Chap. 11: Rolling-Contact Bearings

Balls

Rollers
Applications of Contact Bearings

- Rolling contact bearings are used widely in instruments and machines in order to:
  - Support the shafts
  - Minimize the friction and power loss associated with relative motion.
Bearing Construction

- Contact-rolling bearings usually consist of four parts:
  - An inner ring
  - An outer ring
  - The balls
  - The cage or separator.
Type of Bearings

Ball Bearings
- Radial
- Angular
Type of Bearings

(a) 100 Series Extra Light
(b) 200 Series Light
(c) 300 Series Medium
(d) Axial Thrust Bearing
(e) Angular Contact Bearing
(f) Self-aligning Bearing
Ball Bearings

- Ball bearings are made in a wide variety of types and sizes:
  - Single-row radial (carry mostly radial loads, but can also carry axial loads).
  - Angular contact bearing (Will take both axial and radial load).
  - Axial thrust bearing (When load is directed entirely along the axis, thrust type of bearing should be used).
  - Self-aligning bearing (will take care of large amount of misalignment).
  - An increase in radial capacity may be secured by using rings with deep grooves, or by employing a double-row radial bearing.

Fig. 11-12: Various types of ball bearings
ROLLER BEARINGS

- Needle roller
- Cylindrical roller
- Tapered roller
- Spherical roller
Types Roller Bearings

- Roller bearings are usually used when shock and impact are present, or when large bearing are needed.
- Tapered roller bearing can carry a large axial load. The magnitude depends on the angularity of the rollers. The radial load will also produce a thrust component.
- Roller bearing in general can be applied only where the angular misalignment caused by shaft deflection is very small.
- Spherical roller bearing has excellent load capacity and carry a thrust component in either direction. High misalignment.

Fig. 11-3: Types of roller Bearings
Rolling Contact Bearing Materials

- Plain roller bearing
- Helical roller bearing
- Needle bearing
- Tapered roller thrust bearing
- Self-aligning spherical roller bearing
- Roller thrust bearing
Rolling Contact Bearing Materials

- High-carbon chromium steel 52100, 440C stainless steel and M50 steel are used for balls and rings, and are treated to high strength and hardness. $T \ (360\text{-}600^\circ F)$.

- Silicon nitride is used if high $T \ (2200^\circ F)$ and HRC 78.

- The surface are smooth ground and polished. Minimum accepted hardness for bearing components is HRC 58.
Bearing Life: Static Load Capacity

• Static Load Capacity ($C_0$):
  – The static capacity is ordinarily defined as the maximum allowable static load that does not impair the running characteristics of the bearing to make it unusable.
  – The bearing is not rotating when the measurement is made.
Bearing Load life

• The life of a ball bearing is the life in hours at some known speed, or the number of revolutions, that the bearing will attain before the first evidence of fatigue appears on any of the moving part.

• Following nomenclature and definitions are used in the testing of bearing.

• Rate life \((L_{10})\) is the life at which 10 percent of bearing have failed and 90% of them are still good.
Bearing load Life at Rated Reliability

- **Median Life** \( (L_{50}) \) is the life at which 50% of the bearings failed and 50% are still good. It is generally not more than 5 times the rate life \( L_{10} \).

- **Basic Load Rating** \( (C) \) For angular or radial contact ball bearing is the calculated, constant, radial load which a group of apparently identical bearings with stationary outer ring can theoretically endure for a rating life of one million revolutions of the inner ring.

- For thrust ball bearing it is the calculated, constant, centric, thrust load which a group of apparently identical bearing can theoretically endure for a rating life of one million revolution of one of the bearing washers.
Load/ Life Relationship

\[ FL^{\frac{1}{a}} = C \]

- \( C = \text{constant} \)
- \( a = 3 \) for ball bearing
- \( a = \frac{10}{3} \) for roller bearing

\[ F_1 L_1^{\frac{1}{a}} = F_2 L_2^{\frac{1}{a}} \]

Associating \( F_1 \) with \( C_{10} \)
and \( L_1 \) with \( L_{10} \), the equation becomes:

\[ C_{10} L_{10}^{\frac{1}{a}} = FL^{\frac{1}{a}} \]

The units of \( L \) is revolutions
Load/life relationship

- Basic Dynamic Load rating ($C_{10}$)

  - The basic Dynamic load rating ($C_{10}$) is that load which will cause 10% of sample of bearings to fail at or before 1 millions revolutions.

  - 90% of the bearings would achieve at least 1 million revolutions at this load.
## Typically Life at Constant Speed

(data from SKF Industries)

<table>
<thead>
<tr>
<th>Type of Machine</th>
<th>Life in Hours of Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruments and apparatus which are only infrequently used. Ex: demonstration apparatus, devices for operation of sliding doors.</td>
<td>500</td>
</tr>
<tr>
<td>Aircraft Engines.</td>
<td>500–2000</td>
</tr>
<tr>
<td>Machines for service of short duration or intermittent operation, where service interruptions are of minor importance. Ex: hand tools, lifting tackle in machinery shops, hand-driven machines in general, farm machinery, assembly cranes, charging machines, foundry cranes, household machines.</td>
<td>4000–8000</td>
</tr>
<tr>
<td>Machines for intermittent service where dependable operation is of great importance. Ex: auxiliary machines in power stations, conveying-equipment in production lines, elevators, general-cargo cranes, machine tools less frequently used.</td>
<td>8000–12000</td>
</tr>
<tr>
<td>Machines for 8-hour service which are not always fully utilized. Ex: machines in general in the mechanical industries, cranes for continuous service, blowers, jackshafts.</td>
<td>20000–30000</td>
</tr>
<tr>
<td>Machines for continuous operation (24-hour service). Ex: separators, compressors, pumps, mainline shafting, roller beds and conveyor rollers, mine hoists, stationary electric motors.</td>
<td>40000–60000</td>
</tr>
<tr>
<td>Machines for 24-hour service where dependability is of great importance. Ex: pulp and paper machines, public power stations, mine pumps, public pumping stations, machines for continuous service aboard ships.</td>
<td>100000–200000</td>
</tr>
</tbody>
</table>

Also see: Table 11-4 of Shigley’s book
Mounting of Bearings

• For a rotating shaft:
  – Prevent relative rotation between shaft and bearing by mounting the inner ring with a *press fit* and securing it with a nut threaded on the shaft.
  – Avoid excessive interference of metal in press fits. The stretching of the inner ring may decrease the small required internal looseness of the bearing.
  – The outer ring is mounted more loosely than the inner ring and rotational creep between the ring and the housing should be prevented.
Deviations for Bearing Fits on Shafts

- The following Table gives the tolerances for shafts as a function of their respective sizes. Please note that the nominal sizes are given in millimeters, however, the tolerances themselves are given in inches.

<table>
<thead>
<tr>
<th>Nominal diam (mm)</th>
<th>Over</th>
<th>Incl.</th>
<th>g6</th>
<th>h6</th>
<th>h5</th>
<th>j5</th>
<th>j6</th>
<th>k5</th>
<th>k6</th>
<th>m5</th>
<th>m6</th>
<th>n6</th>
<th>p6</th>
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<tbody>
<tr>
<td>3</td>
<td>6</td>
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<td>-0.0005</td>
<td>0</td>
<td>-0.0003</td>
<td>0</td>
<td>+0.0002</td>
<td>-0.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6</td>
<td>10</td>
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<td>-0.0006</td>
<td>0</td>
<td>-0.0004</td>
<td>0</td>
<td>-0.0002</td>
<td>-0.0003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>-0.0002</td>
<td>-0.0007</td>
<td>0</td>
<td>-0.0004</td>
<td>0</td>
<td>-0.0002</td>
<td>-0.0003</td>
<td>-0.0004</td>
<td>-0.0005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>30</td>
<td>-0.0003</td>
<td>-0.0008</td>
<td>0</td>
<td>-0.0005</td>
<td>0</td>
<td>-0.0003</td>
<td>-0.0004</td>
<td>-0.0006</td>
<td>-0.0007</td>
<td>-0.0008</td>
<td>-0.0003</td>
<td>-0.0006</td>
</tr>
<tr>
<td>30</td>
<td>50</td>
<td>-0.0004</td>
<td>-0.0010</td>
<td>0</td>
<td>-0.0006</td>
<td>0</td>
<td>-0.0004</td>
<td>-0.0004</td>
<td>-0.0005</td>
<td>-0.0007</td>
<td>-0.0006</td>
<td>-0.0010</td>
<td>-0.0007</td>
</tr>
<tr>
<td>50</td>
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<td>-0.0011</td>
<td>0</td>
<td>-0.0007</td>
<td>0</td>
<td>-0.0004</td>
<td>-0.0005</td>
<td>-0.0006</td>
<td>-0.0008</td>
<td>-0.0009</td>
<td>-0.0012</td>
<td>-0.0008</td>
</tr>
<tr>
<td>80</td>
<td>120</td>
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<td>-0.0013</td>
<td>0</td>
<td>-0.0009</td>
<td>0</td>
<td>-0.0005</td>
<td>-0.0005</td>
<td>-0.0006</td>
<td>-0.0007</td>
<td>-0.0008</td>
<td>-0.0010</td>
<td>-0.0014</td>
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<tr>
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<td>-0.0015</td>
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<td>-0.0010</td>
<td>0</td>
<td>-0.0006</td>
<td>-0.0006</td>
<td>-0.0008</td>
<td>-0.0009</td>
<td>-0.0009</td>
<td>-0.0011</td>
<td>-0.0016</td>
</tr>
</tbody>
</table>
Deviations for Bearing Fits in Housings

The following Table gives the tolerances for housings as a function of their respective sizes. Please note that the nominal sizes are given in millimeters, however, the tolerances themselves are given in inches.

<table>
<thead>
<tr>
<th>Fit inner ring to shaft</th>
<th>Close running fit</th>
<th>Slide fit</th>
<th>Push fit</th>
<th>Wringing fit</th>
<th>Drive fit</th>
<th>Heavy drive fit</th>
<th>Light force fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal diam (mm)</td>
<td>G7</td>
<td>H8</td>
<td>H7</td>
<td>J7</td>
<td>J6</td>
<td>K6</td>
<td>K7</td>
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<tr>
<td>10</td>
<td>-0.0002</td>
<td>-0.0009</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0003</td>
<td>0.0002</td>
</tr>
<tr>
<td>18</td>
<td>-0.0011</td>
<td>-0.0011</td>
<td>-0.0007</td>
<td>0</td>
<td>0</td>
<td>0.0000</td>
<td>0.0002</td>
</tr>
<tr>
<td>30</td>
<td>-0.0003</td>
<td>-0.0013</td>
<td>-0.0008</td>
<td>0</td>
<td>0</td>
<td>0.0004</td>
<td>0.0006</td>
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<tr>
<td>50</td>
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<td>-0.0008</td>
<td>0</td>
<td>0</td>
<td>0.0000</td>
<td>0.0004</td>
</tr>
<tr>
<td>80</td>
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<td>-0.0019</td>
<td>-0.0009</td>
<td>0</td>
<td>0</td>
<td>0.0002</td>
<td>0.0002</td>
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<tr>
<td>120</td>
<td>-0.0006</td>
<td>-0.0021</td>
<td>-0.0011</td>
<td>0</td>
<td>0</td>
<td>0.0006</td>
<td>0.0004</td>
</tr>
<tr>
<td>180</td>
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<td>-0.0012</td>
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<td>0.0003</td>
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<td>-0.0018</td>
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<td>0.0003</td>
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<td>-0.0032</td>
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<td>0</td>
<td>0</td>
<td>0.0009</td>
<td>0.0003</td>
</tr>
<tr>
<td>400</td>
<td>-0.0007</td>
<td>-0.0035</td>
<td>-0.0022</td>
<td>0</td>
<td>0</td>
<td>0.0009</td>
<td>0.0003</td>
</tr>
<tr>
<td>500</td>
<td>-0.0009</td>
<td>-0.0041</td>
<td>-0.0027</td>
<td>0</td>
<td>0</td>
<td>0.0014</td>
<td>0.0003</td>
</tr>
</tbody>
</table>
Typical Mounting Details

-Examples of typical mounting details with oil retainers are shown.
-The catalogs of the various manufacturers contain useful mounting illustrations as well as other practical information.
Typical Mounting Requirements

– When two bearings are mounted on the same shaft, the outer ring of one of them should be permitted to shift axially to care for any differential expansion between shaft and housing.

– Shafts or spindles in machine tools and precision equipment that must rotate without play or clearance in either the radial or axial directions can be mounted on preloaded ball bearings.

– The preloading, which removes all play from the bearing, can be secured in a number of different ways.
  • Tapered shaft or sleeve to expand the inner ring.
  • Interference fit for outer ring.
  • Buy bearing with outer ring preshrunk over the rollers.
ABMA Boundary Dimensions

![Diagram showing ABMA Boundary Dimensions with Width series and Diameter series, indicating bore and OD (Outside Diameter).]