MIET2510

Mechanical Design

Week 4 – Bearing and Lubrication – Part 1

School of Science and Technology, RMIT Vietnam

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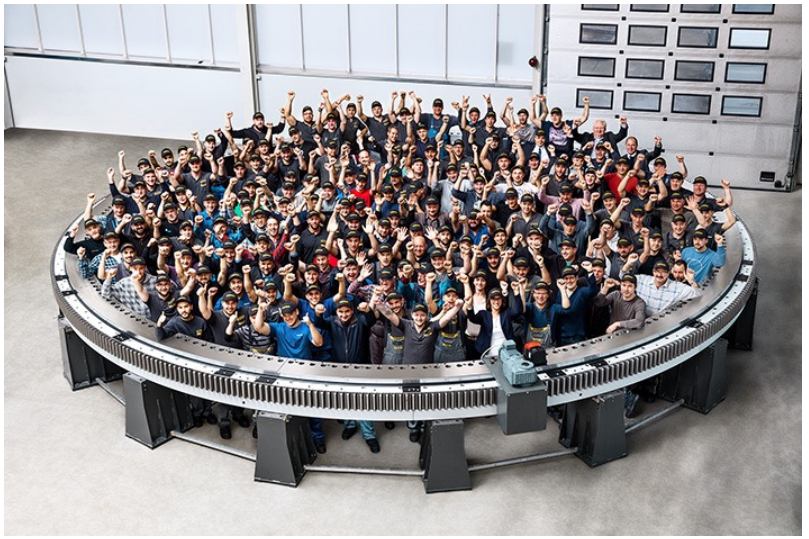
What is Bearing?

The goal of a bearing is to provide relative positioning and rotational freedom while transmitting a load between two parts, commonly a shaft and its housing.



Worlds largest diameter roller bearing – 10m

https://tinyurl.com/rrtrent

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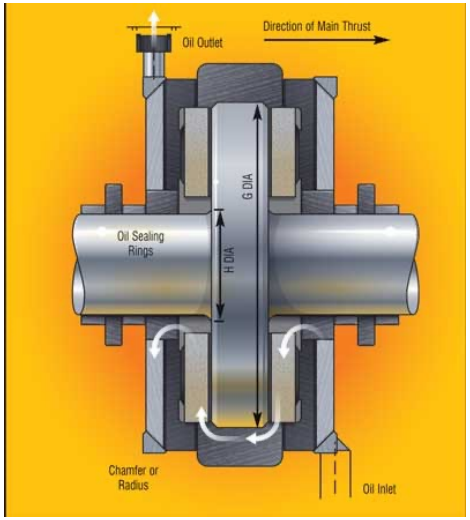
Types of Bearing

- **Journal Bearing (the so-called sleeve or sliding bearings)**

Journal bearings support loads perpendicular to the shaft axis by pressure developed in the liquid. A journal bearing is a typical sliding bearing requiring sliding of the load carrying member on its support. Sleeve thrust bearings support loads in the direction of the shaft axis.



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Types of Bearing

- **Rolling Bearings (the so-called rolling-element bearings)**

Rolling-element bearings are employed to transfer the main load through elements in rolling contact.

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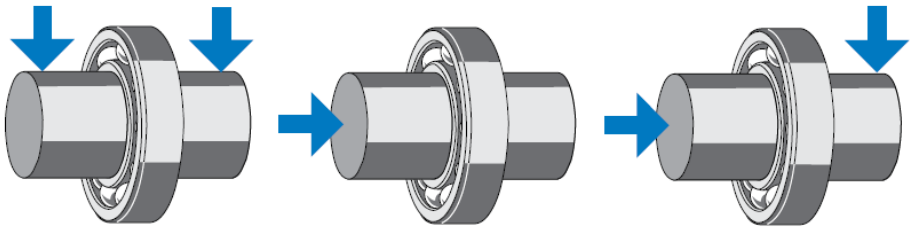
Rolling Bearing

Advantages	Disadvantages
Low starting and good operating friction torque	Greater diametric space
Ease of lubrication	More severe alignment requirements
Requiring less axial space	Higher initial cost
Generally, taking both radial and axial loads	Noisier normal operation
Warning of impending failure by increasing noisiness	Finite life due to eventual failure by fatigue
Rapid replacement	Ease of damage by foreign matter
Good low-temperature starting	Poor damping ability

Types of Rolling Bearing

- **Rolling bearings** can carry radial, thrust, or combinations of the two loads, depending on their design. Most rolling bearings are categorized in one of the three groups: **radial contact** for carrying loads that are primarily radial, **thrust or axial contact** for supporting loads that are primarily axial, and **angular contact** for carrying combined axial and radial loads.
- The rolling-element bearings are of two types: **ball bearings** and **roller bearings**. The former are capable of higher speeds, and the latter can take greater loads.



Radial load
a

Axial load
b

Combined load
c

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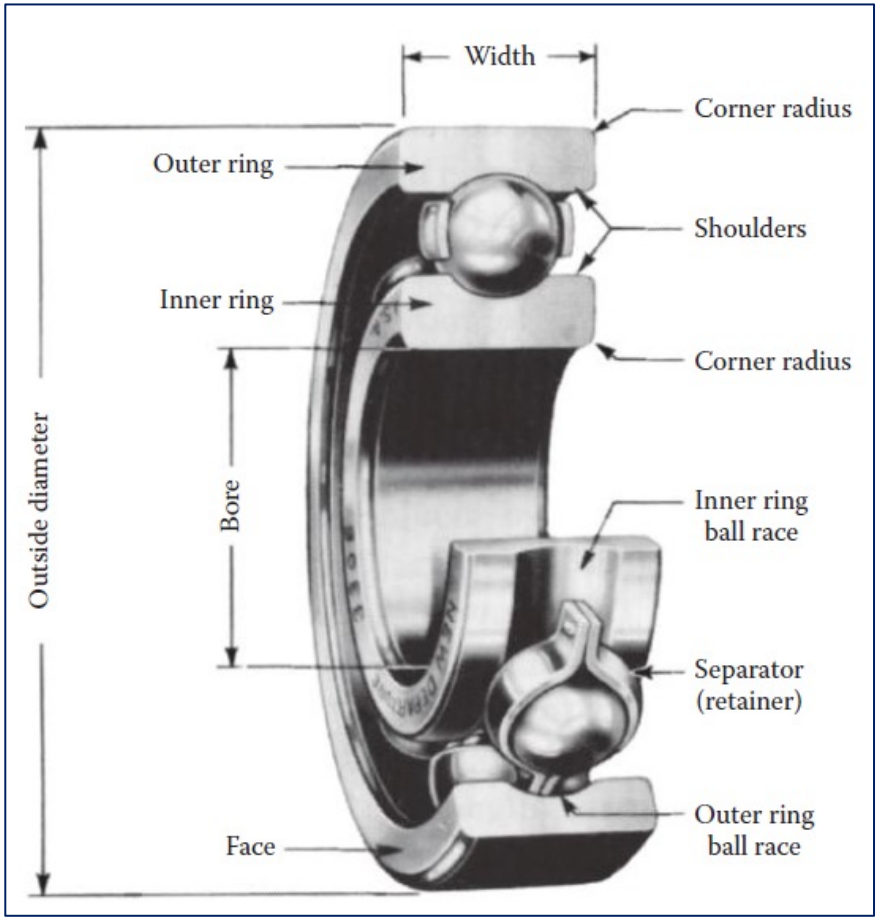
Rolling Bearing - Ball Bearings

A ball bearing is employed in almost every type of machine or mechanism with rotating parts. Observe that the basic bearing consists of an inner ring, an outer ring, the balls, and the separator (also known as cage or retainer).



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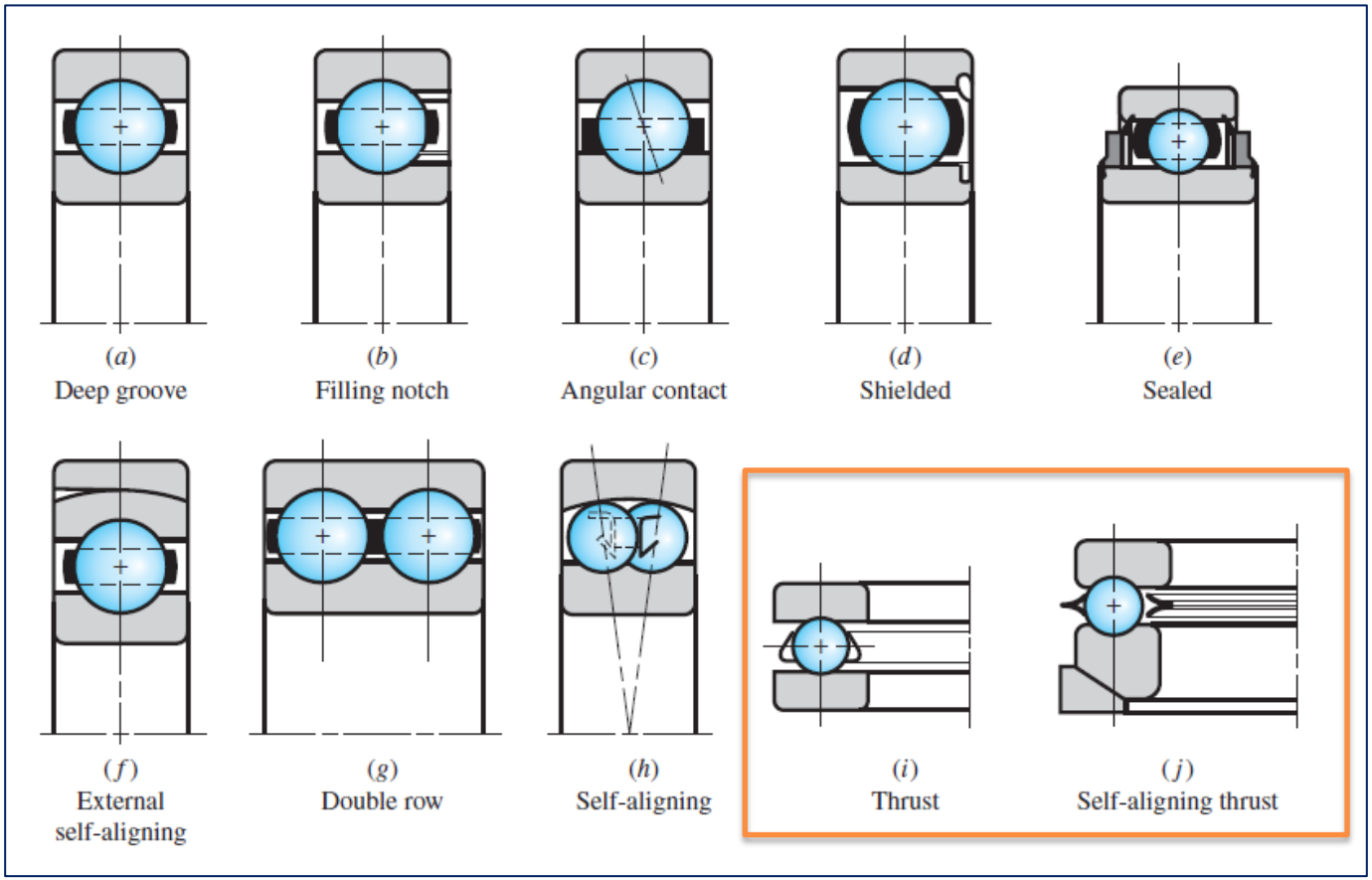
Rolling Bearing - Ball Bearings



Reference: Mechanical Design of Machine Components (2nd) by Ansel C.Ugural.

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Rolling Bearing - Roller Bearing

- A roller bearing uses straight, tapered, or contoured cylindrical rollers. When shock and impact loads are present or when a large bearing is needed, these bearings are usually employed.
- Roller bearings can support much higher static and dynamic (shock) loads than comparably sized ball bearings, since they have line contact instead of point contact.

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Rolling Bearing - Roller Bearing

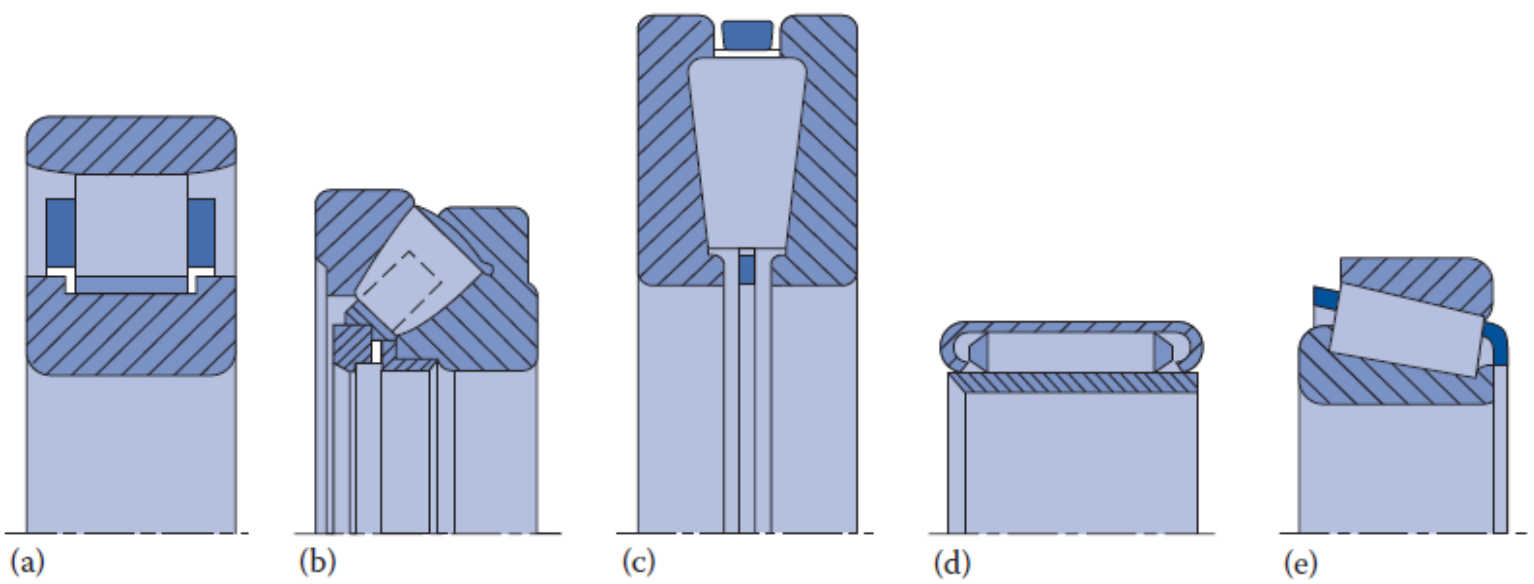

FIGURE 10.23
Some types of roller bearings: (a) straight cylindrical, (b) spherical, (c) tapered thrust, (d) needle, and (e) tapered. (Courtesy of the Timken Company, Canton, OH.)

Reference: Mechanical Design of Machine Components (2nd) by Ansel C.Ugural.

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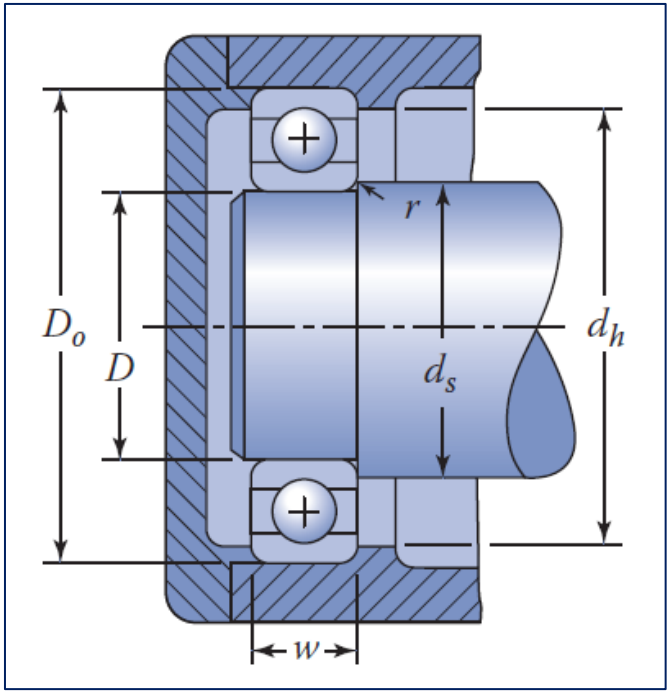
Rolling Bearing - Standard Dimensions

Standard boundary dimensions for the rolling-element bearings, shafts, and housing shoulders are illustrated in the Figure, where:

- D is the bearing bore,
- D_0 is the outside diameter (OD),
- w is the width,
- d_S is the shaft shoulder diameter,
- d_h is the housing diameter
- r is the fillet radius.



For a given bore, there are various widths and ODs. Similarly, for a particular OD, we can find many bearings with different bores and widths.

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Reference: Mechanical Design of Machine Components (2nd) by Ansel C.Ugural.

Rolling Bearing - Load Life

- **The life of a rolling bearing** is the life in hours at some known speed, or the number of revolutions, at which the bearing operates until failure.
- **Basic life (Rating life) or L_{10}**, refers to the number of revolutions (or hours at a uniform speed) that 90% of the group of identical bearings will complete or exceed before the first evidence of failure develops. Median life refers to the life that 50% of the group of bearings would complete or exceed.
- **Dynamic Load Rating, C**: The load to which the bearing can be subjected to while achieve a L_{10} rated life of 10^6 revolutions.
- **Basic Static Load Rating, C_s**: the maximum allowable static load that does not impair the running characteristics of the bearing.

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Rolling Bearing - Equivalent Radial Load

Catalogue ratings are based only on the radial load. However, with the exception of thrust bearings, bearings are usually operated with some combined radial and axial loads. It is then necessary to define an equivalent radial load that has the same effect on bearing life as the applied loading. The equivalent radial load, for rolling bearings, is the maximum of the values of these two equations:

$$P = XVF_r + YF_a$$

$$P = VF_r$$

where
P = the equivalent radial load
F_r = the applied radial load
F_a = the applied axial load (thrust)
V = a rotational factor

$$= \begin{cases} 1.0 \text{ (for inner-ring rotation)} \\ 1.2 \text{ (for outer-ring rotation)} \end{cases}$$

X = a radial factor
Y = a thrust factor

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Equivalent Shock Loading

Some applications have various degrees of shock loading, which has the effect of increasing the equivalent radial load. Therefore, a shock or service factor, Ks, can be substituted into previous equations to account for any shock and impact conditions to which the bearing may be subjected. In so doing, the equivalent radial load becomes the larger of the values given by the two equations:

$$P = K_s\left(XVF_r + YF_a\right)$$

$$P = K_s VF_r$$

Shock or Service Factors K_s

Type of Load	Ball Bearing	Roller Bearing
Constant or steady	1.0	1.0
Light shocks	1.5	1.0
Moderate shocks	2.0	1.3
Heavy shocks	2.5	1.7
Extreme shocks	3.0	2.0

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Selection of Rolling Bearings

- Identical bearings may differ slightly in materials, in surface finish, in roundness of rolling elements, and so on. Consequently, no two bearings within the same family may have the exact number of operating hours to fatigue failure after having been subjected to the identical speed and load condition. Therefore, the selection of rolling bearings is often made from **tables of standard types and sizes** containing data on their load and life ratings.
- Usually, the basic static load rating C_S has little effect in the ball or roller bearing selection. However, if a bearing in a machine is stationary over an extended period of time with a load higher than C_S, local permanent deformation can occur. In general, the bearings cannot operate at very low speeds under loading that exceeds the basic static load rating.

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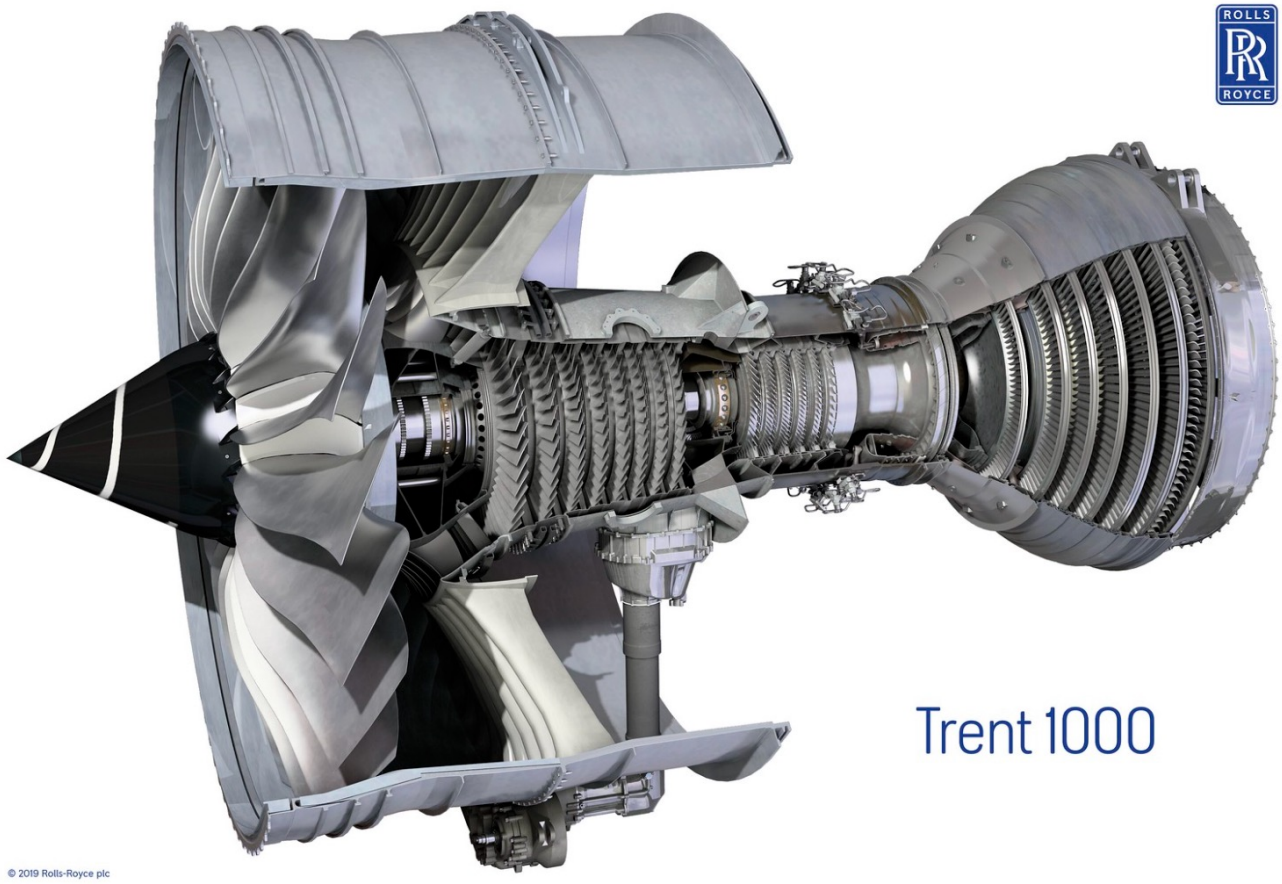
Bearing Selection – RR Trent 1000



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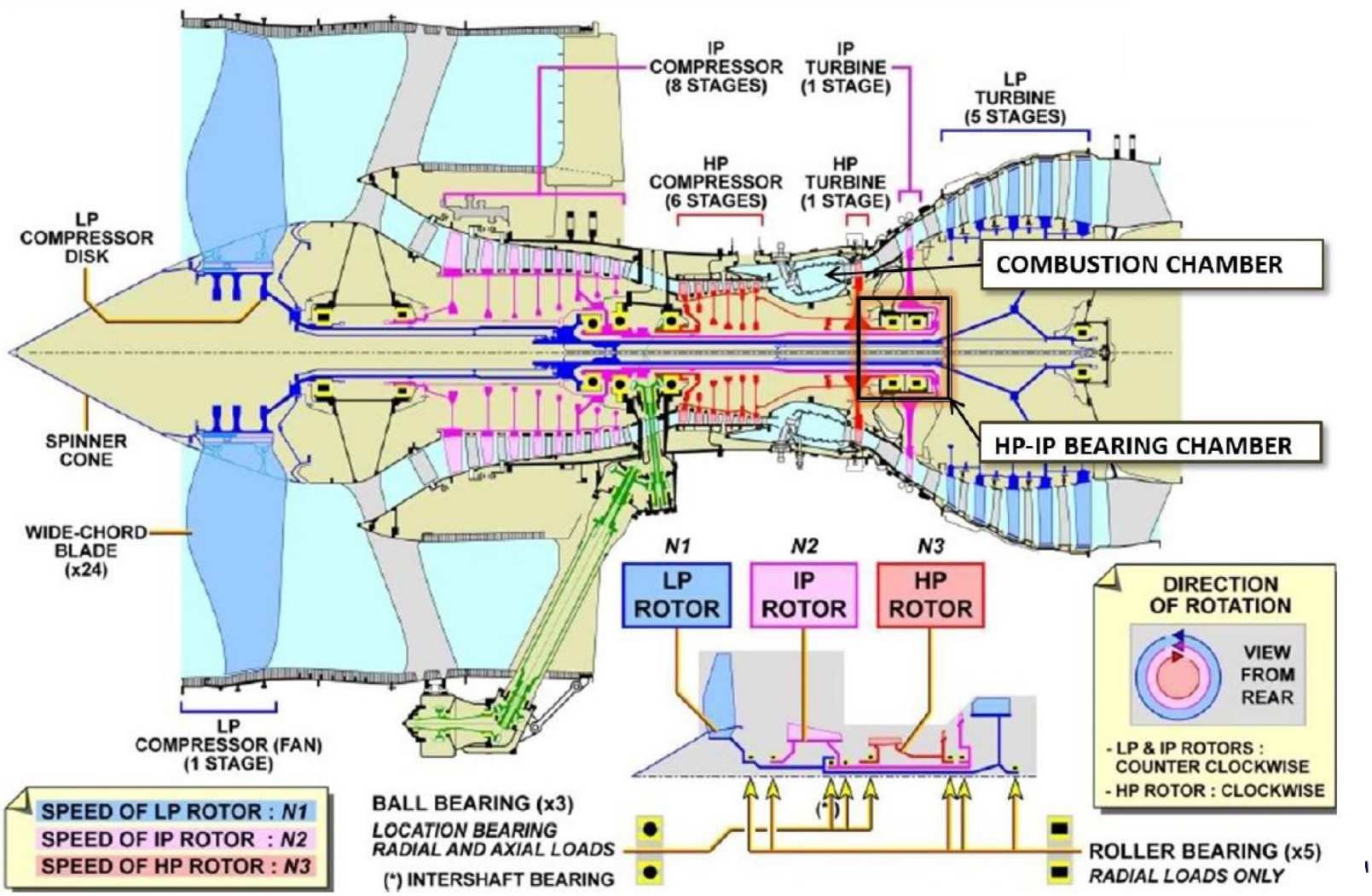
Bearing Selection – RR Trent 1000



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Selection of Rolling Bearings (cont.)

Extensive testing of rolling bearings and subsequent statistical analysis has shown that load and life of a bearing are related statistically.

Life equation

$$L_{10} = \left(\frac{C}{P}\right)^{a} \quad \text{or} \quad \frac{C}{P} = (L_{10})^{\frac{1}{a}}$$

where

- L_{10} = **Life in 10^6 revolution**
- C = **Basic Dynamic load rating (in N)**
- P = **Equivalent Radial Load (in N)**
- a = **Exponent of life equation; a = 3 for ball bearings; a = 10/3 for roller bearings.**

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Selection of Rolling Bearings (cont.)

The previous equation may be written in the following form:

Life equation

$$L_{10} = \frac{10^6}{60n}\left(\frac{C}{P}\right)^a$$

where:

- L_{10} represents the life in hours
- n is the rotational speed in rpm

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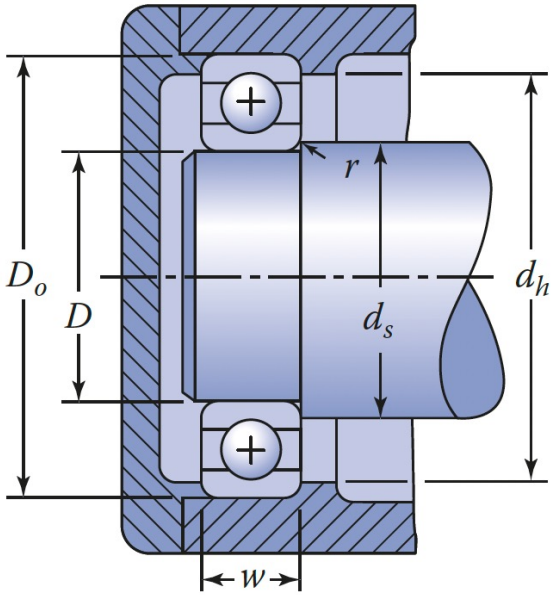
Selection of Rolling Bearings (cont.)

Table 11–2

Dimensions and Load Ratings for Single-Row 02-Series Deep-Groove and Angular-Contact Ball Bearings

Bore, mm	OD, mm	Width, mm	Fillet Radius, mm	Shoulder Diameter, mm		Load Ratings, kN			
						Deep Groove		Angular Contact	
				d_s	d_H	C_{10}	C_0	C_{10}	C_0
10	30	9	0.6	12.5	27	5.07	2.24	4.94	2.12
12	32	10	0.6	14.5	28	6.89	3.10	7.02	3.05
15	35	11	0.6	17.5	31	7.80	3.55	8.06	3.65
17	40	12	0.6	19.5	34	9.56	4.50	9.95	4.75
20	47	14	1.0	25	41	12.7	6.20	13.3	6.55
25	52	15	1.0	30	47	14.0	6.95	14.8	7.65
30	62	16	1.0	35	55	19.5	10.0	20.3	11.0
35	72	17	1.0	41	65	25.5	13.7	27.0	15.0
40	80	18	1.0	46	72	30.7	16.6	31.9	18.6
45	85	19	1.0	52	77	33.2	18.6	35.8	21.2
50	90	20	1.0	56	82	35.1	19.6	37.7	22.8
55	100	21	1.5	63	90	43.6	25.0	46.2	28.5
60	110	22	1.5	70	99	47.5	28.0	55.9	35.5
65	120	23	1.5	74	109	55.9	34.0	63.7	41.5
70	125	24	1.5	79	114	61.8	37.5	68.9	45.5
75	130	25	1.5	86	119	66.3	40.5	71.5	49.0
80	140	26	2.0	93	127	70.2	45.0	80.6	55.0
85	150	28	2.0	99	136	83.2	53.0	90.4	63.0
90	160	30	2.0	104	146	95.6	62.0	106	73.5
95	170	32	2.0	110	156	108	69.5	121	85.0



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Selection of Rolling Bearings (cont.)








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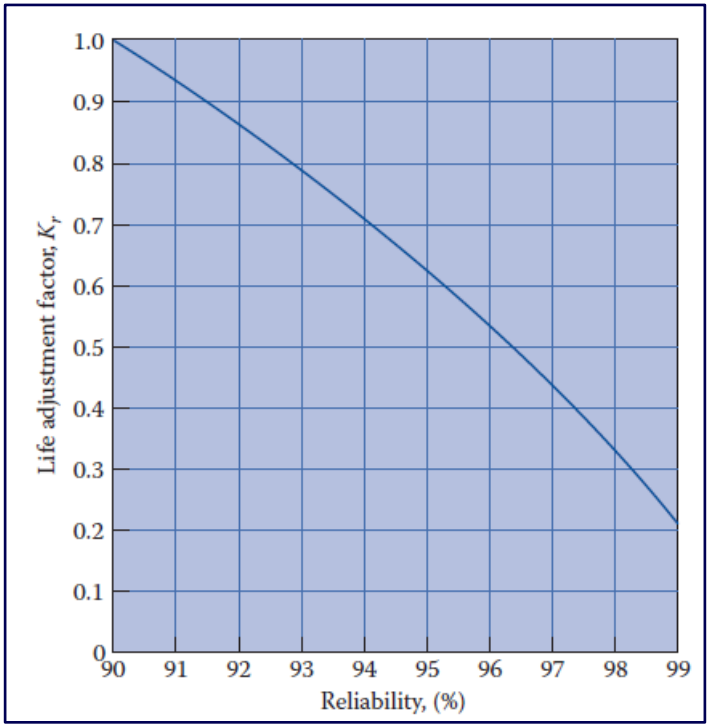
Reliability Requirement

- Definition of rating life L_{10} is based on a 90% reliability (or 10% failure). In some applications, the foregoing survival rate cannot be tolerated (e.g., nuclear power plant controls, medical equipment).
- The recommended life adjustment factors, K_r, is introduced to represent the rating life for any given reliability greater than 90%.

$$L_5 = K_r \left(\frac{C}{P} \right)^a$$



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Reference: Mechanical Design of Machine Components (2nd) by Ansel C.Ugural.

Bearing Selection in Practical Design

In many cases, several factors have to be considered and weighed against each other when selecting a bearing type, so that no general rules can be given. The information provided here should serve to indicate which are the most important factors to be considered when selecting a standard bearing type and thus facilitate an appropriate choice:

• Available space	• Speed
• Loads	• Quiet running
• Misalignment	• Stiffness
• Precision	• Mounting and dismounting
• Axial displacement	• Integral seals

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Thank you for your attendance :D

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Reference

- *SKF Catalogue.*
- *Mechanical Design of Machine Components (2nd) by Ansel C.Ugural.*
- *Mechanical Engineering Design (10th) by Richard G.Budynas and J. Keith Nisbett.*
- *Theory of Machines and Mechanisms (5th) by John J.Uicker, Gordon R.Pennock, Joseph E. Singley.*

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