5.2 ROLLING CONTACT BEARINGS

5.2.1 Introduction

In rolling contact bearings, the contact between the bearing surfaces is rolling instead of sliding as in sliding contact bearings. We have already discussed that the ordinary sliding bearing starts from rest with practically metal-to-metal contact and has a high coefficient of friction. It is an outstanding advantage of a rolling contact bearing over a sliding bearing that it has a low starting friction. Due to this low friction offered by rolling contact bearings, these are called ***antifriction bearings.***

5.2.2 Advantages and Disadvantages of Rolling Contact Bearings Over Sliding Contact Bearings

The following are some advantages and disadvantages of rolling contact bearings over sliding contact bearings.

Advantages

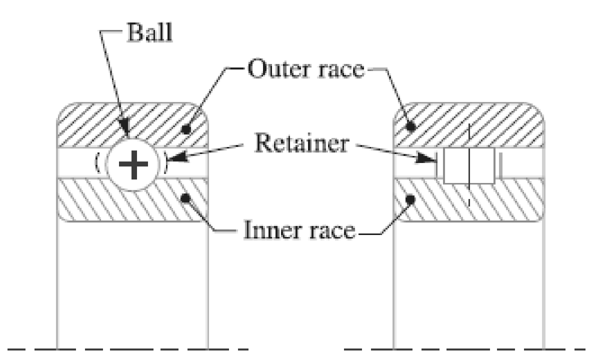
1. Low starting and running friction except at very high speeds.
2. Ability to withstand momentary shock loads.
3. Accuracy of shaft alignment.
4. Low cost of maintenance, as no lubrication is required while in service.
5. Small overall dimensions.
6. Reliability of service.
7. Easy to mount and erect.
8. Cleanliness.

Disadvantages

1. More noisy at very high speeds.
2. Low resistance to shock loading.
3. More initial cost.
4. Design of bearing housing complicated.

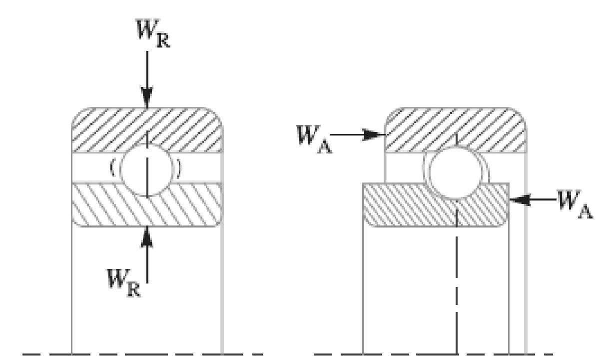
5.2.3 Types of Rolling Contact Bearings

Following are the two types of rolling contact bearings:
1. Ball bearings; and **2.** Roller bearings.



(*a*) Ball bearing. (*b*) Roller bearing.

Fig.5.6. Ball and roller bearings.



(*a*) Radial ball bearing. (*b*) Thrust ball bearing.

Fig.5.7. Radial and thrust ball bearings.

The ***ball and roller bearings*** consist of an inner race which is mounted on the shaft or journal and an outer race which is carried by the housing or casing. In between the inner and outer race, there are balls or rollers as shown in Fig.5.6. A number of balls or rollers are used and these are held at proper distances by retainers so that they do not touch each other. The retainers are thin strips and is usually in two parts which are assembled after the balls have been properly spaced. The ball bearings are used for light loads and the roller bearings are used for heavier loads.

The rolling contact bearings, depending upon the load to be carried, are classified as :
(*a*) Radial bearings, and **(*b*)** Thrust bearings.
The radial and thrust ball bearings are shown in Fig. 5.7 (*a*) and (*b*) respectively. When a ball bearing supports only a radial load (*W*R), the plane of rotation of the ball is normal to the centre line of the bearing, as shown in Fig. 5.7 (*a*). The action of thrust load (*W*A) is to shift the plane of rotation of the balls, as shown in Fig. 5.7 (*b*). The radial and thrust loads both may be carried simultaneously.

5.2.4 Types of Radial Ball Bearings

Following are the various types of radial ball bearings:
1. *Single row deep groove bearing.* A single row deep groove bearing is shown in Fig. 5.8(*a*).

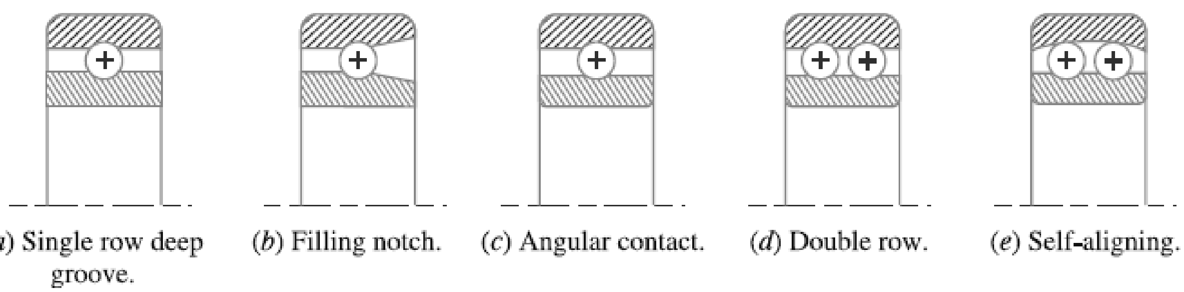


Fig 5.8. Types of radial ball bearing

During assembly of this bearing, the races are offset and the maximum number of balls are placed between the races. The races are then centred and the balls are symmetrically located by the use of a retainer or cage. The deep groove ball bearings are used due to their high load carrying capacity and suitability for high running speeds. The load carrying capacity of a ball bearing is related to the size and number of the balls.

2. *Filling notch bearing.* A filling notch bearing is shown in Fig. 5.8 (*b*). These bearings have notches in the inner and outer races which permit more balls to be inserted than in a deep groove ball bearings. The notches do not extend to the bottom of the race way and therefore the balls inserted through the notches must be forced in position. Since this type of bearing contains larger number of balls than a corresponding unnotched one, therefore it has a larger bearing load capacity.

3. *Angular contact bearing*. An angular contact bearing is shown in Fig. 5.8 (*c*). These bearings
have one side of the outer race cut away to permit the insertion of more balls than in a deep groove bearing but without having a notch cut into both races. This permits the bearing to carry a relatively large axial load in one direction while also carrying a relatively large radial load. The angular contact bearings are usually used in pairs so that thrust loads may be carried in either direction.

4. *Double row bearing.* A double row bearing is shown in Fig. 5.8 (*d*). These bearings may be made with radial or angular contact between the balls and races. The double row bearing is appreciably narrower than two single row bearings. The load capacity of such bearings is slightly less than twice that of a single row bearing.

5. *Self-aligning bearing.* A self-aligning bearing is shown in Fig. 5.8 (*e*). These bearings permit shaft deflections within 2-3 degrees. It may be noted that normal clearance in a ball bearing are too small to accommodate any appreciable misalignment of the shaft relative to the housing. If the unit is assembled with shaft misalignment present, then the bearing will be subjected to a load that may be in excess of the design value and premature failure may occur.

Following are the two types of self-aligning bearings :

(a) Externally self-aligning bearing, and **(*b*)** Internally self-aligning bearing.

In an ***externally self-aligning bearing,*** the outside diameter of the outer race is ground to a spherical surface which fits in a mating spherical surface in a housing, as shown in Fig. 5.8 (*e*). In case of ***internally self-aligning bearing,*** the inner surface of the outer race is ground to a s surface. Consequently, the outer race may be displaced through a small angle without interfering with the normal operation of the bearing. The internally self-aligning ball bearing is interchangeable with other ball bearings.

5.2.5 Standard Dimensions and Designations of Ball Bearings

The dimensions that have been standardised on an international basis are shown in Fig. 5.9. These dimensions are a function of the bearing bore and the series of bearing. The standard dimensions are given in millimetres. There is no standard for the size and number of steel balls. The bearings are designated by a number. In general, the number consists of atleast three digits. Additional digits or letters are used to indicate special features *e.g*. deep groove, filling notch etc. The last three digits give the series and the bore of the bearing. The last two digits from 04 onwards, when multiplied by 5, give the bore diameter in millimetres. The third from the last digit designates the series of the bearing.

The most common ball bearings are available in four series as follows :

1. Extra light (100), **2.** Light (200),
3. Medium (300), **4.** Heavy (400)

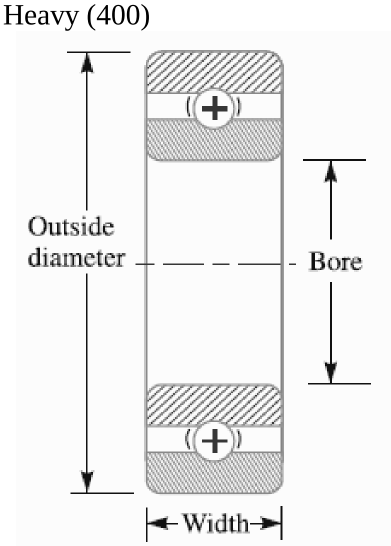
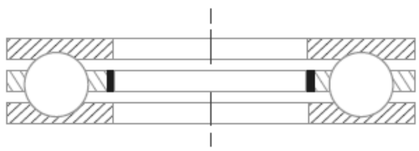


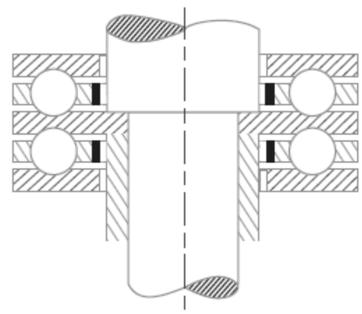
Fig. 5.9. Standard designations of ball bearings.

5.2.6 Thrust Ball Bearings

The thrust ball bearings are used for carrying thrust loads exclusively and at speeds below 2000 r.p.m. At high speeds, centrifugal force causes the balls to be forced out of the races. Therefore at high speeds, it is recommended that angular contact ball bearings should be used in place of thrust ball bearings. thrust ball bearing may be a single direction, flat face as shown in Fig.5.10 (*a*) or a double direction with flat face as shown in Fig. 5.10 (*b*).



(*a*) Single direction thrust ball bearing.



(*b*) Double direction thrust ball bearing.

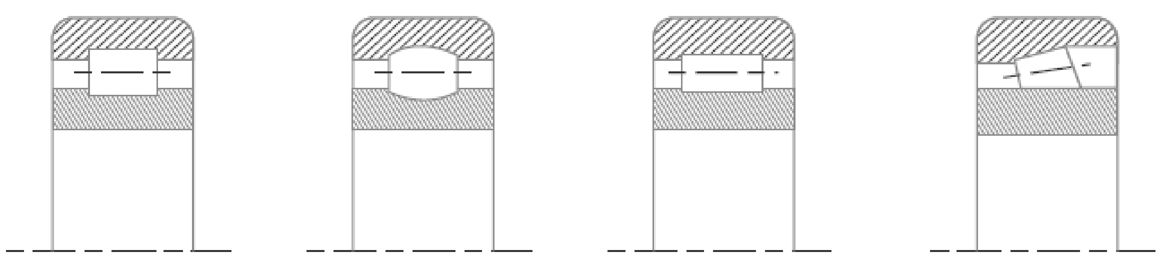
Fig. 5.10. Thrust ball bearing

5.2.7 Types of Roller Bearings

Following are the principal types of roller bearings :

1. *Cylindrical roller bearings.* A cylindrical roller bearing is shown in Fig. 5.11 (*a*). These bearings have short rollers guided in a cage. These bearings are relatively rigid against radial motion and have the lowest coefficient of friction of any form of heavy duty rolling-contact bearings. Such type of bearings are used in high speed service.

2. *Spherical roller bearings.* A spherical roller bearing is shown in Fig. 5.11 (*b*). These bearings are self-aligning bearings. The self-aligning feature is achieved by grinding one of the races in the form of sphere.



(*a*) Cylindrical roller. (*b*) Spherical roller. (*c*) Needle roller. (*d*) Tapered roller.

Fig. 5.11. Types of roller bearings.

3. *Needle roller bearings.* A needle roller bearing is shown in Fig. 5.11. (*c*). These bearings are relatively slender and completely fill the space so that neither a cage nor a retainer is needed. These bearings are used when heavy loads are to be carried with an oscillatory motion, *e.g.* piston pin bearings in heavy duty diesel engines, where the reversal of motion tends to keep the rollers in correct alignment.

4. *Tapered roller bearings.* A tapered roller bearing is shown in Fig. 5.11 (*d*). The rollers and race ways of these bearings are truncated cones whose elements intersect at a common point. Such type of bearings can carry both radial and thrust loads. These bearings are available in various combinations as double row bearings and with different cone angles for use with different relative magnitudes of radial and thrust loads.

5.2.8 Life of a Bearing

The ***life*** of an individual ball (or roller) bearing may be defined as the number of revolutions (or hours at some given constant speed) which the bearing runs before the first evidence of fatigue develops in the material of one of the rings or any of the rolling elements. The ***rating life*** of a group of apparently identical ball or roller bearings is defined as the number of revolutions (or hours at some given constant speed) that 90 per cent of a group of bearings will complete or exceed before the first evidence of fatigue develops (*i.e.* only 10 per cent of a group of bearings fail due to fatigue).

The term ***minimum life*** is also used to denote the rating life. It has been found that the life which 50 per cent of a group of bearings will complete or exceed is approximately 5 times the life which 90 per cent of the bearings will complete or exceed. In other words, we may say that the average life of a bearing is 5 times the rating life (or minimum life). It may be noted that the longest life of a single bearing is seldom longer than the 4 times the average life and the maximum life of a single bearing is about 30 to 50 times the minimum life.

The life of bearings for various types of machines is given in the following table.

Table 5.3. Life of bearings for various types of machines.

S. No.	*Application of bearing*	*Life of bearing, in hours*
1.	Instruments and apparatus that are rarely used	
	(*a*) Demonstration apparatus, mechanism for operating sliding doors	500
	(*b*) Aircraft engines	1000 – 2000
2.	Machines used for short periods or intermittently and whose breakdown would not have serious consequences *e.g.* hand tools, lifting tackle in workshops, and operated machines, agricultural machines, cranes in erecting shops, domestic machines.	4000 – 8000
3.	Machines working intermittently whose breakdown would have serious consequences *e.g.* auxillary machinery in power stations, conveyor plant for flow production, lifts, cranes for piece goods, machine tools used frequently.	8000 – 12 000
4.	Machines working 8 hours per day and not always fully utilised *e.g.* stationary electric motors, general purpose gear units.	12 000 – 20 000
5.	Machines working 8 hours per day and fully utilised *e.g.* machines for the engineering industry, cranes for bulk goods, ventilating fans, counter shafts.	20 000 – 30 000
6.	Machines working 24 hours per day *e.g.* separators, compressors, pumps, mine hoists, naval vessels.	40 000 – 60 000
7.	Machines required to work with high degree of reliability 24 hours per day *e.g.* pulp and paper making machinery, public power plants, mine-pumps, water works.	100 000 – 200 000

5.2.9 Dynamic Equivalent Load for Rolling Contact Bearings

The dynamic equivalent load may be defined as the constant stationary radial load (in case of radial ball or roller bearings) or axial load (in case of thrust ball or roller bearings) which, if applied to a bearing with rotating inner ring and stationary outer ring, would give the same life as that which the bearing will attain under the actual conditions of load and rotation. The dynamic equivalent radial load (W) for radial and angular contact bearings, except the filling slot types, under combined constant radial load (WR) and constant axial or thrust load (WA) is given by

$$W = X \cdot V \cdot W\text{R} + Y \cdot W\text{A}$$

where $V = A$ rotation factor,

= 1, for all types of bearings when the inner race is rotating,

= 1, for self-aligning bearings when inner race is stationary,

= 1.2, for all types of bearings except self-aligning, when inner race is stationary.

The values of radial load factor (X) and axial or thrust load factor (Y) for the dynamically loaded bearings may be taken from the following table:

Table 5.4. Values of X and Y for dynamically loaded bearings.

Type of bearing	*Specifications*	$\frac{W_A}{W_R} \le e$		$\frac{W_A}{W_R} > e$		e
		X	Y	X	Y	
Deep groove ball bearing	$\frac{W_A}{C_0} = 0.025$				2.0	0.22
	$= 0.04$				1.8	0.24
	$= 0.07$				1.6	0.27
	$= 0.13$	1	0	0.56	1.4	0.31
	$= 0.25$				1.2	0.37
	$= 0.50$				1.0	0.44
Angular contact ball bearings	Single row		0	0.35	0.57	1.14
	Two rows in tandem		0	0.35	0.57	1.14
	Two rows back to back	1	0.55	0.57	0.93	1.14
	Double row		0.73	0.62	1.17	0.86
Self-aligning bearings	Light series : for bores					
	10 – 20 mm		1.3		2.0	0.50
	25 – 35	1	1.7	6.5	2.6	0.37
	40 – 45		2.0		3.1	0.31
	50 – 65		2.3		3.5	0.28
	70 – 100		2.4		3.8	0.26
	105 – 110		2.3		3.5	0.28
	Medium series : for bores					
	12 mm		1.0	0.65	1.6	0.63
	15 – 20		1.2		1.9	0.52
	25 – 50		1.5		2.3	0.43
	55 – 90		1.6		2.5	0.39
Spherical roller bearings	For bores :					
	25 – 35 mm		2.1		3.1	0.32
	40 – 45	1	2.5	0.67	3.7	0.27
	50 – 100		2.9		4.4	0.23
	100 – 200		2.6		3.9	0.26
Taper roller bearings	For bores :					
	30 – 40 mm				1.60	0.37
	45 – 110	1	0	0.4	1.45	0.44
	120 – 150				1.35	0.41

5.2.10 Reliability of a Bearing.

The reliability (R) is defined as the ratio of the number of bearings which have successfully completed L million revolutions to the total number of bearings under test. Sometimes, it becomes necessary to select a bearing having a reliability of more than 90%. According to Wiebull, the relation between the bearing life and the reliability is given as

$$\log_e\left(\frac{1}{R}\right) = \left(\frac{L}{a}\right)^b \quad \text{or} \quad \frac{L}{a} = \left[\log_e\left(\frac{1}{R}\right)\right]^{1/b} \qquad \ldots(i)$$

where L is the life of the bearing corresponding to the desired reliability R and a and b are constants whose values are

a = 6.84, and b = 1.17

If $L90$ is the life of a bearing corresponding to a reliability of 90% (*i.e.* $R90$), then

$$\frac{L_{90}}{a} = \left[\log_e\left(\frac{1}{R_{90}}\right)\right]^{1/b} \qquad \ldots(ii)$$

Dividing equation (*i*) by equation (*ii*), we have

$$\frac{L}{L_{90}} = \left[\frac{\log_e(1/R)}{\log_e(1/R_{90})}\right]^{1/b} = {}^*6.85\,[\log_e(1/R)]^{1/1.17} \qquad \ldots (\because\ b = 1.17)$$

Example 5.3. *A shaft rotating at constant speed is subjected to variable load. The bearings supporting the shaft are subjected to stationary equivalent radial load of 3 kN for 10 per cent of time, 2 kN for 20 percent of time, 1 kN for 30 per cent of time and no load for remaining time of cycle. If the total life expected for the bearing is 20 × 106 revolutions at 95 per cent reliability, calculate dynamic load rating of the ball bearing.*

Given Data : W_1 = 3 kN

$n_1 = 0.1\ n$
W_2 = 2 kN
$n_2 = 0.2\ n$
W_3 = 1 kN
$n_3 = 0.3\ n$
$W_4 = 0$
$n_4 = (1 – 0.1 – 0.2 – 0.3)\ n = 0.4\ n$
$L_{95} = 20 \times 10^6$ rev

Solution

Let

L_{90} = Life of the bearing corresponding to reliability of 90 per cent,

L_{95} = Life of the bearing corresponding to reliability of 95 per cent

$= 20 \times 10^6$ revolutions …….(Given)

We know that

$$\frac{L_{95}}{L_{90}} = \left[\frac{\log_e (1/R_{95})}{\log_e (1/R_{90})}\right]^{1/b} = \left[\frac{\log_e (1/0.95)}{\log_e (1/0.90)}\right]^{1/1.17} \quad \ldots (\because\ b = 1.17)$$

$$= \left(\frac{0.0513}{0.1054}\right)^{0.8547} = 0.54$$

$$\therefore \quad L_{90} = L_{95} / 0.54 = 20 \times 10^6 / 0.54 = 37 \times 10^6 \text{ rev}$$

We know that equivalent radial load,

$$W = \left[\frac{n_1 (W_1)^3 + n_2 (W_2)^3 + n_3 (W_3)^3 + n_4 (W_4)^3}{n_1 + n_2 + n_3 + n_4}\right]^{1/3}$$

$$= \left[\frac{0.1 n \times 3^3 + 0.2\, n \times 2^3 + 0.3 n \times 1^3 + 0.4\, n \times 0^3}{0.1\, n + 0.2n + 0.3n + 0.4n}\right]^{1/3}$$

$$= (2.7 + 1.6 + 0.3 + 0)^{1/3} = 1.663 \text{ kN}$$

We also know that dynamic load rating,

$$C = W \left(\frac{L_{90}}{10^6}\right)^{1/k} = 1.663 \left(\frac{37 \times 10^6}{10^6}\right)^{1/3} = 5.54 \text{ kN Ans.}$$

$$\ldots (\because\ k = 3, \text{ for ball bearing})$$

5.2.11 Selection of Radial Ball Bearings

In order to select a most suitable ball bearing, first of all, the basic dynamic radial load is calculated. It is then multiplied by the service factor (*K*S) to get the design basic dynamic radial load capacity. The service factor for the ball bearings is shown in the following table

.

Table 5.5. Values of service factor (*K*S).

S.No.	*Type of service*	*Service factor (K_S) for radial ball bearings*
1.	Uniform and steady load	1.0
2.	Light shock load	1.5
3.	Moderate shock load	2.0
4.	Heavy shock load	2.5
5.	Extreme shock load	3.0

Table 5.6. Basic static and dynamic capacities of various types of radial ball bearings.

Bearing No.	Basic capacities in kN							
	Single row deep groove ball bearing		Single row angular contact ball bearing		Double row angular contact ball bearing		Self-aligning ball bearing	
	Static (C_0)	Dynamic (C)	Static (C_0)	Dynamic (C)	Static (C_0)	Dynamic (C)	Static (C_0)	Dynamic (C)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
200	2.24	4	—	—	4.55	7.35	1.80	5.70
300	3.60	6.3	—	—	—	—	—	—
201	3	5.4	—	—	5.6	8.3	2.0	5.85
301	4.3	7.65	—	—	—	—	3.0	9.15
202	3.55	6.10	3.75	6.30	5.6	8.3	2.16	6
302	5.20	8.80	—	—	9.3	14	3.35	9.3
203	4.4	7.5	4.75	7.8	8.15	11.6	2.8	7.65
303	6.3	10.6	7.2	11.6	12.9	19.3	4.15	11.2
403	11	18	—	—	—	—	—	—
204	6.55	10	6.55	10.4	11	16	3.9	9.8
304	7.65	12.5	8.3	13.7	14	19.3	5.5	14
404	15.6	24	—	—	—	—	—	—
205	7.1	11	7.8	11.6	13.7	17.3	4.25	9.8
305	10.4	16.6	12.5	19.3	20	26.5	7.65	19
405	19	28	—	—	—	—	—	—
206	10	15.3	11.2	16	20.4	25	5.6	12
306	14.6	22	17	24.5	27.5	35.5	10.2	24.5
406	23.2	33.5	—	—	—	—	—	—
207	13.7	20	15.3	21.2	28	34	8	17
307	17.6	26	20.4	28.5	36	45	13.2	30.5
407	30.5	43	—	—	—	—	—	—
208	16	22.8	19	25	32.5	39	9.15	17.6
308	22	32	25.5	35.5	45.5	55	16	35.5
408	37.5	50	—	—	—	—	—	—
209	18.3	25.5	21.6	28	37.5	41.5	10.2	18
309	30	41.5	34	45.5	56	67	19.6	42.5
409	44	60	—	—	—	—	—	—
210	21.2	27.5	23.6	29	43	47.5	10.8	18
310	35.5	48	40.5	53	73.5	81.5	24	50
410	50	68	—	—	—	—	—	—

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
211 311 411	26 42.5 60	34 56 78	30 47.5 —	36.5 62 —	49 80 —	53 88 —	12.7 28.5 —	20.8 58.5 —
212 312 412	32 48 67	40.5 64 85	36.5 55 —	44 71 —	63 96.5 —	65.5 102 —	16 33.5 —	26.5 68 —
213 313 413	35.5 55 76.5	44 72 93	43 63 —	50 80 —	69.5 112 —	69.5 118 —	20.4 39 —	34 75 —
214 314 414	39 63 102	48 81.5 112	47.5 73.5 —	54 90 —	71 129 —	69.5 137 —	21.6 45 —	34.5 85 —
215 315 415	42.5 72 110	52 90 120	50 81.5 —	56 98 —	80 140 —	76.5 143 —	22.4 52 —	34.5 95 —
216 316 416	45.5 80 120	57 96.5 127	57 91.5 —	63 106 —	96.5 160 —	93 163 —	25 58.5 —	38 106 —
217 317 417	55 88 132	65.5 104 134	65.5 102 —	71 114 —	100 180 —	106 180 —	30 62 —	45.5 110 —
218 318 418	63 98 146	75 112 146	76.5 114 —	83 122 —	127 — —	118 — —	36 69.5 —	55 118 —
219 319	72 112	85 120	88 125	95 132	150 —	137 —	43 —	65.5 —
220 320	81.5 132	96.5 137	93 153	102 150	160 —	146 —	51 —	76.5 —
221 321	93 143	104 143	104 166	110 160	— —	— —	56 —	85 —
222 322	104 166	112 160	116 193	120 176	— —	— —	64 —	98 —

Example 5.4. *Select a single row deep groove ball bearing for a radial load of 4000 N and an axial load of 5000 N, operating at a speed of 1600 r.p.m. for an average life of 5 years at 10 hours per day. Assume uniform and steady load.*

Given Data :

W_R = 4000 N

W_A = 5000 N ;

N = 1600 r.p.m.

Solution

Since the average life of the bearing is 5 years at 10 hours per day, therefore life of the bearing in hours,

$L_H = 5 \times 300 \times 10 = 15\ 000$ hours .. (Assuming 300 working days per year)

and life of the bearing in revolutions,

$L = 60\ N \times L_H = 60 \times 1600 \times 15\ 000 = 1440 \times 10^6$ rev

We know that the basic dynamic equivalent radial load,

$W = X.V.W_R + Y.W_A$ ...**(*i*)**

In order to determine the radial load factor (X) and axial load factor (Y), we require W_A / W_R and W_A / C_0. Since the value of basic static load capacity (C_0) is not known, therefore let us take $W_A / C_0 = 0.5$. Now from Table 5.4, we find that the values of X and Y corresponding to W_A / C_0

= 0.5 and $W_A/W_R = 5000 / 4000 = 1.25$ (which is greater than $e = 0.44$) are

$X = 0.56$ and $Y = 1$

Since the rotational factor (V) for most of the bearings is 1, therefore basic dynamic equivalent radial load,

$W = 0.56 \times 1 \times 4000 + 1 \times 5000 = 7240$ N

From Table 5.5, we find that for uniform and steady load, the service factor (K_S) for ball bearings is 1. Therefore the bearing should be selected for W = 7240 N.

We know that basic dynamic load rating,

$$C = W\left(\frac{L}{10^6}\right)^{1/k} = 7240\left(\frac{1440 \times 10^6}{10^6}\right)^{1/3} = 81\ 760\ \text{N}$$

= 81.76 kN ... (k = 3, for ball bearings)

From Table 5.6, let us select the bearing No. 315 which has the following basic capacities,

C_0 = 72 kN = 72 000 N and C = 90 kN = 90 000 N

Now $W_A / C_0 = 5000 / 72\ 000 = 0.07$

From Table 5.4, the values of X and Y are

$X = 0.56$ and $Y = 1.6$

Substituting these values in equation **(*i*)**, we have dynamic equivalent load,

$W = 0.56 \times 1 \times 4000 + 1.6 \times 5000 = 10\ 240$ N

Basic dynamic load rating,

$$C = 10\ 240 \left(\frac{1440 \times 10^6}{10^6} \right)^{1/3}$$

$$= 115\ 635 \text{ N} = 115.635 \text{ kN}$$

From Table 5.6, the bearing number 319 having C = 120 kN, may be selected. **Ans.**

Example 5.5. *Design a self-aligning ball bearing for a radial load of 7000 N and a thrust load of 2100 N. The desired life of the bearing is 160 millions of revolutions at 300 r.p.m. Assume uniform and steady load,*

Given Data:
*W*R = 7000 N
*W*A = 2100 N
L = 160 × 106 rev
N = 300 r.p.m.

Solution.

From Table 5.4,
we find that for a self-aligning ball bearing, the values of radial factor (*X*)
And thrust factor (*Y*) for *W*A / *W*R = 2100 / 7000 = 0.3, are as follows :

$X = 0.65$ and $Y = 3.5$

Since the rotational factor (*V*) for most of the bearings is 1, therefore dynamic equivalent load,

$$W = X.V.W\text{R} + Y.W\text{A} = 0.65 \times 1 \times 7000 + 3.5 \times 2100 = 11\ 900 \text{ N}$$

From Table 5.5, we find that for uniform and steady load, the service factor *K*S for ball bearingsis 1.
Therefore the bearing should be selected for *W* = 11 900 N.
We know that the basic dynamic load rating,

$$\text{C} = \quad \text{W} \left(\frac{L}{10^6}\right)^{1/K} = 11900 \left(\frac{160\ X\ 10^6}{10^6}\right)^{1/3}$$

$$= 64\ 600 \text{ N} = 64.6 \text{ kN} \qquad \text{... (} k = 3\text{, for ball bearings)}$$

From Table 5.6, let us select bearing number 219 having C = 65.5 kN **Ans.**

Example 5.6. *Select a single row deep groove ball bearing with the operating cycle listed below, which will have a life of 15 000 hours.*

Fraction of cycle	*Type of load*	*Radial (N)*	*Thrust (N)*	*Speed (R.P.M.)*	*Service factor*
1/10	*Heavy shocks*	*2000*	*1200*	*400*	*3.0*
1/10	*Light shocks*	*1500*	*1000*	*500*	*1.5*
1/5	*Moderate shocks*	*1000*	*1500*	*600*	*2.0*

3/5	*No shock*	*1200*	*2000*	*800*	*1.0*

Assume radial and axial load factors to be 1.0 and 1.5 respectively and inner race rotates.

Given Data :
L_H = 15 000 hours
W_{R1} = 2000 N ; W_{A1} = 1200 N ; N_1 = 400 r.p.m. ; K_{S1} = 3
W_{R2} = 1500 N ; W_{A2} = 1000 N ; N_2 = 500 r.p.m. ; K_{S2} = 1.5
W_{R3} = 1000 N ; W_{A3} = 1500 N ; N_3 = 600 r.p.m. ; K_{S3} = 2
W_{R4} = 1200 N ; W_{A4} = 2000 N ; N_4 = 800 r.p.m. ; K_{S4} = 1
X = 1 ; Y = 1.5

Solution

We know that basic dynamic equivalent radial load considering service factor is

$W = [X.V.W_R + Y.W_A]\, K_S$ ...***(i)***

It is given that radial load factor (X) = 1 and axial load factor (Y) = 1.5. Since the rotational factor (V) for most of the bearings is 1, therefore equation ***(i)*** may be written as

$W = (W_R + 1.5\, W_A)\, K_S$

Now, substituting the values of W_R, W_A and K_S for different operating cycle, we have

$W_1 = (W_{R1} + 1.5\, W_{A1})\, K_{S1} = (2000 + 1.5 \times 1200)\, 3 = 11\,400$ N

$W_2 = (W_{R2} + 1.5\, W_{A2})\, K_{S2} = (1500 + 1.5 \times 1000)\, 1.5 = 4500$ N

$W_3 = (W_{R3} + 1.5\, W_{A3})\, K_{S3} = (1000 + 1.5 \times 1500)\, 2 = 6500$ N

and $W_4 = (W_{R4} + 1.5\, W_{A4})\, K_{S4} = (1200 + 1.5 \times 2000)\, 1 = 4200$ N

We know that life of the bearing in revolutions

$$L = 60\, N.L_H = 60\, N \times 15\,000 = 0.9 \times 10^6\, N \text{ rev}$$

∴ Life of the bearing for 1/10 of a cycle,

$$L_1 = \frac{1}{10} \times 0.9 \times 10^6\, N_1 = \frac{1}{10} \times 0.9 \times 10^6 \times 400 = 36 \times 10^6 \text{ rev}$$

Similarly, life of the bearing for the next 1/10 of a cycle,

$$L_2 = \frac{1}{10} \times 0.9 \times 10^6\, N_2 = \frac{1}{10} \times 0.9 \times 10^6 \times 500 = 45 \times 10^6 \text{ rev}$$

Life of the bearing for the next 1/5 of a cycle,

$$L_3 = \frac{1}{5} \times 0.9 \times 10^6\, N_3 = \frac{1}{5} \times 0.9 \times 10^6 \times 600 = 108 \times 10^6 \text{ rev}$$

and life of the bearing for the next 3/5 of a cycle,

$$L_4 = \frac{3}{5} \times 0.9 \times 10^6\, N_4 = \frac{3}{5} \times 0.9 \times 10^6 \times 800 = 432 \times 10^6 \text{ rev}$$

We know that equivalent dynamic load,

$$W = \left[\frac{L_1 (W_1)^3 + L_2 (W_2)^3 + L_3 (W_3)^3 + L_4 (W_4)^3}{L_1 + L_2 + L_3 + L_4}\right]^{1/3}$$

$$= \left[\frac{36 \times 10^6 (11\,400)^3 + 45 \times 10^6 (4500)^3 + 108 \times 10^6 (6500)^3 + 432 \times 10^6 (4200)^3}{36 \times 10^6 + 45 \times 10^6 + 108 \times 10^6 + 423 \times 10^6} \right]^{1/3}$$

$$= \left[\frac{1.191 \times 10^8 \times 10^{12}}{621 \times 10^6} \right]^{1/3} = (0.1918 \times 10^{12})^{1/3} = 5767 \text{ N}$$

and $$L = L_1 + L_2 + L_3 + L_4$$

$$= 36 \times 10^6 + 45 \times 10^6 + 108 \times 10^6 + 432 \times 10^6 = 621 \times 10^6 \text{ rev}$$

We know that dynamic load rating,

$$C = W \left(\frac{L}{10^6} \right)^{1/k} = 5767 \left(\frac{621 \times 10^6}{10^6} \right)^{1/3}$$

$$= 5767 \times 8.53 = 49\,193 \text{ N} = 49.193 \text{ kN}$$

From Table 5.6, the single row deep groove ball bearing number 215 having C = 52 kN may be selected. **Ans.**

EXERCISES

1. The main bearing of a steam engine is 100 mm in diameter and 175 mm long. The bearing supports a load of 28 kN at 250 r.p.m. If the ratio of the diametral clearance to the diameter is 0.001 and the absolute viscosity of the lubricating oil is 0.015 kg/m-s, find : 1. The coefficient of friction ; and 2. The heat generated at the bearing due to friction. **[Ans. 0.002 77 ; 101.5 J/s]**

2. A journal bearing is proposed for a steam engine. The load on the journal is 3 kN, diameter 50 mm, length 75 mm, speed 1600 r.p.m., diametral clearance 0.001 mm, ambient temperature 15.5°C. Oil SAE 10 is used and the film temperature is 60°C. Determine the heat generated and heat dissipated. Take absolute viscosity of SAE10 at 60°C = 0.014 kg/m-s. **[Ans. 141.3 J/s ; 25 J/s]**

3. A 100 mm long and 60 mm diameter journal bearing supports a load of 2500 N at 600 r.p.m. If the room temperature is 20°C, what should be the viscosity of oil to limit the bearing surface temperature to 60°C? The diametral clearance is 0.06 mm and the energy dissipation coefficient based on projected area of bearing is 210 W/m^2/°C. **[Ans. 0.0183 kg/m-s]**

4. A tentative design of a journal bearing results in a diameter of 75 mm and a length of 125 mm for supporting a load of 20 kN. The shaft runs at 1000 r.p.m. The bearing surface temperature is not to exceed 75°C in a room temperature of 35°C. The oil used has an absolute viscosity of 0.01 kg/m-s at the operating temperature. Determine the amount of artificial cooling required in watts. Assume d/c = 1000. **[Ans. 146 W]**

5. A ball bearing subjected to a radial load of 5 kN is expected to have a life of 8000 hours at 1450 r.p.m. with a reliability of 99%. Calculate the dynamic load capacity of the bearing so that it can be selected from the manufacturer's catalogue based on a reliability of 90%. **[Ans. 86.5 kN]**

6. A ball bearing subjected to a radial load of 4000 N is expected to have a satisfactory life of 12 000 hours at 720 r.p.m. with a reliability of 95%. Calculate the dynamic load carrying capacity of the bearing, so that it can be selected from manufacturer's catalogue based on 90% reliability. If there are four such bearings each with a reliability of 95% in a system, what is the reliability of the complete system? **[Ans. 39.5 kN ; 81.45%]**