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

Figure 11–2: Various types of ball bearings

(a) Deep groove
(b) Filling notch
(c) Angular contact
(d) Shielded
(e) Sealed

(f) External self-aligning
(g) Double row
(h) Self-aligning
(i) Thrust
(j) Self-aligning thrust

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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

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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.
Bearing Types - Angular Contact

- Greater thrust capacity

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Bearing Types

Figure 11–3: Types of roller bearings

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

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Bearing Types

**Figure 11–3:** Types of roller bearings

d. Needle
e. Tapered roller
f. Steep - angle tapered roller

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Bearing Types - Straight roller

Figure 11–3: Types of roller bearings

- 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

Figure 11-3: Types of roller bearings

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

*Figure 11–3: Types of roller bearings*

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

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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 in²
Bearing Life

- Rating life of a group of nominally identical roller bearings = 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

- **Rating life**: 10th percentile location of the bearing group’s revolutions-to-failure distribution.

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Bearing Life

- **Median life:** 50\(^{\text{th}}\) percentile life of a group of bearings
- **Median life:** 4 to 5 times \(L_{10}\) life
- Most commonly used **rating life:** \(10^6\) revs

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

\[ FL^{1/a} = \text{constant} \]  

(11–1)
Bearing Load Life at Rated Reliability

- **Catalog load rating,** $C_{10} = \text{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

\[ F_R (L_R n_R 60)^{1/a} = F_D (L_D n_D 60)^{1/a} \]

- \( F_R \): catalog rating, lbf or kN
- \( F_D \): desired speed, rev/min
- \( L_R \): rating life in hours
- \( L_D \): desired life, hours
- \( n_R \): rating speed, rev/min
- \( n_D \): desired radial load, lbf or kN

\[ C_{10} = F_R = F_D \left( \frac{L_D}{L_R} \right)^{1/a} = F_D \left( \frac{L_D n_D 60}{L_R n_R 60} \right)^{1/a} \]  (11-3)
Reliability

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

\[ R = 1 - p_f \]  \hspace{1cm} (1-4)

- \( p_f \) = 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

\[
R = R_1 \times R_2 = 0.95 \times (0.98) = 0.93
\]
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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<td>d_s, d_H</td>
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</table>
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 higher than 90% reliability
Bearing Reliability

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

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

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

\( C_{10} = \) catalog basic dynamic load rating @ \( L_R \) hours of life at speed of \( n_R \) rpm

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Example

Select a deep groove ball bearing for a desired life of 5000 hours at 1725 rpm \textit{with 99\% reliability}. Bearing radial load is 400 lb.

<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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<td>(d_s)</td>
<td>(d_H)</td>
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<td>93</td>
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</tbody>
</table>

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Combined Radial and Thrust Loading

- $F_a$ = axial thrust load
- $F_r$ = radial load
- $F_e$ = *equivalent radial load* that does same damage as combined radial & thrust loads
- $V$ = rotation factor
  - $V = 1$ when inner ring rotates
  - $V = 1.2$ when outer ring rotates

- Two dimensionless groups: $F_e/V F_r$ and $F_a/V F_r$
Combined Radial and Thrust Loading

\[ e = \text{intersection of the two lines} \]

\[ \frac{F_e}{V F_r} = 1 \text{ when } \frac{F_a}{V F_r} \leq e \]  
(11–8a)

\[ \frac{F_e}{V F_r} = X + Y \frac{F_a}{V F_r} \text{ when } \frac{F_a}{V F_r} > e \]  
(11–8b)

\[ F_e = X_i V F_r + Y_i F_a \]  
(11–9)

Figure 11–6: \( \frac{F_e}{(V F_r)} \) vs. \( \frac{F_a}{(V F_r)} \)
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 the raceway and rolling element at any contact point of 0.0001 times diameter of the 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>$X_1$</th>
<th>$Y_1$</th>
<th>$X_2$</th>
<th>$Y_2$</th>
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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>
<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 Deep Groove</th>
<th>Load Ratings, kN Angular Contact</th>
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</table>

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Combined Radial and Thrust Loading

- Rotation factor $V$: correct for the rotating ring conditions
- $V = 1.2$ for outer-ring rotation: fatigue life is reduced under these conditions
- 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

ABMA has established standard boundary dimensions for bearings:

- Bearing bore
- Outside diameter (OD)
- Width
- Fillet sizes on shaft & housing shoulders
Combined Radial and Thrust Loading

- Basic plan covers all ball & straight roller bearings in metric sizes.
- For a given bore, an assortment of widths & outside diameters.
- For a particular outside diameter, a variety of bearings having different bores & widths.
Combined Radial and Thrust Loading

- Basic ABMA plan: Fig. 11–7
- Bearings are identified by a two-digit number called *dimension-series code*
  - 1\textsuperscript{st} number = *width series*, 0, 1, 2, 3, 4, 5, and 6
  - 2\textsuperscript{nd} number = *diameter series* (outside) 8, 9, 0, 1, 2, 3, 4
Combined Radial and Thrust Loading

Basic ABMA plan **Apply to:**

- ball bearings
- straight roller bearings
- spherical roller bearings

Do not apply to inch series ball bearings or tapered roller bearings

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Combined Radial and Thrust Loading

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

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## Combined Radial and Thrust Loading

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

<table>
<thead>
<tr>
<th>Bore, mm</th>
<th>OD, mm</th>
<th>Width, mm</th>
<th>Load Rating, kN</th>
<th>OD, mm</th>
<th>Width, mm</th>
<th>Load Rating, kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>52</td>
<td>15</td>
<td>16.8</td>
<td>62</td>
<td>17</td>
<td>28.6</td>
</tr>
<tr>
<td>30</td>
<td>62</td>
<td>16</td>
<td>22.4</td>
<td>72</td>
<td>19</td>
<td>36.9</td>
</tr>
<tr>
<td>35</td>
<td>72</td>
<td>17</td>
<td>31.9</td>
<td>80</td>
<td>21</td>
<td>44.6</td>
</tr>
<tr>
<td>40</td>
<td>80</td>
<td>18</td>
<td>41.8</td>
<td>90</td>
<td>23</td>
<td>56.1</td>
</tr>
<tr>
<td>45</td>
<td>85</td>
<td>19</td>
<td>44.0</td>
<td>100</td>
<td>25</td>
<td>72.1</td>
</tr>
<tr>
<td>50</td>
<td>90</td>
<td>20</td>
<td>45.7</td>
<td>110</td>
<td>27</td>
<td>88.0</td>
</tr>
<tr>
<td>55</td>
<td>100</td>
<td>21</td>
<td>56.1</td>
<td>120</td>
<td>29</td>
<td>102</td>
</tr>
<tr>
<td>60</td>
<td>110</td>
<td>22</td>
<td>64.4</td>
<td>130</td>
<td>31</td>
<td>123</td>
</tr>
<tr>
<td>65</td>
<td>120</td>
<td>23</td>
<td>76.5</td>
<td>140</td>
<td>33</td>
<td>138</td>
</tr>
<tr>
<td>70</td>
<td>125</td>
<td>24</td>
<td>79.2</td>
<td>150</td>
<td>35</td>
<td>151</td>
</tr>
<tr>
<td>75</td>
<td>130</td>
<td>25</td>
<td>93.1</td>
<td>160</td>
<td>37</td>
<td>183</td>
</tr>
<tr>
<td>80</td>
<td>140</td>
<td>26</td>
<td>106</td>
<td>170</td>
<td>39</td>
<td>190</td>
</tr>
</tbody>
</table>

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## 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>

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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 $L_{10}$ life at a speed of 720 rpm.
Selection of Ball & Cylindrical Roller Bearings - Example 11–7

The second 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 second shaft are shown at point A. The bearing reactions at C and 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.

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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

Figure 11–13: Nomenclature of a tapered roller bearing

- \( G \) = 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

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Selection of Tapered Roller Bearings

Figure 11–15: Catalog entry of single-row straight - bore Timken roller bearings
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°.
- \( F_i = \frac{0.47F_r}{K} \) 

(11–15)
Selection of Tapered Roller Bearings

- $K$ factor is geometry specific = $\frac{\text{radial load rating}}{\text{thrust load rating}}$
- $K$ 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

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Selection of Tapered Roller Bearings

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

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

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

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

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

- 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
  - a. External thrust applied to rotating shaft
  - b. External thrust applied to rotating cylinder
Selection of Tapered Roller Bearings

Figure 11–17
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 $F_{iA} \leq (F_{iB} + F_{ae})$

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

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

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

If equivalent radial load is less than original radial load, then original radial load should be used.

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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.

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EXAMPLE 11–8
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

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## Lubrication

<table>
<thead>
<tr>
<th>Use Grease When</th>
<th>Use Oil When</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T \leq 93^\circ C$</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>
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
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

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11–12 Mounting and Enclosure

- **Figure 11–24**: DFF mounting
- DFF mounting, will take heavy radial loads and thrust loads from either direction
Mounting and Enclosure

- **Figure 11–24:** DBB mounting
- DBB mounting has greatest aligning stiffness
- Good for heavy radial loads & thrust loads from either direction.

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Mounting and Enclosure

- **Figure 11–24:** 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.
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>Range</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.
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
11–12 Mounting and Enclosure

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

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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.
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.