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# ROLLING BEARINGS

**Bearing Internal Clearance**

2 WHEELERS   3 WHEELERS   4 WHEELERS   TRACTORS   LCV, HCV   INDUSTRIES   RAILWAYS

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**About National Engineering Industries Ltd. (NBC Bearings)**

A symbol of dependability and flexible engineering solutions, NBC Bearings is the brand of National Engineering Industries. Founded in 1946, National Engineering Industries Ltd (NEI) is India's leading bearings manufacturer and exporter, renowned for excellence in quality and delivery. In 2021, NBC bearings completed 75 years of its incorporation.

Headquartered in Jaipur, Having started with 30,000 bearings in 19 sizes in 1946, NBC has evolved to manufacture over 200 million bearings each year offering in 2300+ variants to serve a host of customers in India and over 30 other countries across five continents in automotive, railways and industrial segments. NBC also serves the Indian aftermarket through a countrywide network of 550+ authorized stockists and thousands of retailers.

**Award & Recognitions :**

NBC has been the recipient of several award and accolades for its quality consciousness and manufacturing prowess. Most prominent being the coveted Deming Grand Prize which is the highest honour in quality awarded to a company for excellence in Total Quality Management (TQM). NBC bearings is the only bearing manufacturer to win both - The Deming Application Award and The Deming Grand Prize Award.

The award is given by the Japanese Union of Scientists and Engineers (JUSE) to companies for demonstrating practicing TQM in the areas of production, customer service, safety, human resource, corporate social responsibility, environment, etc. NBC stands committed to an endless journey of continuous improvement through TQM.

# Bearing Internal Clearance

## Type of Clearance During Operation

Internal clearance of a bearing is an important factor affecting not only the bearing performance but also the proper functioning of a machine. Bearing internal clearance is defined as the relative movement of either rings in radial or axial direction, when one ring is fixed. Movement in the diametrical direction is radial clearance, while movement in the shaft's direction is axial clearance. Internal clearance is critical to bearing performance for many reasons. The amount of clearance influences the load distribution in a bearing, which in turn affects smooth operation. It also influences bearing noise and vibration. There are three types of clearance present in the bearing during operation.

**Initial clearance:** The clearance present inside the bearing before it is mounted on a shaft or housing.

**Mounted clearance:** The clearance in the bearing after mounting but before the bearing comes into operation.

**Operating clearance:** The clearance remaining in the bearing after temperature affect and mounting.

For satisfactorily performance bearings must have the appropriate operating clearance. If sufficient amount of clearance is not present in the bearing it may fail. For calculating clearance, effect of fits and temperature is considered. The selection of the clearance is dependent upon the application. In some cases negative clearance (preload) is required when stiffness or bearing positioning is important. Bearing internal clearances changes due to:

- Thermal expansion or contraction of shaft or housing.
- Elastic deformation of rings under load
- Axial clamping can influence clearance or preload.
- Misalignment during running

To get the accurate measurement of internal clearance a certain 'measured load' has to be applied on the raceways. However, under this 'measured load' a slight elastic deformation of the bearing occurs due to which the measured internal clearance value will be slight greater than the true clearance value. This difference between the bearing's true clearance and the measured clearance under the load must be compensated. These compensation values are given in Table 6.1.

Table 6.1. Adjustment of Radial clearance for DGBB

| Nominal Bore Diameter $d$ mm | | Measuring Load N {Kgf} | | Adjustment of internal clearance (Unit μm) | | | | |
|---|---|---|---|---|---|---|---|---|
| over | incl. | | | C2 | CN | C3 | C4 | C5 |
| 10 | 18 | 24.5 | {2.5} | 3 ~ 4 | 4 | 4 | 4 | 4 |
| 18 | 50 | 49 | {5} | 4 ~ 5 | 5 | 6 | 6 | 6 |
| 50 | 200 | 147 | {15} | 6 ~ 8 | 8 | 9 | 9 | 9 |

Note : For roller bearings the amount of elastic deformation is small enough, to be ignored.

**Radial clearance of the bearing is built up for following reasons:**

1. Accommodate the reduction of clearance in a bearing due to interference for inner ring on the shaft or outer ring in the housing.

2. Accommodate the minor changes in the dimensions of parts without affecting the bearing performance.

3. Compensate for the differential expansion of the two rings when the inner ring of a bearing operates at a higher temperature than the outer ring.

4. It allows a slight misalignment between the shaft and the housing and thereby prevents the premature failure of the bearing.

5. It affects the end play of radial ball bearing, and also affects their capacity for carrying axial loads, the greater the radial clearance the greater the capacity for supporting axial load.

**Important:** Once ball and roller bearings are mounted and running, a small amount of radial internal or running clearance is normally desirable. In the case of bearings under radial load, quieter running is generally obtained when this clearance is minimum.
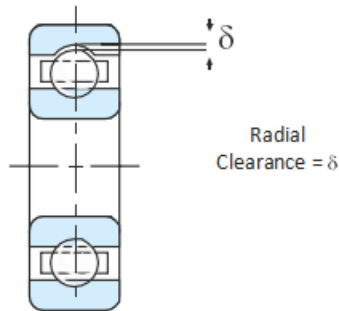
## Types of Radial Internal Clearance:

Radial bearings are made with following different ranges of radial internal clearance- C2, Normal, C3 and C4

**C2:** These bearings have the smallest amount of radial internal clearance. They should only be used where freedom is required in the assembled bearings and there is no possibility of the initial radial internal clearances being eliminated by external causes. Therefore, special attention must be given to the seating dimensions as the expansion of the inner ring or contraction of the outer ring may cause tight bearings. In this respect a C2 bearing should not be used unless recommended.

**CN:** This grade of radial internal clearance is intended for use where only when one ring is made an interference fit and there is no appreciable loss of clearance due to temperature difference. ball and roller bearings for general engineering applications are usually of this clearance.

**C3:** This grade of radial internal clearance should be used when both rings of a bearing are made an interference fit or when only one ring is an interference fit but there is likely to be some loss of clearance due to temperature differences. It is the grade normally used for radial ball bearings that take axial loading but for some purposes even bearings with C4 clearance may be required.

**C4:** Where there will be some loss of clearance due to temperature differences and both rings are interference fit, this grade of radial internal clearance is employed. One example of its use is in bearings for traction motors. Customers should always consult us before ordering bearings with this grade of radial internal clearance.

Radial Clearance = $\delta$

Axial Clearance = $\frac{1}{2} + 2\delta$

$\delta 1$

$\delta 2$
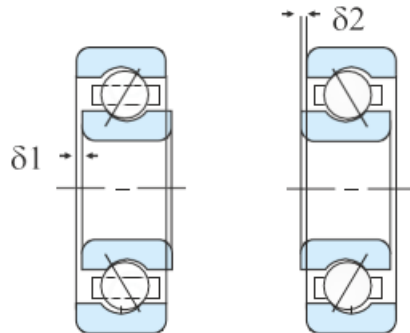
## Criteria For Selection of Internal Clearance

The internal clearance of a bearing under operating conditions (effective clearance) is usually smaller than the same bearing's initial clearance before being installed and operated. This is due to several factors including bearing fit, the difference in temperature between the inner and outer rings, etc. As a bearing's operating clearance has an effect on bearing life, heat generation, vibration, noise, etc. Care must be exercised in selecting the most suitable operating clearance.

### Effective Internal Clearance:

The internal clearance differential between the initial clearance and the operating (effective) clearance (the amount of clearance reduction caused by interference fits, or clearance variation due to the temperature difference between the inner and outer rings) can be calculated by the following formula:

$$\delta eff = \delta o - (\delta f + \delta t)$$

Where,

$\delta$ eff: Effective internal clearance, mm

$\delta o$: Bearing internal clearance, mm

$\delta f$: Reduced amount of clearance due to interference, mm

### Reduced clearance due to interference:

After installation of bearings with interference fit on shaft and housing, the inner ring will expand and the outer ring will contract; thus reducing the bearings' internal clearance. The amount of expansion or contraction will depend on the shape of the bearing, the shape of the shaft or housing, dimensions of the respective parts, and the type of materials used. The differential can range from approximately 70% to 90% of the effective interference.

$$\delta f = (0.70 \sim 0.90) \, \Delta deff$$

Where,

$\delta f$: Reduced amount of clearance due to interference, mm

$\Delta$ deff: Effective interference, mm

**Reduced internal clearance due to inner/outer ring temperature difference.**

In operation, normally the outer ring will be 5° to 10°C cooler than the inner ring or rotating parts. However, if the cooling effect of the housing is large, the shaft is connected to a heat source, or a heated substance is conducted through the hollow shaft; the temperature difference between the two rings can be even greater. The amount of internal clearance is thus further reduced by the differential expansion of the two rings as given in the formula:

$$\delta t = \alpha . \Delta T . Do$$

Where,

$\delta t$: Amount of reduced clearance due to heat differential, mm

$\alpha$ : Bearing material expansion coefficient $12.5 \times 10^{-6}/°C$

$\Delta T$: Inner/outer ring temperature differential, °C

$Do$: Outer ring raceway diameter, mm

Outer ring raceway diameter, Do, values can be approximated by using formula

For ball bearings and spherical roller bearings,

$$Do = 0.20\,(d + 4.0D)$$

For roller bearings (except spherical roller bearing),

$$Do = 0.25\,(d + 3.0D)$$

Where,

d: Bearing bore diameter, mm

D: Bearing outside diameter, mm

## Radial Internal Clearance Values

**Bearing Internal Clearance Values As Per ISO: 5753 / IS: 5935**
**6.4.1 Deep Groove Ball Bearings (Cylindrical bore)**

**Table 6.2** Radial internal clearance for Deep groove ball bearing with cylindrical bore.

Clearance values in microns

| Bore diameter d (mm) Over | Incl. | Group 2 (C2) Min. | Max. | Group N (CN) Min. | Max. | Group 3 (C3) Min. | Max. | Group 4 (C4) Min. | Max. | Group 5 (C5) Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 6 | 0 | 7 | 2 | 13 | 8 | 23 | - | - | - | - |
| 6 | 10 | 0 | 7 | 2 | 13 | 8 | 23 | 14 | 29 | 20 | 37 |
| 10 | 18 | 0 | 9 | 3 | 18 | 11 | 25 | 18 | 33 | 25 | 45 |
| 18 | 24 | 0 | 10 | 5 | 20 | 13 | 28 | 20 | 36 | 28 | 48 |
| 24 | 30 | 1 | 11 | 5 | 20 | 13 | 28 | 23 | 41 | 30 | 53 |
| 30 | 40 | 1 | 11 | 6 | 20 | 15 | 33 | 28 | 46 | 40 | 64 |
| 40 | 50 | 1 | 11 | 6 | 23 | 18 | 36 | 30 | 51 | 45 | 73 |
| 50 | 65 | 1 | 15 | 8 | 28 | 23 | 43 | 38 | 61 | 55 | 90 |
| 65 | 80 | 1 | 15 | 10 | 30 | 25 | 51 | 46 | 71 | 65 | 105 |
| 80 | 100 | 1 | 18 | 12 | 36 | 30 | 58 | 53 | 84 | 75 | 120 |
| 100 | 120 | 2 | 20 | 15 | 41 | 36 | 66 | 61 | 97 | 90 | 140 |
| 120 | 140 | 2 | 23 | 18 | 48 | 41 | 81 | 71 | 114 | 105 | 160 |
| 140 | 160 | 2 | 23 | 18 | 53 | 46 | 91 | 81 | 130 | 120 | 180 |
| 160 | 180 | 2 | 25 | 20 | 61 | 53 | 102 | 91 | 147 | 135 | 200 |
| 180 | 200 | 2 | 30 | 25 | 71 | 63 | 117 | 107 | 163 | 150 | 230 |
| 200 | 225 | 2 | 35 | 25 | 85 | 75 | 140 | 125 | 195 | 175 | 265 |
| 225 | 250 | 2 | 40 | 30 | 95 | 85 | 160 | 145 | 225 | 205 | 300 |
| 250 | 280 | 2 | 45 | 35 | 105 | 90 | 170 | 155 | 245 | 225 | 340 |
| 280 | 315 | 2 | 55 | 40 | 115 | 100 | 190 | 175 | 270 | 245 | 370 |
| 315 | 355 | 2 | 60 | 45 | 125 | 110 | 210 | 195 | 300 | 275 | 410 |
| 355 | 400 | 3 | 70 | 55 | 145 | 130 | 240 | 225 | 340 | 315 | 460 |
| 400 | 450 | 3 | 80 | 60 | 170 | 150 | 270 | 250 | 380 | 350 | 510 |
| 450 | 500 | 3 | 90 | 70 | 190 | 170 | 300 | 280 | 420 | 390 | 570 |
| 500 | 560 | 3 | 100 | 80 | 210 | 190 | 330 | 310 | 470 | 440 | 630 |
| 560 | 630 | 10 | 110 | 90 | 230 | 210 | 360 | 340 | 520 | 490 | 690 |
| 630 | 710 | 10 | 130 | 110 | 260 | 240 | 400 | 380 | 570 | 540 | 760 |
| 710 | 800 | 20 | 140 | 120 | 290 | 270 | 450 | 430 | 630 | 600 | 840 |
| 800 | 900 | 20 | 160 | 140 | 320 | 300 | 500 | 480 | 700 | 670 | 940 |
| 900 | 1000 | 20 | 170 | 150 | 350 | 330 | 550 | 530 | 770 | 740 | 1040 |
| 1000 | 1120 | 20 | 180 | 160 | 380 | 360 | 600 | 580 | 850 | 820 | 1150 |
| 1120 | 1250 | 20 | 190 | 170 | 410 | 390 | 650 | 630 | 920 | 890 | 1260 |

**Table 6.3** Radial internal clearance for cylindrical roller bearing (interchangeable) with cylindrical bore.

Clearance values in microns

| Bore diameter d (mm) Over | Incl. | Group 2 (C2) Min. | Max. | Group N (CN) Min. | Max. | Group 3 (C3) Min. | Max. | Group 4 (C4) Min. | Max. | Group 5 (C5) Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| - | 10 | 0 | 25 | 20 | 45 | 35 | 60 | 50 | 75 | ~ | ~ |
| 10 | 24 | 0 | 25 | 20 | 45 | 35 | 60 | 50 | 75 | 65 | 90 |
| 24 | 30 | 0 | 25 | 20 | 45 | 35 | 60 | 50 | 75 | 70 | 95 |
| 30 | 40 | 5 | 30 | 25 | 50 | 45 | 70 | 60 | 85 | 80 | 105 |
| 40 | 50 | 5 | 35 | 30 | 60 | 50 | 80 | 70 | 100 | 95 | 125 |
| 50 | 65 | 10 | 40 | 40 | 70 | 60 | 90 | 80 | 110 | 110 | 140 |
| 65 | 80 | 10 | 45 | 40 | 75 | 65 | 100 | 90 | 125 | 130 | 165 |
| 80 | 100 | 15 | 50 | 50 | 85 | 75 | 110 | 105 | 140 | 155 | 190 |
| 100 | 120 | 15 | 55 | 50 | 90 | 85 | 125 | 125 | 165 | 180 | 220 |
| 120 | 140 | 15 | 60 | 60 | 105 | 100 | 145 | 145 | 190 | 200 | 245 |
| 140 | 160 | 20 | 70 | 70 | 120 | 115 | 165 | 165 | 215 | 225 | 275 |
| 160 | 180 | 25 | 75 | 75 | 125 | 120 | 170 | 170 | 220 | 250 | 300 |
| 180 | 200 | 35 | 90 | 90 | 145 | 140 | 195 | 195 | 250 | 275 | 330 |
| 200 | 225 | 45 | 105 | 105 | 165 | 150 | 220 | 220 | 280 | 305 | 365 |
| 225 | 250 | 45 | 110 | 110 | 175 | 170 | 235 | 235 | 300 | 330 | 395 |
| 250 | 280 | 55 | 125 | 125 | 195 | 190 | 260 | 260 | 330 | 370 | 440 |
| 280 | 315 | 55 | 130 | 130 | 205 | 200 | 275 | 275 | 350 | 410 | 485 |
| 315 | 355 | 65 | 145 | 145 | 225 | 225 | 305 | 305 | 385 | 455 | 535 |
| 355 | 400 | 100 | 190 | 190 | 280 | 280 | 370 | 370 | 460 | 510 | 600 |
| 400 | 450 | 110 | 210 | 210 | 310 | 310 | 410 | 410 | 510 | 565 | 665 |
| 450 | 500 | 110 | 220 | 220 | 330 | 330 | 440 | 440 | 550 | 625 | 735 |

**Table 6.4** Radial internal clearance for Cylindrical roller bearing (non-interchangeable) with cylindrical bore.

Clearance values in microns

| Nominal Bore diameter d (mm) Over | Incl. | C1NA Min. | Max. | C2NA Min. | Max. | NA Min. | Max. | C3NA Min. | Max. | C4NA Min. | Max. | C5NA Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | 10 | 5 | 10 | 10 | 20 | 20 | 30 | 35 | 45 | 45 | 55 | ~ | - |
| 10 | 18 | 5 | 10 | 10 | 20 | 20 | 30 | 35 | 45 | 45 | 55 | 65 | 75 |
| 18 | 24 | 5 | 10 | 10 | 20 | 20 | 30 | 35 | 45 | 45 | 55 | 65 | 75 |
| 24 | 30 | 5 | 10 | 10 | 25 | 25 | 35 | 40 | 50 | 50 | 60 | 70 | 80 |
| 30 | 40 | 5 | 12 | 12 | 25 | 25 | 40 | 45 | 55 | 55 | 70 | 80 | 95 |
| 40 | 50 | 5 | 15 | 15 | 30 | 30 | 45 | 50 | 65 | 65 | 80 | 95 | 110 |
| 50 | 65 | 5 | 15 | 15 | 35 | 35 | 50 | 55 | 75 | 75 | 90 | 110 | 130 |
| 65 | 80 | 10 | 20 | 20 | 40 | 40 | 60 | 70 | 90 | 90 | 110 | 130 | 150 |
| 80 | 100 | 10 | 25 | 25 | 45 | 45 | 70 | 80 | 105 | 105 | 125 | 155 | 180 |
| 100 | 120 | 10 | 25 | 25 | 50 | 50 | 80 | 95 | 120 | 120 | 145 | 180 | 205 |
| 120 | 140 | 15 | 30 | 30 | 60 | 60 | 90 | 105 | 135 | 135 | 160 | 200 | 230 |
| 140 | 160 | 15 | 35 | 35 | 65 | 65 | 100 | 115 | 150 | 150 | 180 | 225 | 260 |
| 160 | 180 | 15 | 35 | 35 | 75 | 75 | 110 | 125 | 165 | 165 | 200 | 250 | 285 |
| 180 | 200 | 20 | 40 | 40 | 80 | 80 | 120 | 140 | 180 | 180 | 220 | 275 | 315 |
| 200 | 225 | 20 | 45 | 45 | 90 | 90 | 135 | 155 | 200 | 200 | 240 | 305 | 350 |
| 225 | 250 | 25 | 50 | 50 | 100 | 100 | 150 | 170 | 215 | 215 | 265 | 330 | 380 |
| 250 | 280 | 25 | 55 | 55 | 110 | 110 | 165 | 185 | 240 | 240 | 295 | 370 | 420 |
| 280 | 315 | 30 | 60 | 60 | 120 | 120 | 180 | 205 | 265 | 265 | 325 | 410 | 470 |
| 315 | 355 | 30 | 65 | 65 | 135 | 135 | 200 | 225 | 295 | 295 | 360 | 455 | 520 |
| 355 | 400 | 35 | 75 | 75 | 150 | 150 | 225 | 255 | 330 | 330 | 405 | 510 | 585 |
| 400 | 450 | 45 | 85 | 85 | 170 | 170 | 255 | 285 | 370 | 370 | 455 | 565 | 650 |

Note: For bearing with normal clearance, NA is added to bearing number, Ex. NU305NA

## 6.4.2(B.2) Cylindrical Roller Bearings (Non-interchangeable)

**Table 6.5** Radial internal clearance for Cylindrical roller bearing (non-interchangeable) with cylindrical bore.

Clearance values in microns

| Nominal Bore diameter d (mm) Over | Incl. | C9NA Min. | C9NA Max. | CONA Min. | CONA Max. | C1NA Min. | C1NA Max. | C2NA Min. | C2NA Max. | NA Min. | NA Max. | C3NA Min. | C3NA Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | 10 | 5 | 5 | 7 | 17 | 10 | 20 | 20 | 30 | 35 | 45 | 45 | 55 |
|  | 18 | 5 | 10 | 7 | 17 | 10 | 20 | 20 | 30 | 35 | 45 | 45 | 55 |
|  | 24 | 5 | 10 | 7 | 17 | 10 | 20 | 20 | 30 | 35 | 45 | 45 | 55 |
| 24 | 30 | 5 | 10 | 10 | 20 | 10 | 25 | 25 | 35 | 40 | 50 | 50 | 60 |
| 30 | 40 | 5 | 12 | 10 | 20 | 12 | 25 | 25 | 40 | 45 | 55 | 55 | 70 |
| 40 | 50 | 5 | 15 | 10 | 20 | 15 | 30 | 30 | 45 | 50 | 65 | 65 | 80 |
| 50 | 65 | 5 | 15 | 10 | 20 | 15 | 35 | 35 | 50 | 55 | 75 | 75 | 90 |
| 65 | 80 | 10 | 20 | 15 | 30 | 20 | 40 | 40 | 60 | 70 | 90 | 90 | 110 |
| 80 | 100 | 10 | 25 | 20 | 35 | 25 | 45 | 45 | 70 | 80 | 105 | 105 | 125 |
| 100 | 120 | 10 | 25 |  | 35 | 25 | 50 | 50 | 80 | 95 | 120 | 120 | 145 |
| 120 | 140 | 15 | 30 |  | 40 | 30 | 60 | 60 | 90 | 105 | 135 | 135 | 160 |
| 140 | 160 | 15 | 35 |  | 45 | 35 | 65 | 65 | 100 | 115 | 150 | 150 | 180 |
| 160 | 180 | 15 | 35 | 30 | 45 | 35 | 75 | 75 | 110 | 120 | 165 | 165 | 200 |
| 180 | 200 | 20 | 40 | 30 | 50 | 40 | 80 | 80 | 120 | 140 | 180 | 180 | 220 |
| 200 | 225 | 20 | 45 | 35 | 55 | 45 | 90 | 90 | 135 | 155 | 200 | 200 | 240 |
| 225 | 250 | 25 | 50 | 40 | 65 | 50 | 100 | 100 | 150 | 170 | 210 | 215 | 265 |
| 250 | 280 | 25 | 55 | 40 | 65 | 55 | 110 | 110 | 165 | 185 | 240 | 240 | 295 |
| 280 | 315 | 30 | 60 | 45 | 75 | 60 | 120 | 120 | 180 | 205 | 265 | 265 | 325 |
| 315 | 355 | 30 | 65 | 45 | 75 | 65 | 135 | 135 | 200 | 225 | 295 | 295 | 360 |
| 355 | 400 | 35 | 75 | 50 | 90 | 75 | 150 | 150 | 225 | 255 | 330 | 330 | 405 |
| 400 | 450 | 45 | 85 | 60 | 100 | 85 | 170 | 170 | 255 | 285 | 370 | 370 | 455 |
| 450 | 500 | 50 | 95 | 70 | 115 | 95 | 190 | 190 | 285 | 315 | 410 | 410 | 505 |

Note: C9NA, CONA and CINA are applied only to precision bearing of class 5 or higher

## 6.4.3 Double Row Self Aligning Ball Bearing (Cylindrical bore)

**Table 6.6(A)** Radial internal clearance for Double row self-aligning ball bearing with cylindrical bore.

Clearance values in microns

| Bore diameter d (mm) Over | Incl. | Group 2 (C2) Min. | Group 2 (C2) Max. | Group N (CN) Min. | Group N (CN) Max. | Group 3 (C3) Min. | Group 3 (C3) Max. | Group 4 (C4) Min. | Group 4 (C4) Max. | Group 5 (C5) Min. | Group 5 (C5) Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 6 | 1 | 8 | 5 | 15 | 10 | 20 | 15 | 25 | 21 | 33 |
| 6 | 10 | 2 | 9 | 6 | 17 | 12 | 25 | 19 | 33 | 27 | 42 |
| 10 | 14 | 2 | 10 | 6 | 19 | 13 | 26 | 21 | 35 | 30 | 48 |
| 14 | 18 | 3 | 12 | 8 | 21 | 15 | 28 | 23 | 37 | 32 | 50 |
| 18 | 24 | 4 | 14 | 10 | 23 | 17 | 30 | 25 | 39 | 34 | 52 |
| 24 | 30 | 5 | 16 | 11 | 24 | 19 | 35 | 29 | 46 | 40 | 58 |
| 30 | 40 | 6 | 18 | 13 | 29 | 23 | 40 | 34 | 53 | 46 | 66 |
| 40 | 50 | 6 | 19 | 14 | 31 | 25 | 44 | 37 | 57 | 50 | 71 |
| 50 | 65 | 7 | 21 | 16 | 36 | 30 | 50 | 45 | 69 | 62 | 88 |
| 65 | 80 | 8 | 24 | 18 | 40 | 35 | 60 | 54 | 83 | 76 | 108 |
| 80 | 100 | 9 | 27 | 22 | 48 | 42 | 70 | 64 | 96 | 89 | 124 |
| 100 | 120 | 10 | 31 | 25 | 56 | 50 | 83 | 75 | 114 | 105 | 145 |
| 120 | 140 | 10 | 38 | 30 | 68 | 60 | 100 | 90 | 135 | 125 | 175 |
| 140 | 160 | 15 | 44 | 35 | 80 | 70 | 120 | 110 | 161 | 150 | 210 |

**Table 6.6(B)** Radial internal clearance for Double Row Self Aligning Ball Bearing with tapered bore.

Clearance values in microns

| Bore diameter d (mm) Over | Incl. | Group 2 (C2) Min. | Group 2 (C2) Max. | Group N (CN) Min. | Group N (CN) Max. | Group 3 (C3) Min. | Group 3 (C3) Max. | Group 4 (C4) Min. | Group 4 (C4) Max. | Group 5 (C5) Min. | Group 5 (C5) Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 24 | 7 | 17 | 13 | 26 | 20 | 33 | 28 | 42 | 37 | 55 |
| 24 | 30 | 9 | 20 | 15 | 28 | 23 | 39 | 33 | 50 | 44 | 62 |
| 30 | 40 | 12 | 24 | 19 | 35 | 29 | 46 | 40 | 59 | 52 | 72 |
| 40 | 50 | 14 | 27 | 22 | 39 | 33 | 52 | 45 | 65 | 58 | 79 |
| 50 | 65 | 18 | 32 | 27 | 47 | 41 | 61 | 56 | 80 | 73 | 99 |
| 65 | 80 | 23 | 39 | 35 | 57 | 50 | 75 | 69 | 98 | 91 | 123 |
| 80 | 100 | 29 | 47 | 42 | 68 | 62 | 90 | 84 | 116 | 109 | 144 |
| 100 | 120 | 35 | 56 | 50 | 81 | 75 | 108 | 100 | 139 | 130 | 170 |
| 120 | 140 | 40 | 68 | 60 | 98 | 90 | 130 | 120 | 165 | 155 | 205 |
| 140 | 160 | 45 | 74 | 65 | 110 | 100 | 150 | 140 | 191 | 180 | 240 |

## 6.4.4 (A) Spherical Roller Bearing (Cylindrical bore)

**Table 6.7(A)** Radial internal clearance for Spherical roller bearing with cylindrical bore.



Clearance values in microns

| Nominal bore diameter d mm | | Bearing with cylindrical bore | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C2 | | CN | | C3 | | C4 | | C5 | |
| over | Incl. | min | max | min | max | min | max | min | max | min | max |
| 14 | 18 | 10 | 20 | 20 | 35 | 35 | 45 | 45 | 60 | 60 | 75 |
| 18 | 24 | 10 | 20 | 20 | 35 | 35 | 45 | 45 | 60 | 60 | 75 |
| 24 | 30 | 15 | 25 | 25 | 40 | 40 | 55 | 55 | 75 | 75 | 95 |
| 30 | 40 | 15 | 30 | 30 | 45 | 45 | 60 | 60 | 80 | 80 | 100 |
| 40 | 50 | 20 | 35 | 35 | 55 | 55 | 75 | 75 | 100 | 100 | 125 |
| 50 | 65 | 20 | 40 | 40 | 65 | 65 | 90 | 90 | 120 | 120 | 150 |
| 65 | 80 | 30 | 50 | 50 | 80 | 80 | 110 | 110 | 145 | 145 | 180 |
| 80 | 100 | 35 | 60 | 60 | 100 | 100 | 135 | 135 | 180 | 180 | 225 |
| 100 | 120 | 40 | 75 | 75 | 120 | 120 | 160 | 160 | 210 | 210 | 260 |
| 120 | 140 | 50 | 95 | 95 | 145 | 145 | 190 | 190 | 240 | 240 | 300 |
| 140 | 160 | 60 | 110 | 110 | 170 | 170 | 220 | 220 | 280 | 280 | 350 |
| 160 | 180 | 65 | 120 | 120 | 180 | 180 | 240 | 240 | 310 | 310 | 390 |
| 180 | 200 | 70 | 130 | 130 | 200 | 200 | 260 | 260 | 340 | 340 | 430 |
| 200 | 225 | 80 | 140 | 140 | 220 | 220 | 290 | 290 | 380 | 380 | 470 |
| 225 | 250 | 90 | 150 | 150 | 240 | 240 | 320 | 320 | 420 | 420 | 520 |
| 250 | 280 | 100 | 170 | 170 | 260 | 260 | 350 | 350 | 460 | 460 | 570 |
| 280 | 315 | 110 | 190 | 190 | 280 | 280 | 370 | 370 | 500 | 500 | 630 |
| 315 | 355 | 120 | 200 | 200 | 310 | 310 | 410 | 410 | 550 | 550 | 690 |
| 355 | 400 | 130 | 220 | 220 | 340 | 340 | 450 | 450 | 600 | 600 | 750 |
| 400 | 450 | 140 | 240 | 240 | 370 | 370 | 500 | 500 | 660 | 660 | 820 |
| 450 | 500 | 140 | 260 | 260 | 410 | 410 | 550 | 550 | 720 | 720 | 900 |
| 500 | 560 | 150 | 280 | 280 | 440 | 440 | 600 | 600 | 780 | 780 | 1,000 |
| 560 | 630 | 170 | 310 | 310 | 480 | 480 | 650 | 650 | 850 | 850 | 1,100 |
| 630 | 710 | 190 | 350 | 350 | 530 | 530 | 700 | 700 | 920 | 920 | 1,190 |
| 710 | 800 | 210 | 390 | 390 | 580 | 580 | 770 | 770 | 1,010 | 1,010 | 1,300 |
| 800 | 900 | 230 | 430 | 430 | 650 | 650 | 860 | 860 | 1,120 | 1,120 | 1,440 |
| 900 | 1,000 | 260 | 480 | 480 | 710 | 710 | 930 | 930 | 1,220 | 1,220 | 1,570 |
| 1,000 | 1,120 | 290 | 530 | 530 | 780 | 780 | 1,020 | 1,020 | 1,330 | 1,330 | 1,720 |
| 1,120 | 1,250 | 320 | 580 | 580 | 860 | 860 | 1,120 | 1,120 | 1,460 | 1,460 | 1,870 |
| 1,250 | 1,400 | 350 | 640 | 640 | 950 | 950 | 1,240 | 1,240 | 1,620 | 1,620 | 2,080 |

## 6.4.4 (B) Spherical Roller Bearing (Cylindrical bore)

**Table 6.7(B)** Spherical Roller Bearing (Tapered bore)



Clearance values in microns

| Bore diameter d (mm) | | Group 2 (C2) | | Group N (CN) | | Group 3 (C3) | | Group 4 (C4) | | Group 5 (C5) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Over | Incl. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| 18 | 24 | 15 | 25 | 25 | 35 | 35 | 45 | 45 | 60 | 60 | 75 |
| 24 | 30 | 20 | 30 | 30 | 40 | 40 | 55 | 55 | 75 | 75 | 95 |
| 30 | 40 | 25 | 35 | 35 | 50 | 50 | 65 | 65 | 85 | 85 | 105 |
| 40 | 50 | 30 | 45 | 45 | 60 | 60 | 80 | 80 | 100 | 100 | 130 |
| 50 | 65 | 40 | 55 | 55 | 75 | 75 | 95 | 95 | 120 | 120 | 160 |
| 65 | 80 | 50 | 70 | 70 | 95 | 95 | 120 | 120 | 150 | 150 | 200 |
| 80 | 100 | 55 | 80 | 80 | 110 | 110 | 140 | 140 | 180 | 180 | 230 |
| 100 | 120 | 65 | 100 | 100 | 135 | 135 | 170 | 170 | 220 | 220 | 280 |
| 120 | 140 | 80 | 120 | 120 | 160 | 160 | 200 | 200 | 260 | 260 | 330 |
| 140 | 160 | 90 | 130 | 130 | 180 | 180 | 230 | 230 | 300 | 300 | 380 |
| 160 | 180 | 100 | 140 | 140 | 200 | 200 | 260 | 260 | 340 | 340 | 430 |
| 180 | 200 | 110 | 160 | 160 | 220 | 220 | 290 | 290 | 370 | 370 | 470 |
| 200 | 225 | 120 | 180 | 180 | 250 | 250 | 320 | 320 | 410 | 410 | 520 |
| 225 | 250 | 140 | 200 | 200 | 270 | 270 | 350 | 350 | 450 | 450 | 570 |
| 250 | 280 | 150 | 220 | 220 | 300 | 300 | 390 | 390 | 490 | 490 | 620 |
| 280 | 315 | 170 | 240 | 240 | 330 | 330 | 430 | 430 | 540 | 540 | 680 |
| 315 | 355 | 190 | 270 | 270 | 360 | 360 | 470 | 470 | 590 | 590 | 740 |
| 355 | 400 | 210 | 300 | 300 | 400 | 400 | 520 | 520 | 650 | 650 | 820 |
| 400 | 450 | 230 | 330 | 330 | 450 | 450 | 570 | 570 | 720 | 720 | 910 |
| 450 | 500 | 260 | 270 | 270 | 490 | 490 | 630 | 630 | 790 | 790 | 1000 |
| 500 | 560 | 290 | 410 | 410 | 540 | 540 | 680 | 680 | 870 | 870 | 1100 |
| 560 | 630 | 320 | 460 | 460 | 600 | 600 | 760 | 760 | 980 | 980 | 1230 |
| 630 | 710 | 350 | 510 | 510 | 670 | 670 | 850 | 850 | 1090 | 1090 | 1360 |
| 710 | 800 | 390 | 570 | 570 | 750 | 750 | 960 | 960 | 1220 | 1220 | 1500 |
| 800 | 900 | 440 | 640 | 640 | 840 | 840 | 1070 | 1070 | 1370 | 1370 | 1690 |
| 900 | 1000 | 490 | 710 | 710 | 930 | 930 | 1190 | 1190 | 1520 | 1520 | 1860 |

Bearing Preload is the process of applying an axial load, independent of external loads, to a bearing. An axial preload ensures constant contact between the rolling element and raceways reducing or eliminating play inside bearing.

Bearings are preloaded to increase rigidity and thereby to reduce unwanted bearing's displacement. This means that the bearings' internal clearance is negative before operation. This is called "preload" and is commonly applied to angular ball bearings and tapered roller bearings.

The amount of preload applied is important. It must be sufficient to reduce the excess play, but care must be taken not to apply too much preload. Proper preload allows the rolling elements to freely rotate in the bearing races, while excessive preload could lead to skidding. This will increase friction and heat generation, which can ultimately lead to premature bearing failure.

### Purpose of preload

(1) Bearing's rigidity increases, internal clearance tends not to be produced even when heavy load is applied.

(2) The particular frequency of the bearing increases and is becomes suitable for high-speed rotation.

(3) Shaft run-out is suppressed; rotation and position precision are enhanced.

(4) Vibration and noise are controlled.

(5) Sliding of rolling elements by turning, spinning, or pivoting, is controlled and smearing is reduced.

(6) Fretting produced by external vibration is prevented.

### Preloading different types of bearings

#### 1. Deep groove ball bearings

Deep groove ball bearings requiring a preload must be loaded axially. Axial load can be applied to the outer ring or inner ring. The race comes in contact with the ball and translates this load to the raceway of the outer or inner ring. This creates a contact angle, between the race, the ball and the outer race. Preloading of deep groove ball bearings is optional but preloading of angular contact bearings is mandatory. Preloading can be done using a constant-force adjustable spacer (spring washer). Spring preloading reduces noise and is widely used in electric motors
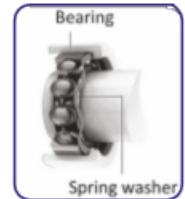


#### 2. Angular contact bearing

Angular contact bearings have large contact angles typically 15°, 25°, 30° or 40°. Angular contact bearings which are manufactured in matched pairs are referred to as duplex bearings. Duplex bearings are manufactured with the bearing faces adjacent to each other in face to face or back to back arrangement. The raceways of duplex bearings are slightly offset but come together when the proper preload is applied during assembly.



In Back-to-back arrangement, the bearings has a clearance between the inner ring faces. After preloading, the inner rings are clamped together, bringing the inner ring and outer ring faces flush with each other and resulting in contact angles that diverge towards the centerline.
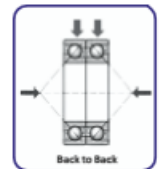
In Face-to-face bearings assembly, there is a clearance between the outer rings. After preloading, the outer ring faces and inner ring faces are clamped together, bringing the faces flush with each other and resulting in contact angles that converge towards the centerline.
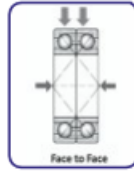
Tandem assembly two or more bearings are arranged in the same orientation. During assembly, the inner rings are clamped together, resulting in contact angles that are parallel to each other and increases the thrust capacity in one direction only.
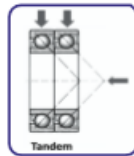
### Preload methods

There are two main methods of preloading bearings

### Rigid preloading

It provides the higher radial and axial rigidity. The preload is obtained by applying a load with a precision locknut or clamping element and a spacers is used between the two bearings. The nut applies an axial load to the inner or outer bearing ring and thus preloads bearings. Shims may also be used to obtain the proper preload
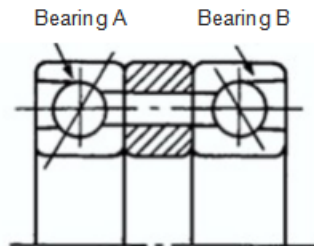
Bearing A          Bearing B

### Spring preload

Also referred as constant pressure preloading. Spring is used for applying an axial force to the non-rotating inner or outer of bearing. The force applied by the spring is relatively constant throughout its compression. Spring preloading can withstand high operating speeds as compared to rigid preloading.

Bearing B          Spring          Bearing B