Chapter 11
Rolling Contact Bearings
Chapter Outline

- Bearing Types
- Bearing Life
- Bearing Load Life at Rated Reliability
- Bearing Survival: Reliability versus Life
- Relating Load, Life, and Reliability
- Combined Radial and Thrust Loading
- Variable Loading
- Selection of Ball and Cylindrical Roller Bearings
- Selection of Tapered Roller Bearings
- Design Assessment for Selected Rolling-Contact Bearings
- Lubrication
- Mounting and Enclosure
Overview

- **Rolling bearing**: class of bearing in which the main load is transferred through elements in rolling contact (No sliding)

- **Load is transferred through rolling elements:**
  - Balls, straight & tapered cylinders
  - Spherical rollers
Overview

Frictional characteristics of a rolling bearing are affected by:

✓ Load
✓ Speed
✓ Operating viscosity of lubricant

Bearings are manufactured to take:

✓ Pure radial loads
✓ Pure thrust loads
✓ Combination of thrust & radial loads
Nomenclature of a ball bearing
Bearing Types

Thrust

Self aligning

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Bearing Types

Deep Groove

- Take radial load & some thrust load
- Balls are inserted into grooves by moving the inner ring to an eccentric position
- Balls are separated after loading, and the separator is then inserted
Bearing Types - Filling Notch

- Use of a filling notch in inner & outer rings enables more balls to be inserted, thus increasing the load capacity.
- Thrust capacity is decreased.

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Bearing Types

Angular Contact

Greater thrust capacity
Bearing Types - roller bearings

a. Straight roller
b. Spherical roller, Thrust
c. Tapered roller, Thrust

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Bearing Types - roller bearings

d. Needle

e. Tapered roller

f. Steep-angle tapered roller

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Bearing Types - **Straight roller**

- Carry a greater radial load than ball bearings of same size because of greater contact area
- A slight misalignment will cause rollers to skew & get out of line
- Will not take thrust loads
Bearing Types: Spherical-roller

- Useful where heavy loads & misalignment occur
- Spherical elements have the advantage of increasing their contact area as load is increased
Bearing Types: **Needle bearings**

- Very useful where radial space is limited
- High load capacity when separators are used
**Bearing Life**

When ball or roller of rolling-contact bearings rolls, contact stresses occur on:

- inner ring
- rolling element
- outer ring
Bearing Life

Common life measures:

- # of *revolutions* of inner ring (outer ring stationary) until first tangible evidence of fatigue

- # of *hours* of use at a standard angular speed until first tangible evidence of fatigue
Bearing Life

Fatigue failure consists of spalling of the load carrying surfaces:

- **American Bearing Manufacturers Association (ABMA) Standard**: failure criterion is the first evidence of fatigue

- **Timken Fatigue criterion**: spalling or pitting of an area of 0.01 in\(^2\)
Bearing Life

- Rating life of a group of nominally identical roller bearings is the number of revolutions (hours at a constant speed) that 90% of a group of bearings will achieve before failure criterion develops.

- **Rating life**: Min life, $L_{10}$ life, and $B_{10}$ life

- Most commonly used **rating life**: $10^6$ revs

- **Timken** Company is rating its bearings at 3000 hours at 500 rpm ($90 \times 10^6$ revs)
Bearing Load Life at Rated Reliability

**Fig. 11-4:** nominally identical groups are tested to the life-failure criterion at different loads

- $a = 3$ for ball bearings
- $a = 10/3$ for roller bearings (cylindrical & tapered roller)

\[ FL^{1/a} = \text{constant} \]
Bearing Load Life at Rated Reliability

- **Catalog load rating, $C_{10}$** = radial load that causes 10% of a group of bearings to fail at bearing manufacturer’s rating life

- If manufacturer’s rating life is $10^6$ rev, Catalog load rating is often referred to as:
  - Basic Dynamic Load Rating
  - Basic Load Rating
Bearing Load Life at Rated Reliability

- Radial load that would be necessary to cause failure at such a low life would be very high.

- **Basic Load Rating**: a reference value, not an actual load to be achieved by a bearing.
Bearing Load Life at Rated Reliability

- In selecting a bearing, relate desired load & life to catalog load rating & catalog rating life:

\[
F_R L_R^{1/a} = F_D L_D^{1/a}
\]

- Units of \( L_R \) & \( L_D \): revolutions
- \( R \) & \( D \): Rated & Desired
Bearing Load Life at Rated Reliability

\[ F_R(L_Rn_R60)^{1/a} = F_D(L_Dn_D60)^{1/a} \]

- Catalog rating, lbf or kN
- Rating life in hours
- Rating speed, rev/min
- Desired speed, rev/min
- Desired life, hours
- Desired radial load, lbf or kN

\[ C_{10} = F_R = F_D \left( \frac{L_D}{L_R} \right)^{1/a} = F_D \left( \frac{L_Dn_D60}{L_Rn_R60} \right)^{1/a} \]
Reliability

- **Reliability**: statistical measure of probability that a mechanical element will not fail in use

\[ R = 1 - p_f \]

- \( p_f \) = probability of failure

- \( 0 \leq R \leq 1 \)
Reliability

- \( R = 0.90 \): 90 % chance that the part will perform its proper function without failure

- Failure of 6 parts out of every 1000 manufactured:

\[
R = 1 - \frac{6}{1000} = 0.994
\]
Reliability

- Consider a shaft with two bearings having reliabilities of 95 % & 98 %.

- Overall reliability of the shaft system is

$$R = R_1 R_2 = 0.95 \times 0.98 = 0.93$$
Example 11–1

Consider SKF, which rates its bearings for $10^6$ revolutions. If you desire a life of 5000 h at 1725 rpm with a load of 400 lbf with a reliability of 90%, for which catalog rating would you search in an SKF catalog?
# Example 11–1

## Table 11–2

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

<table>
<thead>
<tr>
<th>Bore, mm</th>
<th>OD, mm</th>
<th>Width, mm</th>
<th>Fillet Radius, mm</th>
<th>Shoulder Diameter, mm</th>
<th>Load Ratings, kN</th>
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Bearing Reliability

- If a machine is assembled with 4 bearings, each having a reliability of 90%, then reliability of the system is $(0.9)^4 = 0.65$

- Select bearings with reliability higher than 90%

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Bearing Reliability

Distribution of bearing failure can be approximated by two & three parameter Weibull distribution.

\[ C_{10} = F_D \left( \frac{L_D n_D 60}{L_R n_R 60} \right)^{1/a} \]

\[ C_{10} = F_D \left\{ \frac{(L_D n_D / L_R n_R)}{0.02 + 4.439[\ln(1/R)]^{1/1.483}} \right\}^{1/a} \]

\[ C_{10} = \text{catalog basic dynamic load rating} \ @ \ L_R \text{ hours of life at speed of } n_R \text{ rpm} \]
Example: Select a deep groove ball bearing for a desired life of 5000 hours at 1725 rpm with 99% reliability. Bearing radial load is 400 lb.
Combined Radial and Thrust Loading

- $F_a = \text{axial thrust load}$
- $F_r = \text{radial load}$
- $F_e = \text{equivalent radial load that does same damage as combined radial \& thrust loads}$
- $V = \text{rotation factor}$
  - $V = 1 \text{ when inner ring rotates}$
  - $V = 1.2 \text{ when outer ring rotates}$
- Two dimensionless groups: $\frac{F_e}{V F_r}$ \& $\frac{F_a}{V F_r}$
Combined Radial and Thrust Loading

\[
\frac{F_e}{VF_r} = 1 \quad \text{when} \quad \frac{F_a}{VF_r} \leq e
\]

\[
\frac{F_e}{VF_r} = X + Y \frac{F_a}{VF_r} \quad \text{when} \quad \frac{F_a}{VF_r} > e
\]

\[
F_e = X_i VF_r + Y_i F_a
\]

\[
\frac{F_a}{VF_r}
\]

\( e = \text{intersection of the two lines} \)
Combined Radial and Thrust Loading

- $X$ & $Y$ factors depend upon geometry & construction of specific bearing.

- **Table 11-1**: $X_1$, $Y_1$, $X_2$, and $Y_2$ as a function of $e$, which in turn is a function of $F_a/C_0$

- $C_0$ = basic static load rating = Load that will produce a total permanent deformation in raceway & rolling element at any contact point of 0.0001 times diameter of rolling element.
# Combined Radial and Thrust Loading

**Table 11–1:** Equivalent Radial Load Factors for Ball Bearings

<table>
<thead>
<tr>
<th>$F_a/C_0$</th>
<th>$e$</th>
<th>$F_a/(VF_r) \leq e$</th>
<th>$F_a/(VF_r) &gt; e$</th>
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<td>$Y_1$</td>
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</table>

*Use 0.014 if $F_a/C_0 < 0.014$. 

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## Combined Radial and Thrust Loading

**Table 11-2:** Dimensions & Load Ratings for Single-Row 02-Series Deep-Groove and Angular-Contact Ball Bearings

<table>
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<tr>
<th>Bore, mm</th>
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<th>Shoulder Diameter, mm</th>
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</table>
Combined Radial and Thrust Loading

Rotation factor $V$: correction for rotating ring conditions

- $V = 1.2$ for outer-ring rotation
- For Self-aligning bearings, $V = 1$ for rotation of either ring
- Straight or cylindrical roller bearings will take no axial load, or very little, $Y$ factor = zero
Combined Radial and Thrust Loading

Shaft & housing shoulder diameters $d_S$ & $d_H$ should be adequate to ensure good bearing support

Mohammad Suliman Abuhaiba, Ph.D., PE
## Combined Radial and Thrust Loading

**Table 11–3**: Dimensions & Basic Load Ratings for Cylindrical Roller Bearings

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<th>Bore, mm</th>
<th>OD, mm</th>
<th>Width, mm</th>
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<td>51.2</td>
<td>140</td>
<td>33</td>
</tr>
<tr>
<td>70</td>
<td>125</td>
<td>24</td>
<td>79.2</td>
<td>51.2</td>
<td>150</td>
<td>35</td>
</tr>
<tr>
<td>75</td>
<td>130</td>
<td>25</td>
<td>93.1</td>
<td>63.2</td>
<td>160</td>
<td>37</td>
</tr>
<tr>
<td>80</td>
<td>140</td>
<td>26</td>
<td>106</td>
<td>69.4</td>
<td>170</td>
<td>39</td>
</tr>
</tbody>
</table>

Mohammad Suliman Abuhaiba, Ph.D., PE
Combined Radial and Thrust Loading

Table 11–4: Bearing-Life Recommendations for Various Classes of Machinery

<table>
<thead>
<tr>
<th>Type of Application</th>
<th>Life, kh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruments and apparatus for infrequent use</td>
<td>Up to 0.5</td>
</tr>
<tr>
<td>Aircraft engines</td>
<td>0.5–2</td>
</tr>
<tr>
<td>Machines for short or intermittent operation where service interruption is of minor importance</td>
<td>4–8</td>
</tr>
<tr>
<td>Machines for intermittent service where reliable operation is of great importance</td>
<td>8–14</td>
</tr>
<tr>
<td>Machines for 8-h service that are not always fully utilized</td>
<td>14–20</td>
</tr>
<tr>
<td>Machines for 8-h service that are fully utilized</td>
<td>20–30</td>
</tr>
<tr>
<td>Machines for continuous 24-h service</td>
<td>50–60</td>
</tr>
<tr>
<td>Machines for continuous 24-h service where reliability is of extreme importance</td>
<td>100–200</td>
</tr>
</tbody>
</table>
Combined Radial and Thrust Loading

**Table 11–5: Load-Application Factors**

<table>
<thead>
<tr>
<th>Type of Application</th>
<th>Load Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision gearing</td>
<td>1.0–1.1</td>
</tr>
<tr>
<td>Commercial gearing</td>
<td>1.1–1.3</td>
</tr>
<tr>
<td>Applications with poor bearing seals</td>
<td>1.2</td>
</tr>
<tr>
<td>Machinery with no impact</td>
<td>1.0–1.2</td>
</tr>
<tr>
<td>Machinery with light impact</td>
<td>1.2–1.5</td>
</tr>
<tr>
<td>Machinery with moderate impact</td>
<td>1.5–3.0</td>
</tr>
</tbody>
</table>

Use load-application factors to increase the equivalent load before selecting a bearing.
Example 11–4

An SKF 6210 angular-contact ball bearing has an axial load $F_a$ of 400 lbf & a radial load $F_r$ of 500 lbf applied with the outer ring stationary. The basic static load rating $C_0$ is 4450 lbf & the basic load rating $C_{10}$ is 7900 lbf.

Estimate the life of bearing at a speed of 720 rpm.
Example 11–7

The 2nd shaft on a parallel-shaft 25-hp foundry crane speed reducer contains a helical gear with a pitch diameter of 8.08 in. The components of the gear force transmitted to the 2nd shaft are shown at point A. The bearing reactions at C & D, assuming simple-supports, are also shown. A ball bearing is to be selected for location C to accept the thrust, and a cylindrical roller bearing is to be utilized at location D. The life goal of the speed reducer is 10 kh, with a reliability factor for the ensemble of all four bearings (both shafts) to equal or exceed 0.96. The application factor is to be 1.2.
Example 11–7

a) Select roller bearing for location $D$

b) Select ball bearing (angular contact) for location $C$, assuming inner ring rotates
Selection of Tapered Roller Bearings

Components of a tapered roller bearing:
1. Cone (inner ring)
2. Cup (outer ring)
3. Tapered rollers
4. Cage (spacer-retainer)
Selection of Tapered Roller Bearings

Nomenclature of a tapered roller bearing

\[ G = \text{location of effective load center; use this point to estimate radial bearing load} \]
Selection of Tapered Roller Bearings

- Assembled bearing consists of two separable parts:
  1. Cone assembly: cone, rollers, and cage
  2. Cup

- Bearings can be:
  - single-row
  - two row
  - four-row
  - thrust-bearing assemblies
Selection of Tapered Roller Bearings

- Even when an external thrust load is not present, radial Cup load will induce a thrust reaction within bearing because of taper.
- To avoid separation of races & rollers, this thrust must be resisted by an equal & opposite force.
- One way of generating this force is to always use at least two tapered roller bearings on a shaft.
Selection of Tapered Roller Bearings

Mohammad Suliman Abuhaiba, Ph.D., PE
## Selection of Tapered Roller Bearings

**Catalog** entry of single-row straight-bore Timken roller bearings

<table>
<thead>
<tr>
<th>bore diameter (d)</th>
<th>outside diameter (D)</th>
<th>width (T)</th>
<th>rating at 500 rpm for 3000 hours (L10)</th>
<th>one-row radial (N)</th>
<th>thrust (N)</th>
<th>K</th>
<th>a</th>
<th>part numbers</th>
<th>max shaft fillet radius (R)</th>
<th>width (B)</th>
<th>backing shoulder diameters</th>
<th>max housing fillet radius (r)</th>
<th>width (C)</th>
<th>backing shoulder diameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.000</td>
<td>52.000</td>
<td>16.250</td>
<td>8190</td>
<td>5260</td>
<td>5200</td>
<td>1.56</td>
<td>-3.6</td>
<td>0.30</td>
<td>30205</td>
<td>1.0</td>
<td>15.000</td>
<td>30.5</td>
<td>1.0</td>
<td>13.000</td>
</tr>
<tr>
<td>0.9843</td>
<td>2.0472</td>
<td>0.6398</td>
<td>1840</td>
<td>1180</td>
<td>1150</td>
<td>0.9843</td>
<td>2.0472</td>
<td>0.7579</td>
<td>19.250</td>
<td>9520</td>
<td>9510</td>
<td>1.0</td>
<td>18.000</td>
<td>34.0</td>
</tr>
<tr>
<td>25.000</td>
<td>52.000</td>
<td>22.000</td>
<td>13200</td>
<td>7960</td>
<td>7900</td>
<td>1.66</td>
<td>-7.6</td>
<td>0.30</td>
<td>33205</td>
<td>1.0</td>
<td>22.000</td>
<td>34.0</td>
<td>1.0</td>
<td>18.000</td>
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<tr>
<td>0.9843</td>
<td>2.0472</td>
<td>0.8661</td>
<td>2980</td>
<td>1790</td>
<td>1780</td>
<td>0.9843</td>
<td>2.0472</td>
<td>0.7185</td>
<td>18.250</td>
<td>13000</td>
<td>6680</td>
<td>1.5</td>
<td>17.000</td>
<td>32.5</td>
</tr>
<tr>
<td>25.000</td>
<td>62.000</td>
<td>2.4409</td>
<td>3910</td>
<td>8930</td>
<td>8910</td>
<td>1.95</td>
<td>-5.1</td>
<td>0.20</td>
<td>303205</td>
<td>1.5</td>
<td>24.000</td>
<td>35.0</td>
<td>1.5</td>
<td>20.000</td>
</tr>
<tr>
<td>0.9843</td>
<td>2.4409</td>
<td>0.9941</td>
<td>2930</td>
<td>1500</td>
<td>1490</td>
<td>1.95</td>
<td>-9.7</td>
<td>-0.38</td>
<td>32305</td>
<td>1.5</td>
<td>24.000</td>
<td>35.0</td>
<td>1.5</td>
<td>20.000</td>
</tr>
</tbody>
</table>
Selection of Tapered Roller Bearings

- A radial load on a tapered roller bearing will induce a thrust reaction.
- The *load zone* includes about half the rollers and subtends an angle of approximately 180°.
- $F_i = \text{induced thrust load from a radial load with 180° load zone}$, Timken provides the equation

$$F_i = \frac{0.47F_r}{K}$$
Selection of Tapered Roller Bearings

- $K$ factor is geometry specific = radial load rating / thrust load rating
- $K$ can be first approximated with 1.5 for a radial bearing and 0.75 for a steep angle bearing
- After a possible bearing is identified, exact value of $K$ for each bearing can be found in bearing catalog
Selection of Tapered Roller Bearings

Direct-mounted tapered roller bearings, showing radial, induced thrust, & external thrust loads.

Mohammad Suliman Abuhaiba, Ph.D., PE
Selection of Tapered Roller Bearings

- $F_{rA}$ & $F_{rB} =$ radial loads, applied at effective force centers $G_A$ & $G_B$
- $F_{iA}$ & $F_{iB} =$ induced loads due to effect of radial loads
- $F_{ae} =$ externally applied thrust load on shaft
Selection of Tapered Roller Bearings

\[ F_e = X \ V \ F_r + Y \ F_a \]

Timken recommends using \( X = 0.4 \) & \( V = 1 \) for all cases, and using the \( K \) factor for the specific bearing for \( Y \),

\[ F_e = 0.4 \ F_r + K \ F_a \]
**Selection of Tapered Roller Bearings**

- $F_a = \text{net axial load carried by bearing due to combination of induced axial load from the other bearing} \& \text{external axial load}$

- Only one of the bearings will carry the net axial load. Which one it is depends on:
  1. Direction the bearings are mounted
  2. Relative magnitudes of induced loads
  3. Direction of external load
  4. Whether shaft or housing is the moving part
Selection of Tapered Roller Bearings

- **First**, determine visually which bearing is being “squeezed” by the external thrust load, and label it as bearing A
- Label the other bearing as bearing B
- If there is no external thrust, then either bearing can arbitrarily be labeled as bearing A
Selection of Tapered Roller Bearings

Figure 11–17: Examples of determining which bearing carries the external thrust load

In each case, the compressed bearing is labeled as bearing A
Selection of Tapered Roller Bearings

Figure 11–17

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Selection of Tapered Roller Bearings

- **Second**, determine which bearing actually carries the net axial load
- If $F_{iA} > F_{ae} + F_{iB}$, then bearing B will carry the net thrust load
Selection of Tapered Roller Bearings

If $F_{iA} \leq (F_{iB} + F_{ae})$

\[
\begin{align*}
F_{eA} &= 0.4F_{rA} + K_A(F_{iB} + F_{ae}) \\
F_{eB} &= F_{rB}
\end{align*}
\]  \hspace{1cm} (11–16a)

\[
\begin{align*}
F_{eB} &= 0.4F_{rB} + K_B(F_{iA} - F_{ae}) \\
F_{eA} &= F_{rA}
\end{align*}
\]  \hspace{1cm} (11–17a)

If $F_{iA} > (F_{iB} + F_{ae})$

If equivalent radial load is less than original radial load, then original radial load should be used.
EXAMPLE 11–8

The shown shaft carries a helical gear with a tangential force of 3980 N, a radial force of 1770 N, and a thrust force of 1690 N at the pitch cylinder. The pitch diameter of the gear is 200 mm. The shaft runs at a speed of 800 rpm, and the span (effective spread) between the direct-mount bearings is 150 mm. The design life is to be 5000 h and an application factor of 1 is appropriate. If the reliability of the bearing set is to be 0.99, select suitable single-row tapered roller Timken bearings.
EXAMPLE 11–8

Mohammad Suliman Abuhaiba, Ph.D., PE
Lubrication

- When a lubricant is trapped between two surfaces in rolling contact, a tremendous increase in pressure within the lubricant film occurs.
- Viscosity is exponentially related to pressure,
  - A very large increase in viscosity occurs in the lubricant that is trapped between the surfaces
Lubrication

Purposes of an antifriction - bearing lubricant:

1. Provide a film of lubricant between sliding & rolling surfaces
2. Help distribute & dissipate heat
3. Prevent corrosion of bearing surfaces
4. Protect parts from entrance of foreign matter

Mohammad Suliman Abuhaiba, Ph.D., PE
# Lubrication

<table>
<thead>
<tr>
<th>Use Grease When</th>
<th>Use Oil When</th>
</tr>
</thead>
<tbody>
<tr>
<td>T ≤ 93°C</td>
<td>T is high</td>
</tr>
<tr>
<td>Speed is low</td>
<td>Speed is high</td>
</tr>
<tr>
<td>Unusual protection is required from entrance of foreign matter</td>
<td>Oil tight seals are readily employed</td>
</tr>
<tr>
<td>Simple bearing enclosures are desired</td>
<td>Bearing type is not suitable for grease lubrication</td>
</tr>
<tr>
<td>Operation for long periods without attention is desired</td>
<td>Bearing is lubricated from a central supply</td>
</tr>
</tbody>
</table>

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Mounting and Enclosure

- The housing bore & shaft outside diameter must be held to very close limits
- One of the bearings usually has the added function of positioning or axially locating the shaft
Mounting and Enclosure

**Figure 11–20:** A common bearing mounting. Outer ring of RH bearing floats in the housing
Mounting and Enclosure

Fig. 11–20: The function of shaft shoulder may be performed by:

1. retaining rings
2. hub of a gear or pulley
3. spacing tubes or rings

The round nuts may be replaced by:

1. retaining rings
2. washers locked in position by screws
3. Cotters
4. taper pins
Mounting and Enclosure

Fig. 11–20: housing shoulder may be replaced by:

1. a retaining ring
2. Outer ring of bearing may be grooved for a retaining ring
3. a flanged outer ring may be used
4. Force against outer ring of LH bearing is usually applied by:
   a. cover plate
   b. retaining rings

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Mounting and Enclosure

Figure 11–21: Alternative bearing mounting

- Outer races are completely retained.
- If distance between bearings is great, temperature rise during operation may expand the shaft enough to destroy the bearings.
Mounting and Enclosure

- **Figure 11-22**: Two-bearing mountings
- Preload the bearings in an axial direction
Mounting and Enclosure

- **Figure 11–22**: Two-bearing mountings
- Preload the bearings in an axial direction
Mounting and Enclosure

Figure 11–23: Mounting for a washing machine spindle
Mounting and Enclosure

- When maximum stiffness & resistance to shaft misalignment is desired, pairs of angular contact ball bearings are often used in an arrangement called **duplexing**.

- Bearings manufactured for duplex mounting have their rings ground with an offset, so that when a pair of bearings is tightly clamped together, a preload is automatically established.
Mounting and Enclosure

**Figure 11–24:** Arrangements of angular ball bearings

a. Duplex Face-to-face mounting, DFF
b. Duplex Back to back mounting, DBB
c. Duplex Tandem mounting, DT
11–12 Mounting and Enclosure

DFF mounting

- DFF mounting, will take heavy radial loads and thrust loads from either direction
Mounting and Enclosure

DBB mounting

- DBB mounting has greatest aligning stiffness
- Good for heavy radial loads & thrust loads from either direction.
Mounting and Enclosure

DT mounting

Used where thrust is always in same direction
Mounting and Enclosure

- Bearings are usually mounted with the rotating ring a press fit.
- The stationary ring is then mounted with a push fit.
- This permits the stationary ring to creep in its mounting slightly, bringing new portions of the ring into the load-bearing zone to equalize wear.

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Mounting and Enclosure

**Preloading**

The object of preloading is to:

1. remove internal clearance usually found in bearings
2. increase fatigue life
3. decrease shaft slope at the bearing

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Mounting and Enclosure

Preloading

Methods of Preloading straight roller bearings:

1. Mounting bearing on a tapered shaft or sleeve to expand the inner ring
2. Using an interference fit for the outer ring
3. Purchasing a bearing with the outer ring preshrunk over the rollers
Mounting and Enclosure

**Preloading**

- Ball bearings are usually preloaded by the axial load built in during assembly.
- Bearings of Figures a & b are preloaded in assembly because of differences in widths of the inner & outer rings.
Mounting and Enclosure

Alignment

- Permissible misalignment in bearings depends on:
  - Type of bearing
  - Geometric & material properties of specific bearing
- Cylindrical & tapered roller bearings require alignments that are closer than deep-groove ball bearings.
- Spherical ball bearings & self-aligning bearings are the most forgiving.
Mounting and Enclosure

- **Alignment**, Table 7–2: Typical Max Ranges for Slopes & Transverse Deflections

<table>
<thead>
<tr>
<th>Slopes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapered roller</td>
<td>0.0005—0.0012 rad</td>
</tr>
<tr>
<td>Cylindrical roller</td>
<td>0.0008—0.0012 rad</td>
</tr>
<tr>
<td>Deep-groove ball</td>
<td>0.001—0.003 rad</td>
</tr>
<tr>
<td>Spherical ball</td>
<td>0.026—0.052 rad</td>
</tr>
<tr>
<td>Self-align ball</td>
<td>0.026—0.052 rad</td>
</tr>
</tbody>
</table>

- Life of bearing decreases significantly when misalignment exceeds allowable limits.

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Mounting and Enclosure

Enclosures

- To exclude dirt and foreign matter and to retain the lubricant, bearing mountings must include a seal.

- Typical sealing methods

(a) Felt seal
(b) Commercial seal
(c) Labyrinth seal
**Enclosures**

- Used with grease lubrication when speeds are low
- Rubbing surfaces should have a high polish
- Felt seals should be protected from dirt by:
  - placing them in machined grooves
  - using metal stampings as shields

(a) Felt seal
Mounting and Enclosure

**Enclosures**

- An assembly consisting of rubbing element and, generally, a spring backing, which are retained in a sheet-metal jacket.
- Usually made by press fitting them into a counter bored hole in the bearing cover.
- They should not be used for high speeds.

*(b) Commercial seal*
Mounting and Enclosure

**Enclosures**

- Effective for high-speed
- May be used with either oil or grease.
- At least three grooves should be used, and they may be cut on either bore or outside diameter.
- Clearance may vary from 0.010 to 0.040 in, depending upon speed and temperature.