \& -33\end{array}\) \& \(\begin{array}{ll}-100 \& -71\end{array}\) \& -109 -63 \\
\hline \& \& Mean
Probable difference in diameters \& \[
\begin{gathered}
-7.5 \\
+13.5-28.5
\end{gathered}
\] \& \[
\begin{gathered}
-8 \\
+19.5-35.5
\end{gathered}
\] \& \[
\begin{gathered}
-21.5 \\
-0.5 \quad-42.5
\end{gathered}
\] \& \[
\begin{gathered}
-22 \\
+5.5-49.5
\end{gathered}
\] \& \[
\begin{gathered}
\hline-40.5 \\
-19.5-61.5
\end{gathered}
\] \& \[
\begin{gathered}
-41 \\
-13.5-68.5
\end{gathered}
\] \& \[
\begin{gathered}
\hline-70.5 \\
-49.5-91.5
\end{gathered}
\] \& \[
\begin{gathered}
-71 \\
-43.5-98.5 \\
\hline
\end{gathered}
\] \\
\hline \multirow[t]{2}{*}{\(225<D \leq 250\)} \& \multirow[t]{2}{*}{-30} \& Housing tolerance \& \(\begin{array}{ll}-37 \& -8\end{array}\) \& -46 0 \& -51 -22 \& -60 \(\quad-14\) \& -70 -41 \& \(\begin{array}{ll}-79 \& -33\end{array}\) \& \(\begin{array}{ll}-104 \& -75\end{array}\) \& \(\begin{array}{ll}-113 \& -67\end{array}\) \\
\hline \& \& Mean
Probable difference in diameters \& \[
\begin{gathered}
-7.5 \\
+13.5-28.5
\end{gathered}
\] \& \[
\begin{gathered}
-8 \\
+19.5-35.5
\end{gathered}
\] \& \[
\begin{aligned}
\& -21.5 \\
\& -0.5 \quad-42.5
\end{aligned}
\] \& \[
\begin{gathered}
-22 \\
+5.5-49.5
\end{gathered}
\] \& \[
\begin{gathered}
-40.5 \\
-19.5-61.5
\end{gathered}
\] \& \[
\begin{gathered}
-41 \\
-13.5-68.5
\end{gathered}
\] \& \[
\begin{gathered}
-74.5 \\
-53.5-95.5
\end{gathered}
\] \& \[
\begin{gathered}
-75 \\
-47.5-102.5
\end{gathered}
\] \\
\hline \multirow[t]{3}{*}{\(250<D \leq 280\)} \& \multirow[t]{3}{*}{-35} \& Housing tolerance \& -41 \& -52 0 \& -57 -25 \& -66 -14 \& \(\begin{array}{ll}-79 \& -47\end{array}\) \& \(\begin{array}{ll}-88 \& -36\end{array}\) \& \(\begin{array}{ll}-117 \& -85\end{array}\) \& \(\begin{array}{ll}-126 \& -74\end{array}\) \\
\hline \& \&  \& -7.5 \& -8.5 \& -23.5 \& -22.5 \& -45.5 \& -44.5 \& -83.5 \& -82.5 \\
\hline \& \& Probable difference in diameters \& +16 \(\quad-31\) \& +23 \(\quad-40\) \& \(0 \quad-47\) \& +9 \(\quad-54\) \& -22 \(\quad-69\) \& -13 \(\quad-76\) \& \(\begin{array}{ll}-60 \& -107\end{array}\) \& \(\begin{array}{lll}-51 \& -114\end{array}\) \\
\hline \multirow[t]{2}{*}{\(280<D \leq 315\)} \& \multirow[t]{2}{*}{-35} \& Housing tolerance \& -41-9 \& -52 0 \& -57-25 \& -66 -14 \& \(\begin{array}{ll}-79 \& -47\end{array}\) \& \(\begin{array}{ll}-88 \& -36\end{array}\) \& \(\begin{array}{ll}-121 \& -89\end{array}\) \& \(\begin{array}{ll}-130 \& -78\end{array}\) \\
\hline \& \& Mean
Probable difference in diameters \& \[
\begin{array}{r}
-7.5 \\
+16^{-31}
\end{array}
\] \& \[
+23^{-8.5}-40
\] \& \[
0^{-23.5}-47
\] \& \[
+9^{-22.5}-54
\] \& \[
-22^{-45.5}-69
\] \& \[
-13^{-44.5}-76
\] \& \[
\begin{gathered}
-64^{-87.5}-111
\end{gathered}
\] \& \[
-55^{-86.5}-118
\] \\
\hline \multirow[t]{2}{*}{\(315<D \leq 400\)} \& \multirow[t]{2}{*}{-40} \& Housing tolerance \& -46-10 \& \(-57 \quad 0\) \& -62 -26 \& -73 -16 \& \(\begin{array}{ll}-87 \& -51\end{array}\) \& \(\begin{array}{ll}-98 \& -41\end{array}\) \& \& \\
\hline \& \& Mean
Probable difference in diameters \& \[
\begin{array}{r}
-10.5 \\
+15^{-36}
\end{array}
\] \& \[
\begin{array}{r}
-11 \\
+22^{-44}
\end{array}
\] \& \[
-1^{-26.5}-52
\] \& \[
+6^{-27}-60
\] \& \[
-26^{-51.5}-77
\] \& \[
-19^{-52} \quad-85
\] \& \& \\
\hline \multirow[t]{2}{*}{\(400<D \leq 500\)} \& \multirow[t]{2}{*}{-45} \& Housing tolerance \& -50 \(\quad-10\) \& -63 0 \& -67 -27 \& -80 \(\quad-17\) \& \(\begin{array}{ll}-95 \& -55\end{array}\) \& -108 -45 \& \& \\
\hline \& \& Mean
Probable difference in diameters \& \[
\begin{array}{r}
-12.5 \\
+14^{-39}
\end{array}
\] \& \[
+22^{-14}-50
\] \& \[
-3^{-29.5}-56
\] \& \[
+5^{-31}-67
\] \& \[
-31^{-57.5}-84
\] \& \[
-23^{+25}-95
\] \& \& \\
\hline \multirow[t]{2}{*}{\(500<D \leq 630\)} \& \multirow[t]{2}{*}{-50} \& Housing tolerance \& -70 -26 \& -96-26 \& -88 -44 \& -114 -44 \& \(\begin{array}{ll}-122 \& -78\end{array}\) \& \(\begin{array}{ll}-148 \& -78\end{array}\) \& \& \\
\hline \& \& Mean
Probable difference in diameters \& \[
-2^{-30.5}-59
\] \& \[
-4^{-43.5}-83
\] \& \[
-20^{-48.5}-77
\] \& \[
-22^{-61.5}-101
\] \& \[
-54^{-82.5}-111
\] \& \[
-56^{-95.5}-135
\] \& \& \\
\hline \multirow[t]{3}{*}{\(630<D \leq 800\)} \& \multirow[t]{3}{*}{-75} \& Housing tolerance \& \(\begin{array}{ll}-80 \& -30\end{array}\) \& -110 -30 \& \(-100-50\) \& \(\begin{array}{ll}-130 \& -50\end{array}\) \& \(\begin{array}{ll}-138 \& -88\end{array}\) \& \(\begin{array}{ll}-168 \& -88\end{array}\) \& \& \\
\hline \& \& Mean

Probable difference in diameters \& $7^{-37.5}$ \& ${ }^{-52.5}$ \& ${ }^{-57.5}$ \& ${ }^{-72.5}$ \& ${ }^{-95.5}$ \& -110.5 \& \& <br>
\hline \& \& Probable difference in diameters \& -7 768 \& -9 96 \& $\begin{array}{lll}-27 & -88\end{array}$ \& $\begin{array}{ll}-29 & -116\end{array}$ \& -65 -126 \& $\begin{array}{ll}-67 & -154\end{array}$ \& \& <br>
\hline \multirow[t]{3}{*}{$800<$ < 1000} \& \multirow[t]{3}{*}{$-1000$} \& Housing tolerance \& -90 -34 \& -124 \& -112 -56 \& -146-56 \& -156-100 \& -190-100 \& \& <br>
\hline \& \& Mean \& -44.5 \& -61.5 \& -66.5 \& -83.5 \& -110.5 \& -127.5 \& \& <br>
\hline \& \& Probable difference in diameters \& -11 718 \& -13 $\quad-110$ \& -33 -100 \& $\begin{array}{ll}-35 & -132\end{array}$ \& $\begin{array}{ll}-77 & -144\end{array}$ \& $\begin{array}{ll}-79 & -176\end{array}$ \& \& <br>
\hline
\end{tabular}

1. A negative value denotes an interference fit and a positive value a loose fit
2. The probable fit values are calculated on the assumption that the statistical distribution of the dimensions within the tolerances follows a "normal" law (Gauss distribution law)
3. Bearing tolerances and fits: values in microns ( $\mu \mathrm{m}$ )
4. $\boldsymbol{\nabla}$ The most common fits

## Bearing seats (continued)

## Geometry and surface conditions of shaft and housing seats

## Shoulder diameters and fillet radii

A contact surface is necessary between the ring and the shoulder to ensure good retention of the bearing.

D The sections in this catalog of Standard Bearings specifies:

- the shaft and housing shoulder diameters ( $\mathrm{D}_{1}$ and $\mathrm{d}_{3}$ )
- the shoulder fillet radii (ri)


If for construction reasons the shoulder seat dimension cannot be respected, provide an extra spacer between the bearing ring and the shoulder.
The fillet radii between the shoulders and the ring seats must be less than the corner radius of the corresponding ring. The values are indicated in the chapter corresponding to each family.


D Fillet greater than the bearing corner radius
When a shaft is subjected to high bending stresses, the shoulder must be given a fillet radius that is greater than that of the bearing.

In this case, a chamfered spacer is placed between the shaft shoulder and the bearing ring to give a sufficiently large contact surface.

## D Special corner radius

If the bearing must be fixed close to the shoulder, a special corner radius can be machined on its inner ring.


## D Elimination of the fillet radius

If there are no particular requirements for the shaft profile and strength, it is possible to make an undercut that facilitates grinding of the seats and ensures in all cases the best contact between the ring and the shoulder.


## Removal seat

The bearing is usually removed using an extraction tool whose claws clamp on the part of the ring that protrudes beyond the shoulder. See page 140. If the mounting configuration does not leave a sufficiently large removal seat, notches can be cut in the shoulder or a washer can be placed between the shoulder and the bearing inner ring.


SNR. Bearing retention and clearances

## Bearing seats (continued)

Tolerances and surface conditions of shaft and housing seats
D Shaft



D Housing



## Radial clearance of radial contact bearings

## Residual radial clearance: definition, calculation

The residual radial clearance is the radial clearance of the bearing after installation or in operation. It depends on the internal radial clearance, the fits, the temperatures and the deformations.

The residual clearance must be sufficient to ensure satisfactory operating conditions.

To calculate the residual clearance, it is given an algebraic value. When this value is positive, there is a mechanical clearance, when it is negative there is a preload.
The operating residual clearance of the bearing has a direct influence on its service life and general performance (precision of rotation, noise, etc. ). It must therefore be determined as accurately as possible.

## Ratio of interference effect on clearance

When two parts are assembled together with an interference fit, each part displays a change in diameter after assembly.

The ratio is:

$$
\mathrm{t}_{\mathrm{i}} \text { or } \mathrm{t}_{\mathrm{e}}=\frac{\text { reduction of internal radial clearance }}{\text { interference on inner or outer ring }}
$$

The ratio is calculated using the standard material strength formulae which introduce the crosssectional dimensions of the parts concerned, the E modulus of elasticity and their respective Poisson ratios.

We propose the following approximate ratios for the most common cases:

| Bearing element | Seat | Ratio |
| :--- | :---: | :---: |
| Inner ring | Solid shaft | $\mathrm{t}_{\mathrm{i}} \approx 0.8$ |
|  | Hollow shaft | $\mathrm{t}_{\mathrm{i}} \approx 0.6$ |
| Outer ring | Steel or cast-iron housing | $\mathrm{t}_{\mathrm{e}} \approx 0.7$ |
|  | Light alloy housing | $\mathrm{t}_{\mathrm{e}} \approx 0.5$ |

SNR can provide a precise calculation of the clearance reduction.

## Radial clearance of radial contact bearings (continued)

Residual clearance after fitting: $\mathbf{J}_{\mathbf{r m}}$

$$
J_{r m}=J_{o}-t_{i} \cdot S_{i}-t_{e} \cdot S_{e}
$$

$J_{0}$ Internal radial clearance
$\mathrm{S}_{\mathrm{i}} \quad$ Interference of the inner ring on the shaft
$t_{i} \quad$ Inner ring/shaft effect ratio
$\mathrm{S}_{\mathrm{e}} \quad$ Interference of the outer ring in its housing
$t_{e} \quad$ Outer ring/housing effect ratio

- Required approximate mean residual clearance after fitting (in mm)

| Ball bearings | $J_{\mathrm{rm}}=10^{-3} \mathrm{~d}^{1 / 2}$ |
| :--- | :--- |
| Cylindrical roller bearings | $\mathrm{J}_{\mathrm{rm}}=4 \cdot 10^{-3} \mathrm{~d}^{1 / 2}$ |
| Self-aligning ball bearings | $\mathrm{J}_{\mathrm{rm}}=2 \cdot 10^{-3} \mathrm{~d}^{1 / 2}$ |
| Spherical roller bearings | $\mathrm{J}_{\mathrm{rm}}=5 \cdot 10^{-3} \mathrm{~d}^{1 / 2}$ |

Example of calculation of residual clearance and its range using the fits tables of page 102.

Bearing 6305 - bore 25 mm - outside diameter 62 mm

- Solid steel shaft: tolerance ky
- Cast-iron housing: tolerance N6


## $\square$ Mean residual clearance

The fits tables give:

|  | min | mean | max |
| :--- | :---: | :---: | :---: |
| Shaft tolerances | +2 |  | +11 |
| Mean theoretical <br> and probable value Si |  | -11.5 |  |
| Probable clearance $(+)$ <br> or interference $(-)$ | -5 |  | -18 |


|  | min | mean | max |
| :--- | :---: | :---: | :---: |
| Housing tolerances | -33 |  | +14 |
| Mean theoretical <br> and probable value Si |  | -17 |  |
| Probable clearance $(+)$ <br> or interference $(-)$ | -5.5 | -28.5 |  |

Table in previous page gives the respective effect ratios of $t_{i}=0.8$ (shaft) and $t_{e}=0.7$ (housing).

The mean reduction in clearance is:
$R_{j m}=\left(t_{i} \cdot S_{i}\right)+\left(t_{e} \cdot S_{e}\right)$
(only valid if $\mathrm{Si}<0$ and $\mathrm{Se}<0$ )

$$
R_{j m}=(0.8 x-11.5)+(0.7 x-17)=-21 \mu m
$$

The minimum initial clearance value must be greater than the mean reduction in clearance $\mathrm{R}_{\mathrm{jm}}$

The table in page 156 of initial clearances for this type of bearing shows that a category 4 clearance is necessary ( 23 to $41 \mu \mathrm{~m}$ : mean value $32 \mu \mathrm{~m}$ ) to have a satisfactory residual clearance after fitting the bearing:

Mean residual clearance:

$$
\mathrm{J}_{\mathrm{rm}}=32-21=11 \mu \mathrm{~m}
$$

The definition of the bearing will therefore be 6305 J 40 (C4)

Range of residual clearance after fitting

Probable range of interference on the shaft (difference between extreme values):

$$
\mathrm{D}_{\mathrm{pa}}=13 \mu \mathrm{~m}
$$

Probable range of interference in the housing (difference between extreme values):

$$
\mathrm{D}_{\mathrm{pl}}=23 \mu \mathrm{~m}
$$

Considering the previous effect ratios, the probable ranges on radial clearance are:

Range of bearing internal clearance:

According to the laws of probabilities, the range of the residual clearance will be:

The 6305 bearing with a category 4 clearance mounted with k5 and N6 fits has an operating clearance of:

$$
\mathrm{D}_{\mathrm{er}}=41-23=18 \mu \mathrm{~m}
$$

$$
\begin{aligned}
\Delta \mathrm{Jr} & =\left(D_{\mathrm{pci}}{ }^{2}+D_{\mathrm{pce}^{2}}+\mathrm{Der}_{\mathrm{er}}\right)^{1 / 2} \\
& =\left(10.5^{2}+16^{2}+18^{2}\right)^{1 / 2}=26 \mu \mathrm{~m}
\end{aligned}
$$

$$
J_{f}=J_{r m} \pm D_{J r} / 2=11 \pm 13 \mu \mathrm{~m}
$$

$$
\begin{aligned}
\mathrm{D}_{\mathrm{pci}}=\mathrm{D}_{\mathrm{pa}} \cdot \mathrm{t}_{\mathrm{i}} & =13 \mu \mathrm{~m} \times 0.8 \\
& =10.5 \mu \mathrm{~m} \\
& \text { for the inner ring } \\
\mathrm{D}_{\mathrm{pce}}=\mathrm{D}_{\mathrm{pl}} \cdot \mathrm{t}_{\mathrm{e}} & =23 \mu \mathrm{~m} \times 0.7 \\
& =16 \mu \mathrm{~m} \\
& \text { for the outer ring }
\end{aligned}
$$

## Radial clearance of radial contact bearings (continued)

## Choice of internal clearance as a function of shaft and housing fits

The example on the previous page shows that interference fits on shaft and housing require a bearing with increased clearance.

The table below defines the limit fits for the shaft and housing.


## $\Rightarrow$ Calculation of the residual clearance in operation

The residual clearance in operation is a function of the residual clearance after mounting and the relative temperature differential between shaft and housing.

Materials with different coefficients of expansion
Bearing mounted in a light alloy housing.
The difference in the bearing and housing diameters resulting from differential expansion is:

$$
\Delta \mathrm{D}=\left(\mathrm{C}_{2}-\mathrm{C}_{1}\right) \mathrm{D} \cdot \Delta \mathrm{t}=8 \cdot 10^{-6} \cdot \mathrm{D} \cdot \Delta \mathrm{t}
$$

where:
$\Delta t \quad$ Operating temperature $20^{\circ} \mathrm{C}\left(68^{\circ} \mathrm{F}\right)$
D Bearing outside diameter
C1 Expansion coefficient of steel $=12 \times 10^{-6} \mathrm{~mm} / \mathrm{mm} /{ }^{\circ} \mathrm{C}$
C2 Expansion coefficient of the light alloy housing $=20 \times 10^{-6} \mathrm{~mm} / \mathrm{mm} /{ }^{\circ} \mathrm{C}$

The different expansion of the materials will increase the clearance of the outer ring in its housing and can allow it to rotate. This differential expansion must be compensated for by having a tighter fit and using a bearing with increased clearance.

## D Example

Choice of housing fit for a 6305 bearing ( $\mathrm{D}=62 \mathrm{~mm}$ ) mounted in light alloy with an operating temperature of $80^{\circ} \mathrm{C}\left(176^{\circ} \mathrm{F}\right)$.

$$
\begin{aligned}
& \Delta \mathrm{t}=60^{\circ} \mathrm{C} \\
& \Delta \mathrm{D}=8 \cdot 10^{-6} \cdot 62 \cdot 60=0.030 \mathrm{~mm}
\end{aligned}
$$

With a J 7 tolerance, the housing diameter is on average $10 \mu \mathrm{~m}$ larger than the bearing diameter.

At $80^{\circ} \mathrm{C}$, it is $10 \mu \mathrm{~m}+\Delta \mathrm{D}=40 \mu \mathrm{~m}$
See page 101.

This value is too high to secure a good retention of the bearing in the housing. Therefore, choosing a P7 housing tolerance with a mean interference of $30 \mu \mathrm{~m}$ will compensate for the effect of differential expansion at $80^{\circ} \mathrm{C}\left(176^{\circ} \mathrm{F}\right)$.

Choosing a P7 tolerance for the outer ring will lead to a reduction in the radial clearance of the bearing equal to:

If the shaft with a k6 tolerance gives a mean interference of $13,5 \mu \mathrm{~m}$ on the inner ring, the reduction of the radial clearance due to the inner ring fit is:

$$
t_{e} \cdot S_{e}=0,5 \cdot 29 \cdot 5=15 \mu \mathrm{~m}
$$

$$
t_{i} \cdot S_{i}=0.8 \cdot 13,5=11 \mu \mathrm{~m}
$$

The total reduction in the bearing clearance due to fitting is:
$R_{j m}=t_{e} \cdot S_{e}+t_{i} \cdot S_{i}=15+11=26 \mu m$

One therefore chooses a 6305J40/C4 bearing (clearance category 4: mean radial clearance of $32 \mu \mathrm{~m})$ to avoid cancelling the clearance during operation at $20^{\circ} \mathrm{C}\left(68^{\circ} \mathrm{F}\right)$ normal temperature.

## Radial clearance of radial contact bearings (continued)

## Temperature difference between shaft and housing

Both the shaft and housing are made of steel, but the temperature of the shaft is higher than that of the housing.

The differential expansion between the bearing inner ring and the outer ring will reduce the radial clearance by the value

$$
\Delta \mathrm{J}=\mathrm{C} 1 \times(\mathrm{D} \cdot \Delta \mathrm{tl}-\mathrm{d} \cdot \Delta \mathrm{ta})
$$

where:
C1 Expansion coefficient of the steel
D Bearing outside diameter
d Bearing bore
$\Delta$ ta Difference between the running temperature of the shaft and the room temperature (specified at $20^{\circ} \mathrm{C}$ or $68^{\circ} \mathrm{F}$ )
$\Delta \mathrm{tl} \quad$ Difference between the running temperature of the housing and the room temperature (specified at $20^{\circ} \mathrm{C}$ or $68^{\circ} \mathrm{F}$ )

## D Example

Let us assume that a 6305 bearing ( $25 \times 62$ ) has a residual clearance $\mathrm{J}_{\mathrm{rm}}$ of $10 \mu \mathrm{~m}$ after fitting at $20^{\circ} \mathrm{C}\left(68^{\circ} \mathrm{F}\right)$.
In operation:

- the temperature of the shaft and the inner ring is $70^{\circ} \mathrm{C}\left(158^{\circ} \mathrm{F}\right)$
- the temperature of the housing and the outer ring is $50^{\circ} \mathrm{C}\left(122^{\circ} \mathrm{F}\right)$

The reduction in radial clearance of the bearing is:

$$
\Delta J=12 \cdot 10^{-6} \cdot((62 \cdot 30)-(25 \cdot 50))=7 \mu \mathrm{~m}
$$

The operating residual radial clearance is:

$$
J \mathrm{Jff}=\mathrm{Jrm}-\Delta \mathrm{J}=10 \mu \mathrm{~m}-7 \mu \mathrm{~m}=3 \mu \mathrm{~m}
$$

In this case it is recommended to use a bearing from Group 3 increased clearance.

## Axial clearance of angular contact bearings

## Axial preload

A preload is a permanent axial force applied to the bearings when they are fitted. It is obtained by the penetration of the inner ring with respect to the outer ring of each bearing from the reference position.

## Axial penetration and preload

Under load, the rolling element / raceway contact points undergo plastic deformation due to the very high Hertz pressures, giving an axial displacement of one ring in respect to the other. A curve gives the value of the relative displacement of the two rings according to the axial load.


In an assembly with two bearings mounted in opposition, the penetration of one bearing increases the clearance of the other.

In assemblies demanding very high guidance precision (machine-tool spindle, bevel gears, oscillating systems, etc.), a preload must be applied to get rid of the clearance and give optimum rigidity.


## Axial clearance of angular contact bearings (continued)

Determining the preload

The preload value $P$ is chosen as a function of the mean axial load applied (Am)

$$
P=A m / 3
$$

The two preloaded bearings are studied using the diagram of associated penetration curves.

Without an external axial load, the meeting point (P) corresponds to the applied preload that creates on each bearing a penetration of (di) and (d2) respectively, the total closing of the two bearings being $p=d 1+d 2$

When an external axial load $A$ is applied to the assembly, each bearing follows its penetration curve. One of the two bearings is subject to an additional penetration (da) which reduces the penetration of the opposite bearing by as much

To find the loads Fay and Fan applied to each bearing, the axial load $A$ is positioned between the two curves (points Ml and M 2 ).
The axial equilibrium of the shaft is:
Fa1-Fa2 = A

If A exceeds the value Fd (unseating axial load), the opposite bearing gets an operating axial clearance.


## D Remarks:

The diagram of associated penetration curves is modified by any radial loads applied to the bearings.
As any preload influences the resultant loads applied to the bearings, bearing performances must be calculated taking into account the preload value. Consult SNR for these calculations that bring into play the rigidity characteristics. A preloaded assembly has greater friction drag torque than an assembly with clearance. Its lubrication must therefore be studied with the utmost care.

## Adjustment

The adjustment enables an assembly to be given the predetermined axial clearance or preload. This is done by sliding one ring (inner or outer) of one of the two bearings of the assembly. This ring must therefore be loose fitted on its seat.

If the assembly is to have an axial clearance $\mathrm{j}_{\mathrm{a}}$, it is checked using a dial comparator.


If the assembly is to have a preload value $p$, one starts with any axial clearance $J_{a}$ and then the loose bearing ring is moved by the value $J_{a}+p$. This operation is usually achieved with the shaft nut or by adapting the thickness of the adjustment spacers in the housing. The allowed tolerance on a preloaded setting is tight (about half the one permitted for the axial clearance).

## Influence of the temperature on the axial clearance of bearings

## Modification of clearance on assembly

The axial clearance or preload of a shaft mounted on two angular-contact bearings (ball or tapered roller bearings) can be changed by the operating temperatures.

The assembly opposite schematically illustrates:

- a change in the axial clearance of the assembly due to the difference of axial expansion between the housing and the shaft
- a modification in the outer ring / housing interference that results in a variation of the radial clearance and therefore the axial clearance of the assembly

The total change of the axial clearance of the assembly is the algebraic sum of these two variations.


In an O assembly (case shown in the sketch), the two variations are in opposite directions and may cancel each other out. Conversely, in an X assembly the two variations are in the same direction.

## Axial clearance of angular contact bearings (continued)

## Theoretical calculation of the variation in the axial clearance of an assembly

$\square$ Variation due to shaft and housing different axial expansion

$$
\Delta \mathrm{Ja}_{1}=\left(\mathrm{I} \cdot \mathrm{C}_{2} \cdot \Delta \mathrm{t}\right)-\left(\mathrm{I} \cdot \mathrm{C}_{1} \cdot \Delta \mathrm{t}\right)=\left(\mathrm{C}_{2}-\mathrm{C}_{1}\right) \cdot \mathrm{I} \cdot \Delta \mathrm{t}
$$

where:
I Distance between the bearings
C1 Expansion coefficient of the shaft
C2 Expansion coefficient of the housing
$\Delta t \quad$ Difference between the operating temperature and the room temperature (specified at $20^{\circ} \mathrm{C}$ or $68^{\circ} \mathrm{F}$ )

Variation due to the modification of the outer ring/housing interference


Total variation in the axial clearance of the assembly

| Assembly in X arrangement | $\Delta \mathrm{Ja}=\Delta \mathrm{Ja}_{2}+\Delta \mathrm{Ja}_{1}$ |
| :--- | :--- |
| Assembly in O arrangement | $\Delta \mathrm{Ja}=\Delta \mathrm{Ja}_{2}-\Delta \mathrm{Ja}_{1}$ |

These calculations enable the initial clearance to be fixed in order to get the desired clearance values in operation.

## Example

Take an assembly of two 32210 tapered roller bearings mounted in an O arrangement in an aluminium housing (P7 fit); operating temperature $80^{\circ} \mathrm{C}\left(176^{\circ} \mathrm{F}\right)$ :

```
I \(=240 \mathrm{~mm}\)
\(\mathrm{D}_{1}=\mathrm{D}_{2}=90 \mathrm{~mm}\)
\(\mathrm{C}_{2}-\mathrm{C}_{1}=8 \times 10-6 \mathrm{~mm} / \mathrm{mm} /{ }^{\circ} \mathrm{C}\)
\(Y_{1}=Y_{2}=1.43\)
\(\mathrm{S}_{1}=\mathrm{S}_{2}=0.0335\) mean value
\(\Delta t \quad=60^{\circ} \mathrm{C}\left(140^{\circ} \mathrm{F}\right)\)
\(t e_{1}=t e_{2}=0.5\) see page 109
```

D Variation in axial clearance due to axial expansion $\Delta \mathrm{Ja}_{1} \Delta \mathrm{Ja}_{1}=8 \cdot 10^{-6} \cdot 240.60=0.114 \mathrm{~mm}$
D Variation due to the modification in the outer ring/housing interference

|  | Bearing 1 | Bearing 2 |
| :---: | :---: | :---: |
| Temperature at which the outer ring/housing interference is cancelled by the expansion of the housing | $\Delta t 0_{1}=\Delta t 0_{2}=0.0335 /(8.10-6.90)=47^{\circ} \mathrm{C}$ |  |
| Variations of interference with temperature | $\begin{gathered} \Delta t>\Delta t 0_{1} \text { and } \Delta t 0_{2} \\ \Delta \mathrm{~S}_{1}=\Delta \mathrm{S}_{2}=0.0335 \end{gathered}$ |  |
| Variation of axial clearance due to the modification in outer ring/housing interference | $\Delta \mathrm{Ja}_{2}=((1.43 / 0.8) \cdot 0.5 \cdot 0.0335)+(1.78 \cdot 0.5 \cdot 0.0335)=0.060$ |  |

D Total variation in the axial clearance of the assembly
$\Delta \mathrm{Ja}=+0.060-0.114=-0.054$
The following graphs illustrate the variation in axial clearance of the assembly according to the operating temperature in the X and O assembly arrangements.

## Assembly in O arrangement



## Assembly in X arrangement



