Bearing basics
Introduction to Anti-Friction Bearings

Why do we use a bearing in a mechanic system?
THE 4 FUNCTIONS OF A BEARING ARE*

- to eliminate friction
- to radially support and align the shaft
- to carry & disperse loads
- to locate the shaft axially

Note:
* valid for any type
1. To eliminate friction

Friction induces problems of

• torque
• heat
• wear
• inefficiency, power loss

“High friction results in high frustration”

Diagram showing frictional force calculations:

- At rest but at threshold of motion:
  \[ f = \mu_s N \]
  \[ \mu_s = 0.5 \]
  \[ N = 50 \text{ N} \]
  \[ f = 0.5 \times 50 \text{ N} = 25 \text{ N} \]

- In motion at constant velocity:
  \[ f = \mu_k N \]
  \[ \mu_k = 0.4 \]
  \[ N = 40 \text{ N} \]
  \[ f = 0.4 \times 40 \text{ N} = 16 \text{ N} \]

**Coefficient of static friction**
\[ \mu_s = \frac{50 \text{ N}}{100 \text{ N}} = 0.5 \]

**Coefficient of kinetic friction**
\[ \mu_k = \frac{40 \text{ N}}{100 \text{ N}} = 0.4 \]
2. To radially support and align the shaft
3. To carry & disperse loads

Radial load

Axial load

Combined load
4. To locate the shaft axially
**FRICTION**

In a bearing, friction is affected by:

- Rolling element
- Surface finish
- Lubrication
FRICION BEARING

- Bushings
- Plain Bearing
ROLLING FRICTION

Low friction
Low temperature
High speed
Light load

High friction
High Temperature
Low speed
High load
ANTI-FRICTION BEARINGS

- Tapered roller bearing
- Ball bearing
- Cylindrical roller bearing
- Spherical roller bearing
- Needle roller bearing
Anatomy of an anti-friction bearing

- Roller bearing
- Tapered roller bearing
- Raceway outer ring
- Outer ring
- Inner ring
- Cage
The bearing ring is used as a wear surface and is replaced when damaged; This allows to preserve the shaft from any damages.
There are different ways to design a bearing arrangement.

The bearing is fitted on shaft and housing through the inner and outer ring (position 1).

The shaft can take the role of the inner ring (position 2).

The housing can take the role of the outer ring (position 3).

In this case, the customer needs to provide a surface equivalent to the appropriate ring quality.
ROLLING ELEMENTS

- Ball
- Cylindrical roller
- Needle roller
- Tapered roller
- Symmetrical barrel roller
- Asymmetrical barrel roller
CAGE

Functions:

• Separates rollers to prevent inter-roller rubbing
• Retains and guides the rollers
• Noise damping
• Increases space for lubricant
Effect of Contra-rotation on Rollers

Although all rollers are revolving the same way, at the contact point they are travelling in opposite directions (contra-rotation).

This results in friction, heat and wear.
INTER-ROLLER RUBBING

Non separated rollers gives inter-roller rubbing

Cage separates rollers and lowers friction

Produces heat and expansion

Not suitable for high speed running
CAGES

- Pressed steel cages
CAGES

- Machined brass cages
CAGES

- Moulded polymer cages
CAGES

- Pin type
Boundary dimensions
BEARING INDUSTRY STANDARDS

- ANSI - American National Standards Institute
- ABMA - American Bearing Manufacturers Association
- ISO - International Standardization Organization
- DIN - Deutsches Institut für Normung
- JIS - Japanese Industrial Standards
- Bearing manufacturers internal specifications
Boundary Dimensions

Radial ball & roller bearings

Angular contact ball & roller bearings

Thrust ball & roller bearings

TIMKEN
World Part Numbering system for Metric (ISO) bearings

<table>
<thead>
<tr>
<th>Bearing series codes</th>
<th>Dimensions (Width &amp; Diameter) series codes</th>
<th>Bore size</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td># #</td>
<td># #</td>
</tr>
<tr>
<td>or ##</td>
<td>or / ###</td>
<td>or / ####</td>
</tr>
<tr>
<td>or ###</td>
<td>or / ###</td>
<td></td>
</tr>
<tr>
<td>or ######</td>
<td>or / ######</td>
<td></td>
</tr>
</tbody>
</table>

**Examples:**

<table>
<thead>
<tr>
<th>Bearing series code</th>
<th>Dimensions (Width &amp; Diameter) series code</th>
<th>Bore size</th>
</tr>
</thead>
<tbody>
<tr>
<td>23292</td>
<td>2 32 92</td>
<td></td>
</tr>
<tr>
<td>NNU4980</td>
<td>NNU 49 80</td>
<td></td>
</tr>
<tr>
<td>240 / 800</td>
<td>2 40 / 800</td>
<td></td>
</tr>
</tbody>
</table>
## Bearing serie codes and design types

<table>
<thead>
<tr>
<th>Bearing Family</th>
<th>Design Type Code</th>
<th>Design Code + Width &amp; Diameter Series</th>
<th>Bearing Type</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radial Ball Bearings</strong></td>
<td>1</td>
<td>10; 12; 13</td>
<td>Self Aligning Ball Bearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>112; 113</td>
<td>Self Aligning Ball Bearing with wider inner rings</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>160; 161</td>
<td>Deep groove single row ball bearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>22; 23</td>
<td>Self Aligning Ball Bearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>60</td>
<td>Deep groove single row ball bearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60; 61; 62; 63; 64; 622; 623</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Angular contact Ball Bearings</strong></td>
<td>23</td>
<td>2344; 2347</td>
<td>Thrust double direction angular contact ball bearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>32; 33</td>
<td>Double row angular contact ball bearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>72; 73</td>
<td>Single row angular contact ball bearing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>76</td>
<td>7602; 7603</td>
<td>Thrust single direction angular contact ball bearing</td>
<td></td>
</tr>
<tr>
<td><strong>Spherical Roller Bearings</strong></td>
<td>2</td>
<td>202; 203</td>
<td>Single row spherical roller bearings</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>213</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>222; 223</td>
<td>Double row spherical roller bearings</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>230; 231; 232; 233; 239</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>292; 293; 294</td>
<td>Thrust spherical roller bearing</td>
<td></td>
</tr>
<tr>
<td><strong>Tapered Roller Bearings</strong></td>
<td>3</td>
<td>302; 303; 313</td>
<td>Single row tapered roller bearing (original ISO)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>320; 322; 323; 329; 330; 331; 332</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>J</td>
<td>JC; JD; JF; JN; JP; JS; JT; JW</td>
<td>Single row tapered roller bearing (new metric)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>J</td>
<td>JL; JLM; JM; JHM; JH; JHH</td>
<td>Single row tapered roller bearing (metricified inch design)</td>
<td></td>
</tr>
</tbody>
</table>

### Cylindrical Roller Bearings

<table>
<thead>
<tr>
<th>Design Code + Width &amp; Diameter Series</th>
<th>Bearing Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2; N3; NJ2; NJ3; NJ22; NJ33; NU10; NU19; NU2; NU22; NU23; NU3; NUP2; NUP22; NUP23; NUP3</td>
<td>Single row cylindrical roller bearing</td>
</tr>
<tr>
<td>NCF18; NCF22; NCF29; NCF30; NCF31; NCF32</td>
<td>Full complement single row cylindrical roller bearing</td>
</tr>
</tbody>
</table>

### Needle Roller Bearings

<table>
<thead>
<tr>
<th>Design Code + Width &amp; Diameter Series</th>
<th>Bearing Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA48; NA49; NA69</td>
<td>Needle roller bearing with inner rings</td>
</tr>
<tr>
<td>RNA48; RNA49; RNA69</td>
<td>Needle roller bearing without inner rings</td>
</tr>
<tr>
<td>BK + dia x OD x width</td>
<td>One closed end Drawn cup needle roller bearing</td>
</tr>
<tr>
<td>HK + dia x width</td>
<td>Open ends drawn cup needle roller bearing</td>
</tr>
<tr>
<td>K + dia x OD x width</td>
<td>Single &amp; double row needle roller &amp; cage radial assembly</td>
</tr>
<tr>
<td>AXK + d D</td>
<td>Thrust needle roller &amp; cage assembly</td>
</tr>
<tr>
<td>FNT - d D; FNTK - d D; FNTKF - d D</td>
<td>Thrust unitized needle roller bearing assembly</td>
</tr>
</tbody>
</table>
Dimensions serie codes

Dimensions Series for Radial Bearings

ISO 15
(Radial Roller Bearings EXCLUDING TRBs)

- **First Number**
- **Width Series**
  - 8, 0, 1, 2, 3, 4, 5, 6
- **Second Number**
- **Diameter Series**
  - 7, 8, 9, 0, 1, 2, 3, 4
- Wider Bearing
- Established within each Diameter Series
- Larger OD
- Standard Outside Diameters for each Bore Size Range

Dimension Series for Thrust Bearings

ISO 104
(Appplies to Non-Tapered Thrust Bearings)

<table>
<thead>
<tr>
<th>First Number</th>
<th>Second Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height Series</td>
<td>Diameter Series</td>
</tr>
<tr>
<td>7, 9, 1</td>
<td>7, 8, 9, 0, 1, 2, 3, 4</td>
</tr>
<tr>
<td>Taller Bearings</td>
<td>Larger OD’s</td>
</tr>
<tr>
<td>Established Within Each Diameter Series</td>
<td>Standard Outside Diameters for Each Bore Size Range</td>
</tr>
</tbody>
</table>

- **Common** Thrust SRB Series: 92, 93 and 94
Dimensions serie code

Dimension Series for Radial Bearings

Note: For 02, 03, 04, the zero is ignored

Example: NJ 0315 becomes NJ315
# Bearing Bore Size (d)

<table>
<thead>
<tr>
<th>d &lt; 20 mm</th>
<th>20 mm ≤ d &lt; 500 mm</th>
<th>d ≥ 500 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 = 10 mm</td>
<td>Last Two Digits × 5 = Bore (in mm)</td>
<td>/Bore Size</td>
</tr>
<tr>
<td>01 = 12 mm</td>
<td>Examples</td>
<td>Examples</td>
</tr>
<tr>
<td>02 = 15 mm</td>
<td>04×5 = 20 mm</td>
<td>/500 = 500 mm bore</td>
</tr>
<tr>
<td>03 = 17 mm</td>
<td>07×5 = 35 mm</td>
<td>/750 = 750 mm bore</td>
</tr>
<tr>
<td></td>
<td>10×5 = 50 mm</td>
<td>/1120 = 1120 mm bore</td>
</tr>
<tr>
<td></td>
<td>96×5 = 480 mm</td>
<td></td>
</tr>
</tbody>
</table>
Examples

- Deep groove ball bearing
  - Width serie: 0
  - Diameter serie: 3
  - $09 \times 5 = 45$ mm bore diameter

- Angular contact ball bearing
  - Width serie: 0
  - Diameter serie: 2
  - $12 \times 5 = 60$ mm bore diameter
Examples

Tapered roller bearing
- Width serie: 0
- Diameter serie: 3
- 09 x 5 = 45 mm bore diameter

Cylindrical roller bearing
- Width serie: 2
- Diameter serie: 3
- 09 x 5 = 45 mm bore diameter
Precision Classes & Tolerances
What does ONE (1) Micrometer look like?
# ISO and ABMA Tolerance Classes for Metric Roller Bearings except TRB

---

<table>
<thead>
<tr>
<th>ISO</th>
<th>ABMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (Designated <strong>P0 or without any indication</strong>)</td>
<td>ABEC/RBEC 1 (≈ P0)</td>
</tr>
<tr>
<td>6 - More Accurate than Normal (Designated <strong>P6</strong>)</td>
<td>ABEC/RBEC 3 (≈ P6)</td>
</tr>
<tr>
<td>5 - More Accurate than P6 (Designated <strong>P5</strong>)</td>
<td>ABEC/RBEC 5 (≈ P5)</td>
</tr>
<tr>
<td>4 - More Accurate than P5 (Designated <strong>P4</strong>)</td>
<td>ABEC/RBEC 7 (≈ P4)</td>
</tr>
<tr>
<td>2 - More Accurate than P4 (Designated <strong>P2</strong>)</td>
<td>ABEC/RBEC 9 (≈ P2)</td>
</tr>
</tbody>
</table>
## COMPARISON WITH METRIC TRB

<table>
<thead>
<tr>
<th>CRB/SRB</th>
<th>ISO</th>
<th>ABMA (metric)</th>
<th>TRB</th>
<th>ISO</th>
<th>ABMA (metric)</th>
<th>ABMA (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0</td>
<td>ABEC/RBEC 1</td>
<td>Normal</td>
<td>K</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P6</td>
<td>ABEC/RBEC 3</td>
<td>6X</td>
<td>N</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>ABEC/RBEC 5</td>
<td>5</td>
<td>C</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>ABEC/RBEC 7</td>
<td>4</td>
<td>B</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>ABEC/RBEC 9</td>
<td>2</td>
<td>A</td>
<td>00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CRB/SRB Tolerances are **NOT** Equivalent to TRB Tolerances

Slide Intended to Show General Class Structure **ONLY**!
Radial tolerances

Inch design (ABMA) have
Positive tolerances

Metric designed (ISO) have
Negative tolerances
RADIAL RUNOUT

Bearing Centerline
Rotational precision of the assembled bearing.
WHY BEARINGS FAIL

- Improper lubrication or lubricant failure 43%
  - Insufficient lubrication, either quantity or viscosity
  - Deterioration of lubricant; Improper relube interval or excess temperatures
  - Contamination of lubricant and/or bearing
  - Use of grease when oil was required
  - Incorrect grease selection for the application
- Improper mounting 27%
- Metal fatigue 9%
- Other causes 21%
THE IMPORTANCE OF LUBRICATION

- Permit to achieve the provided bearing life
  - Avoid metal/metal contact (reduce friction & wear)
  - Protect the bearing surfaces from corrosion and outside contaminants
  - Add an additional sealing barrier (grease)
- Transfer heat from the bearing surfaces (with oil)
- Separate the sliding contacts
SURFACE FINISH

- Average Surface Roughness (Ra) is the average distance between surface peaks/valleys

  - Super finish: $0.05 \, \mu m$
  - Hone: $0.070 \, \text{à} \, 0.250 \, \mu m$
  - Grind: $0.250 \, \text{à} \, 0.635 \, \mu m$
  - Turn: $>0.635 \, \mu m$
Film Thickness

- Lubricant film thickness on raceway depends on the operating conditions
  - Surface velocity
  - Loads
  - Lubricant viscosity
  - Pressure/viscosity relationship

- Required minimum film thickness: 0.1 µm
Viscosity

The most important physical property of a lubricant

- Measure of the flow characteristics
- Varies inversely with temperature

Viscosity comparison
Basic methods of Lubrication

- Grease
- Oil - Mist
- Air - Oil
- Oil bath
- Circulating oil
DIMENSIONAL STABILITY

• What is it?
  • Ability of a substance or part to retain its shape when subjected to varying degrees of temperature, moisture, pressure, or other stress—primarily temperature when talking about bearings

• What happens? -- Microstructure size increases and changes mechanical properties
  • Martensite is metastable - responds to heavy loading, pressure, heat, high cycles
  • Retained austenite changes at high temperatures and extreme cyclic loading
Maximum Operating Temperatures for Standard Timken Bearings - Guidelines

- The following are guidelines for how standard Timken bearings are generally produced.

Maximum Operating Temperatures for Standard Bearings

<table>
<thead>
<tr>
<th></th>
<th>Case Carburized</th>
<th>Through Hardened</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taper</td>
<td>120°C (250°F)</td>
<td>120°C (250°F)</td>
</tr>
<tr>
<td>Cylindrical (one row)</td>
<td>120°C (250°F)</td>
<td>200°C (392°F) &lt; 300mm bore</td>
</tr>
<tr>
<td>Spherical</td>
<td>120°C (250°F)</td>
<td>200°C (392°F) &lt; 300mm bore</td>
</tr>
<tr>
<td>Ball</td>
<td>120°C (250°F)</td>
<td>120°C (250°F)</td>
</tr>
</tbody>
</table>
Maximum Operating Temperatures for Enhanced Dimensional Stability Timken Bearings

- Bearings with enhanced dimensional stability are available from Timken.
- These special bearings are made to DIN 623-1, Paragraph 3.3.6

<table>
<thead>
<tr>
<th>SN</th>
<th>Rings or washers suitable for operation at service temperatures up to 120°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>S0</td>
<td>Rings or washers suitable for operation at service temperatures up to 150°C</td>
</tr>
<tr>
<td>S1</td>
<td>Rings or washers suitable for operation at service temperatures up to 200°C</td>
</tr>
<tr>
<td>S2</td>
<td>Rings or washers suitable for operation at service temperatures up to 250°C</td>
</tr>
<tr>
<td>S3</td>
<td>Rings or washers suitable for operation at service temperatures up to 300°C</td>
</tr>
<tr>
<td>S4</td>
<td>Rings or washers suitable for operation at service temperatures up to 350°C</td>
</tr>
</tbody>
</table>

- Enhanced Dimensional Stability bearings are marked with either the DIN code in the case of CRBs/SRBs/BBs (e.g. ‘-S2’, ‘-S3’) or a modified code in the case of Tapers.

TIMKEN
Mounting types
Bearing arrangement

In order to guide and support a rotating shaft, at least two bearings are required which are arranged at a certain distance from each other that we call “spread”
BEARING ARRANGEMENT

• Depending on the types of bearing used and the application, different bearing arrangements can be selected:

1. with locating and floating bearings,
2. with adjusted bearings
3. with floating bearings
1. **Locating-floating bearing arrangement**

- Locating or Fixed bearing
- Non locating or Floating bearing
1. **Locating-Floating Bearing Arrangement**

![Diagram of locating-float bearing arrangement with Thermal expansion arrow]
1. Locating-floating bearing arrangement
1. Locating-floating bearing arrangement

Using a cylindrical roller bearing

Thermal expansion
1. Locating-Floating Bearing Arrangement
1. LOCATING-FLOATING BEARING ARRANGEMENT
1. Locating-Floating Bearing Arrangement
2. ADJUSTED BEARINGS

As a rule, an adjusted bearing arrangement consists of two symmetrically arranged angular contact ball bearings or tapered roller bearings. During mounting, the required bearing clearance or the preload must be set.

Indirect or “O” mounting
2. ADJUSTED BEARINGS

Direct or “X” mounting
DOUBLE ROW TAPERED BEARING ARRANGEMENT
Bearing life
Performance

- Bearing life,
- Speed capability,
- Temperature,
- General environment,
- ...

Cost

- Bearing cost,
- Assembly, mounting,
- Existing, new product,
- Available product,
- ...
Some Definitions:

Bearing life
In a broad sense, bearing life is the period during which bearings continue to operate and satisfy their required function.

Rolling fatigue life
Rolling fatigue life – also called “fatigue life” -- is defined by the number of revolutions before the bearing surface begins to flake due to stress. The bearing surface is generally an inner ring and an outer ring raceway.

Bearing $L_{10}$ Life

- Life that 90% of a group of apparently identical bearings will complete or exceed before the area of spalling reaches a defined limit. (Timken = 6 mm² or .01 in²)
  - $L = \text{fatigue}$ life of a rolling element bearing
  - $10 = 10\%$ of population that failed criteria (reliability)
**TIMKEN L_{10} LIFE**

\[
L_{10} = \left( \frac{C_{90}}{P} \right)^{\frac{10}{3}} \times \left( 90 \times 10^6 \right) \text{ Revolutions}
\]

\[
L_{10} = \left( \frac{C_{90}}{P} \right)^{\frac{10}{3}} \left( \frac{1.5 \times 10^6}{S} \right) \text{ Hours}
\]

- 2 X Load = 1/10 Life
- 1/2 Load = 10 X Life
- 2 X Speed = 1/2 Life
- 1/2 Speed = 2 X Life

Linear contact => Power = (10/3)
Point contact => Power = 3
WEIBULL DISTRIBUTION OF BEARING FATIGUE LIFE

For Timken bearings, the average or mean life is approximately 4 times L10. This is defined by a spall criteria which is very conservative for many applications.

Theoretical life frequency distribution of one hundred apparently identical bearings operating under similar conditions.
WHAT IS A RATING?

• Describes the expected life and performance of a product
**BEARING RATINGS**

- Used by customers to:
  - Select the right Timken bearing for their application
  - Compare bearings
  - Compare bearings with competitor bearings

Ratings are defined by:

- Roller diameter
- Contact length
- Contact angle
- Number of rollers
- Number of bearing rows
Dynamic Ratings
**Dynamic Load Rating**

- Based on:
  - Stress cycles per revolution
  - Bearing life test empirical data
- Load ratings based on algorithms that are empirically tested.
  - Insures brand promise
- The load that 90% or more of a large group of bearings could survive for 90 million revolutions before a 0.01 in² (6mm²) spall develops

\[ C_{90} \text{ or } C(90) = \text{radial rating} \]
\[ C_{a90} \text{ or } C_a(90) = \text{thrust rating} \]
Dynamic Radial Rating

- Rating equations: radial capacity

\[ C_{90} = H M(Z L \cos \alpha)^{4/5} N^{7/10} D^{16/15} \text{ (lbs.)} \]

- \( C_{90} \) based on life of 90 million revolutions, or 3000 hours at 500 rev/min.
- \( H \) = Geometry dependent factor
- \( M \) = Material constant
- \( Z \) = Number of bearing rows in assembly
- \( L \) = Effective roller contact length
- \( \alpha \) = 1/2 Included cup angle
- \( N \) = Number of rollers per rating row
- \( D \) = Mean roller diameter
**Dynamic Load Rating**

- Two-row bearing rating is not simply two times the single-row rating

\[
(Z L \cos \alpha)^{4/5}
\]

Since: from rating equation, therefore \(2.8 = 1.74\)

\[
C(90)_2 = 1.74C(90)
\]
**Dynamic Load Rating**

- 4-Row radial ratings = 2 times the 2-row rating

\[
(1.74 C_{90}) \times 2
\]
C1 RATING EQUATIONS

• Timken uses C90 (90 million revolutions) and C1 (1 million revolutions)
• To convert \( C_1 \) to \( C_{90} \)
  \[
  C_1 = 90^{10} C_{90}
  \]
  \[
  C_1 = 3.86 C_{90}
  \]
• Using \( C_1 \) in \( L_{10} \) equation

\[
L_{10} = \left( \frac{C_1}{P} \right)^{10/3} \times \left( 1 \times 10^6 \right) \text{ Revolutions}
\]
**BEARING RATINGS**

- $C_1$ is a theoretical number. The bearing should never be loaded to this magnitude.

- "Working" load range is 1/3 to 1/4 of the C rating for roller contact bearings.

- Ball products – "Working" load up to or <70% of the static rating (C0)

- Life testing for other bearing types done at C90 load levels.
OTHER RATING EQUATIONS

• Most organizations use C1
  • ISO (International Standards Organization)
  • ANSI (American National Standards Institute)
  • ABMA (American Bearing Manufacturers Association)
  • Competitors

• Ratings may differ from ISO / ABMA / ANSI ratings due to:
  • Different internal dimensions
  • Different material factors
  • Other factors
ISO 281 BEARING RATING – ROLLER BEARINGS

- C1: 1 million revolutions

\[ C_1 = b_m f_c \left( i L_{we} \cos \alpha \right)^\frac{7}{9} Z^{\frac{3}{4}} D_{we}^{\frac{29}{27}} \]

- \( b_m \) = material factor and manufacturing quality. Current factor is 1.1
- \( f_c \) = geometry, accuracy, and material factor
- \( i \) = number of rows in a bearing
- \( L_{we} \) = effective roller length
- \( \alpha \) = nominal contact angle of a bearing [deg]
- \( Z \) = number of rollers in a single/multi-row bearing
- \( D_{we} \) = roller diameter
ISO 281 Bearing Rating – Ball Bearings

• C1: 1 million revolutions

\[ C_1 = b_m f_c \left( i \cos \alpha \right) ^{\left( \frac{7}{10} \right)} \left( \frac{2}{3} \right) Z \left( \frac{9}{5} \right) \]

\( b_m \) = rating factor for contemporary, normally used material and manufacturing quality
\( f_c \) = geometry, accuracy, and material factor
\( i \) = number of rows in a bearing
\( \alpha \) = nominal contact angle of a bearing [deg]
\( Z \) = number of rolling elements in a bearing
\( D \) = ball diameter
Static Load Ratings
**STATIC LOAD RATING (ISO 76)**

- Used to determine maximum permissible load that can be applied to a non-rotating bearing
  - Load that can be applied without altering the physical properties in a way that degrades bearing performance when it is rotated with a lesser load
  - Based on maximum contact stress of 580,000 psi (580 KSI or 4000 MPa) with a load zone of 180 degrees
  - Based on system stiffness – shaft/housing, the actual load may vary.
  - Static load ratings good for comparison from 1 part number to another or 1 bearing type to another.

\[
C_0 = \text{Radial} \\
C_{0a} = \text{Thrust}
\]
Static Load Rating – TRB Bearings

- Radial capacity rating equation (lbs)
  \[ C_0 = 7850 \times D \times L \times N \times (\cos \alpha / \cos 2\nu) \times (\sin \beta / \sin \gamma) \]

- Thrust capacity rating equation (lbs)
  \[ C_{0a} = 34300 \times D \times L \times N \times (\sin \alpha / \cos 2\nu) \times (\sin \beta / \sin \gamma) \]

- Symbols:
  - D = Mean roller diameter
  - L = Effective roller contact length
  - N = Number of rollers
  - \( \alpha \) = 1/2 Included cup angle
  - \( 2\nu \) = Included roller angle
  - \( \beta \) = 1/2 Included cone angle
  - \( \gamma \) = Roller centerline angle
STATIC LOAD RATING

- Stacked bearings - radial and thrust
  - Static load ratings for 2 or more similar, single-row TRBs mounted side-by-side on the same shaft and operating in tandem, when manufactured and mounted for equal load distribution, equals the number of bearings times the rating of a single row bearing

Static Load Rating = # of bearings X single row rating

2TS-TM Assembly
STATIC LOAD RATING

- For applications where sound, vibration, and rolling torque are critical to bearing performance, a rule of thumb is to load the bearing to no more than approximately 1/2 the static rating.

Shock Load Rating

- Maximum allowable shock load that can be applied to a stationary bearing is 1/2 the static rating.
  - Implies impact loading from “G” loading
  - Rule of thumb
- True for both radial and thrust loading
- Factor applicable for ball and roller bearings
What create the load on a bearing?
EXTERNAL LOAD OF THE BEARING SYSTEM

- Gear,
- Pulley,
- Wheel,
- Tool,
- Acceleration,
- Chocks
- ...

Internal load of the system

- Thermal expansion,
- System Preload,
- Induced load,
- ...

TIMKEN
Load zone and contact pressure
Pressure

\[
\text{Pressure} = \frac{\text{force}}{\text{area}}
\]

Force = 100 N

Area = 1 mm\(^2\)

Area = 1 mm\(^2\)

Force = 100 N
Pressure

Area = 1 mm²
Pressure = 100 N/mm²

Area = 1/2 mm²
Pressure = 200 N/mm²
**PROFILES**

- Hertzian pressure creates elastic deformation

At the end of the loaded roller, the raceway deforms and create a tension generating stress concentration.

- Two cylinders pressed together under load form line contact.

  - Maximum Compressive Stress
  - (elliptical pressure profile)

Amount of stress

---

**TIMKEN**

Edge Stress

Edge stresses are too high

Max Allowable Stress

Straight surfaces in contact
Edge Stress

Profiled surfaces in contact

Edge stresses are reduced to a reasonable level

Max Allowable Stress
**PROFILES**

**Objective**: better stress distribution

- **Standard roller under heavy load**
- **Standard roller under misalignment**
- **Specific profile roller under heavy load**
LOAD ZONE

- A bearing load can be radial, axial or combined.
- Each kind of bearing will tolerate these loads in different ways.
LOAD ZONE

Outer ring
Inner ring
Rolling elements

Load zone 360°
Load zone 180°
Load zone 90°

Radial load
LOAD ZONE

General load distribution

In a ball or roller bearing, the rolling elements transmit the external load from one ring to the other.

The external force generally composed of a radial force and an axial force is always distributed over a number of rolling elements.
LOAD ZONE CONDITIONS

1) Clearance
2) Zero clearance
3) Light preload
4) Heavy preload
**RELATIONSHIP OF SETTING TO BEARING LIFE**

Note – the optimum setting is obtained at light preload value.
Relationship of setting to bearing life
Related to housing geometry

Housing bore is within tolerance
Large load zone

Housing bore is out of tolerance
Small load zone
SELECT BEARING TYPE
BEARING SETTING

- Adjustable bearings
  By moving the raceway:

- Non-adjustable bearings
  Tight fits
BALL BEARING PERFORMANCE

1) A low performance indicates a bearing life reduction due to misalignment
2) A low performance indicates a low torque level
CYLINDRICAL ROLLER BEARING PERFORMANCE

- Radial load
- Axial load
- Combined load
- Speed
- Cost
- Life
- Misalignment¹
- Torque²

1) A low performance indicates a bearing life reduction due to misalignment.
2) A low performance indicates a low torque level.
1) A low performance indicates a bearing life reduction due to misalignment
2) A low performance indicates a low torque level
TAPERED ROLLER BEARING PERFORMANCE

- Radial load
- Axial load
- Combined load
- Speed
- Cost
- Life
- Misalignment
- Torque

1) A low performance indicates a bearing life reduction due to misalignment
2) A low performance indicates a low torque level
EXAMPLE OF OVERLOAD
EXAMPLE OF OVERLOAD
EXAMPLE OF OVERLOAD
AND RELIABILITY...
QUESTIONS