10. PRELOAD

Rolling bearings usually retain some internal clearance while in operation. In some cases, however, it is desirable to provide a negative clearance to keep them internally stressed. This is called “preloading”. A preload is usually applied to bearings in which the clearance can be adjusted during mounting, such as angular contact ball bearings or tapered roller bearings. Usually, two bearings are mounted face-to-face or back-to-back to form a duplex set with a preload.

10.1 Purpose of Preload

The main purposes and some typical applications of preloaded bearings are as follows:

(1) To maintain the bearings in exact position both radially and axially and to maintain the running accuracy of the shaft.
…Main shafts of machine tools, precision instruments, etc.
(2) To increase bearing rigidity
…Main shafts of machine tools, pinion shafts of final drive gears of automobiles, etc.
(3) To minimize noise due to axial vibration and resonance
…Small electric motors, etc.
(4) To prevent sliding between the rolling elements and raceways due to gyroscopic moments
…High speed or high acceleration applications of angular contact ball bearings, and thrust ball bearings
(5) To maintain the rolling elements in their proper position with the bearing rings
…Thrust ball bearings and spherical thrust roller bearings mounted on a horizontal shaft

10.2 Preloading Methods

10.2.1 Position Preload

A position preload is achieved by fixing two axially opposed bearings in such a way that a preload is imposed on them. Their position, once fixed, remain unchanged while in operation.
In practice, the following three methods are generally used to obtain a position preload.

(1) By installing a duplex bearing set with previously adjusted stand-out dimensions (see Page A7, Fig. 1.1) and axial clearance.
(2) By using a spacer or shim of proper size to obtain the required spacing and preload. (Refer to Fig. 10.1)
(3) By utilizing bolts or nuts to allow adjustment of the axial preload. In this case, the starting torque should be measured to verify the proper preload.

10.2.2 Constant-Pressure Preload

A constant pressure preload is achieved using a coil or leaf spring to impose a constant preload. Even if the relative position of the bearings changes during operation, the magnitude of the preload remains relatively constant (refer to Fig. 10.2)

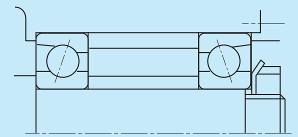


Fig. 10.1 Position Preload

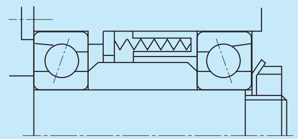


Fig. 10.2 Constant-Pressure Preload

10.3 Preload and Rigidity

10.3.1 Position Preload and Rigidity

When the inner rings of the duplex bearings shown in Fig.10.3 are fixed axially, bearings A and B are displaced δ_{a0} and axial space $2\delta_{a0}$ between the inner rings is eliminated. With this condition, a preload F_{a0} is imposed on each bearing. A preload diagram showing bearing rigidity, that is the relation between load and displacement with a given axial load F_a imposed on a duplex set, is shown in Fig. 10.4.

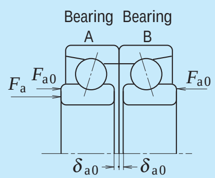


Fig. 10.3 Back-to-Back Duplex Bearing Preload

10.3.2 Constant-Pressure Preload and Rigidity

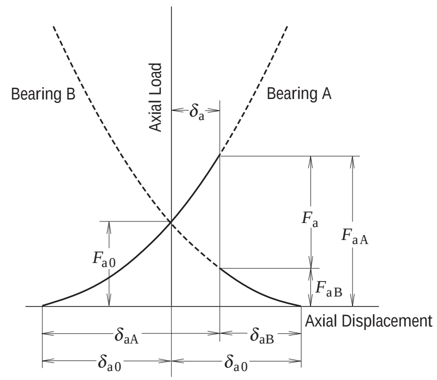
A preload diagram for duplex bearings under a constant-pressure preload is shown in Fig. 10.5. The deflection curve of the spring is nearly parallel to the horizontal axis because the rigidity of springs is lower than that of the bearing. As a result, the rigidity under a constant-pressure preload is approximately equal to that for a single bearing with a preload F_{a0} applied to it. Fig. 10.6 presents a comparison of the rigidity of a bearing with a position preload and one with a constant-pressure preload.

10.4 Selection of Preloading Method and Amount of Preload

10.4.1 Comparison of Preloading Methods

A comparison of the rigidity using both preloading methods is shown in Fig. 10.6. The position preload and constant-pressure preload may be compared as follows:

(1) When both of the preloads are equal, the position preload provides greater bearing rigidity, in other words, the deflection due to external loads is less for bearings with a position preload.
(2) In the case of a position preload, the preload varies depending on such factors as a difference in axial expansion due to a temperature difference between the shaft and housing, a difference in radial expansion due to a temperature difference between the inner and outer rings, deflection due to load, etc.



F_a : Axial load applied from outside
F_{aA}: Axial load imposed on Bearing A
F_{aB}: Axial load imposed on Bearing B
δ_a : Displacement of duplex bearing set
δ_{aA} : Displacement of Bearing A
δ_{aB} : Displacement of Bearing B

Fig. 10.4 Axial Displacement with Position Preload

In the case of a constant-pressure preload, it is possible to minimize any change in the preload because the variation of the spring load with shaft expansion and contraction is negligible. From the foregoing explanation, it is seen that position preloads are generally preferred for increasing rigidity and constant-pressure preloads are more suitable for high speed applications, for prevention of axial vibration, for use with thrust bearings on horizontal shafts, etc.

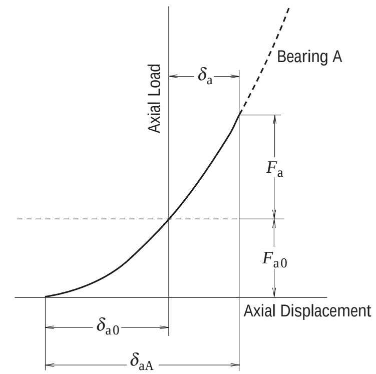


Fig. 10.5 Axial Displacement with Constant-Pressure Preload

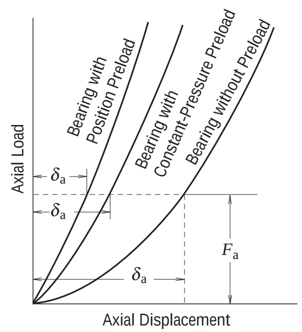


Fig. 10.6 Comparison of Rigidities and Preloading Methods

10.4.2 Amount of Preload

If the preload is larger than necessary, abnormal heart generation, increased frictional torque, reduced fatigue life, etc. may occur. The amount of the preload should be carefully determined considering the operating conditions and the purpose of the preload.

(1) Preloading of Duplex Angular Contact Ball Bearings

Average preloads for duplex angular contact ball bearings (contact angle of 15°) with precision better than P5 class, which are used on the main shafts of machine tools, are listed in Table 10.2.

The recommended fitting between the shaft and inner ring and between the housing and outer ring are listed in Table 10.1. In the case of fits with housings, the lower limit of the fitting range should be selected for fixed-end bearings and the upper limit for free-end bearings.

As a general rule, an extra light or light preload should be selected for grinding spindles and the main shafts of machining centers, while a medium preload should be adopted for the main shafts of lathes requiring rigidity.

When speeds result in a value of $D_{pw} \times n$ ($d_m n$ value) higher than 500000, the preload should be very carefully studied and selected. In such a case, please consult with NSK beforehand.

Table 10. 1 Recommended Fitting for High Accuracy Duplex Angular Contact Ball Bearings with Preload

Units : μm

Nominal Bore Dia. d (mm) over	Nominal Bore Dia. d (mm) incl.	Target Shaft Interference	Nominal Outside Dia. D (mm) over	Nominal Outside Dia. D (mm) incl.	Target Housing Clearance
—	18	0 to 2	—	18	—
18	30	0 to 2.5	18	30	2 to 6
30	50	0 to 2.5	30	50	2 to 6
50	80	0 to 3	50	80	3 to 8
80	120	0 to 4	80	120	3 to 9
120	150	—	120	150	4 to 12
150	180	—	150	180	4 to 12
180	250	—	180	250	5 to 15

(2) Preload of Thrust Ball Bearings

When the balls in thrust ball bearings rotate at relatively high speeds, sliding due to gyroscopic moments on the balls may occur. The larger of the two values obtained from Equations(10.1) and (10.2) below should be adopted as the minimum axial load in order to prevent such sliding

$$F_{a\ min} = \frac{C_{0a}}{100}\left(\frac{n}{N_{max}}\right)^2 \quad \cdots\cdots (10.1)$$

$$F_{a\ min} = \frac{C_{0a}}{1000} \quad \cdots\cdots (10.2)$$

where $F_{a\ min}$: Minimum axial load (N), {kgf}
n : Speed (min^{-1})
C_{0a} : Basic static load rating (N), {kgf}
N_{max} : Limiting speed (oil lubrication) (min^{-1})

(3) Preload of Spherical Thrust Roller Bearings

When spherical thrust roller bearings are used, damage such as scoring may occur due to sliding between the rollers and outer ring raceway. The minimum axial load $F_{a\ min}$ necessary to prevent such sliding is obtained from the following equation:

$$F_{a\ min} = \frac{C_{0a}}{1000} \quad \cdots\cdots (10.3)$$

Table 10. 2 Preloads for Duplex Angular Contact Ball Bearings

Table 10. 2. 1 Duplex Bearings of Series 79

Units : N

Bearing No.	Preloads Extra light Preload EL	Light Preload L	Medium Preload M	Heavy Preload H
7900 C	7	15	29	59
7901 C	8.6	15	39	78
7902 C	12	25	49	100
7903 C	12	25	59	120
7904 C	19	39	78	150
7905 C	19	39	100	200
7906 C	24	49	100	200
7907 C	34	69	150	290
7908 C	39	78	200	390
7909 C	50	100	200	390
7910 C	50	100	250	490
7911 C	60	120	290	590
7912 C	60	120	290	590
7913 C	75	150	340	690
7914 C	100	200	490	980
7915 C	100	200	490	980
7916 C	100	200	490	980
7917 C	145	290	640	1 270
7918 C	145	290	740	1 470
7919 C	145	290	780	1 570
7920 C	195	390	880	1 770

Table 10. 2. 2 Duplex Bearings of Series 70

Units : N

Bearing No.	Preloads Extra light Preload EL	Light Preload L	Medium Preload M	Heavy Preload H
7000 C	12	25	49	100
7001 C	12	25	59	120
7002 C	14	29	69	150
7003 C	14	29	69	150
7004 C	24	49	120	250
7005 C	29	59	150	290
7006 C	39	78	200	390
7007 C	60	120	250	490
7008 C	60	120	290	590
7009 C	75	150	340	690
7010 C	75	150	390	780
7011 C	100	200	490	980
7012 C	100	200	540	1 080
7013 C	125	250	540	1 080
7014 C	145	290	740	1 470
7015 C	145	290	780	1 570
7016 C	195	390	930	1 860
7017 C	195	390	980	1 960
7018 C	245	490	1 180	2 350
7019 C	270	540	1 180	2 350
7020 C	270	540	1 270	2 550

Table 10. 2. 3 Duplex Bearings of Series 72

Units : N

Bearing No.	Preloads Extra light Preload EL	Light Preload L	Medium Preload M	Heavy Preload H
7200 C	14	29	69	150
7201 C	19	39	100	200
7202 C	19	39	100	200
7203 C	24	49	150	290
7204 C	34	69	200	390
7205 C	39	78	200	390
7206 C	60	120	290	590
7207 C	75	150	390	780
7208 C	100	200	490	980
7209 C	125	250	540	1 080
7210 C	125	250	590	1 180
7211 C	145	290	780	1 570
7212 C	195	390	930	1 860
7213 C	220	440	1 080	2 160
7214 C	245	490	1 180	2 350
7215 C	270	540	1 230	2 450
7216 C	295	590	1 370	2 750
7217 C	345	690	1 670	3 330
7218 C	390	780	1 860	3 730
7219 C	440	880	2 060	4 120
7220 C	490	980	2 350	4 710