COMP0205 Mechatronics and Making

Mechanical Components - Bearings

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Today's Objectives

- To have an appreciation of different bearing types
- To understand and apply the friction coefficient
- To be aware of the basic working principles of each type
- To be aware of the applications for each type

TRIBOLOGY “The study of friction, wear, lubrication, and the design of bearings; the science of interacting surfaces in relative motion”.

Bearing design is a specialist field of engineering and something that you are unlikely to get involved in during your career.

However,

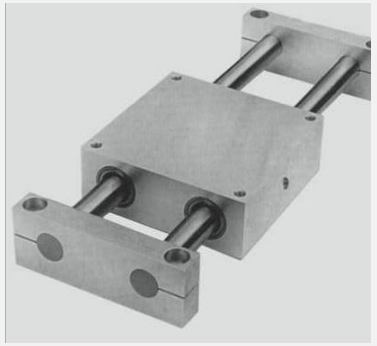
as Mechatronics and Robotics engineers, you need to be aware of bearings so that you can design from a base of knowledge and awareness and communicate effectively and intelligently with other engineering disciplines such as fabrication companies and mechanical engineers

Bearing Types (1)

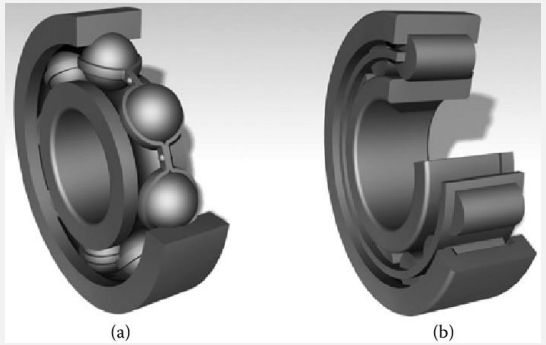
Bearings are machine elements that allow components to move with respect to each other. There are two types of bearings:

1: Mechanical contact:

Sliding



Rolling



Flexural

Bearing Types (2)

2: Non-contact:

Fluid film (hydrostatic)

Fluid film (hydrodynamic)

Magnetic passive: https://www.youtube.com/watch?v=aSoCYi19NJ0 [1]

Magnetic active: https://www.youtube.com/watch?v=n5MMGZSi60Q [2]

[1] PlasmaStar9, 2019. Tesla Turbine with Magnetic Bearings. Sourced from associated link

[2] Siemans, 2019. SIMOTICS Active Magnetic Bearing from Siemens. Sourced from associated link

Basic motions

All mechanisms have moving parts, and their efficiency of motion is dependent on a very basic, yet critical, mechanical component i.e. the bearing.

There are two basic types of motion:

Linear

Rotary

Bearing provides for **free linear movement** of the moving part or for **free rotation** around a fixed axis, or it may **prevent a motion** by controlling the vectors of normal forces that bear on the moving parts.

Friction

Before we discuss these bearings in more detail we need to know a little bit about friction.

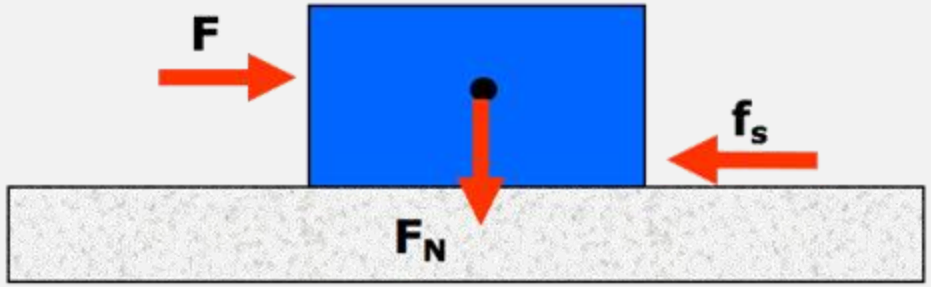
There are two types of friction:

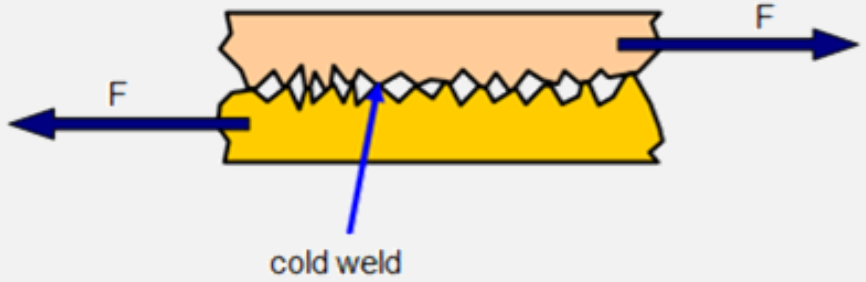
Static Friction

AND

Kinectic/Dynamic Friction

Static Friction



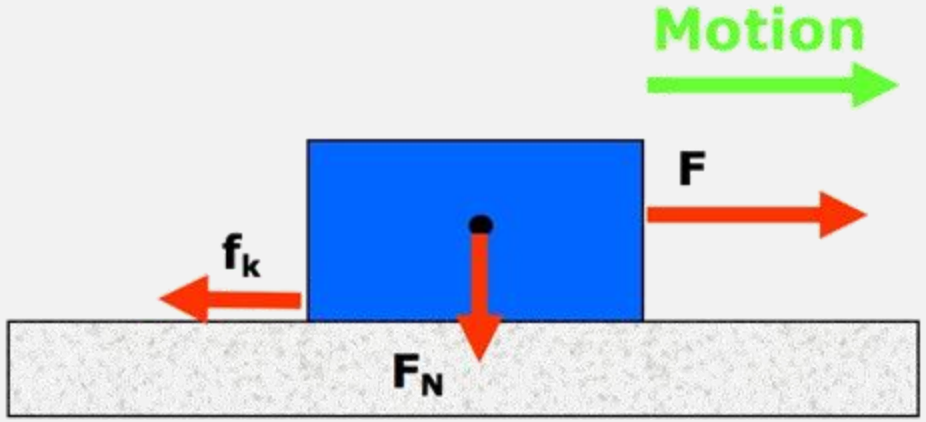


Static friction (f_s) = $\mu_s.F_N$

where μ_s (Mu) is the coefficient of static friction between the two surfaces

- Static friction is caused by the microscopic roughness of surfaces
- When these surfaces meet, a molecular process known as ‘Cold Welding’ takes place
- In order for this effect to be broken or deformed, a force must be applied
- To start moving the object, $F = f_s$ where $F = \mu_s$ mg (where g = 9.81 m/s^2)
- Once the object is moving, a process known as ‘Abrasion’ occurs

Kinetic/Dynamic Friction



Kinetic friction (f_k) = $\mu_k.F_N$

where μk is the coefficient of kinetic friction between the two surfaces

- Once the object is moving then the force required to overcome ‘Abrasion’ must be applied i.e. F >= f_k = $\mu_k.F_N$
- Once an object is moving there is no time for ‘cold welding’ to take place
- In general, KINETIC friction is less than STATIC friction

The Coefficient of Friction Calculation

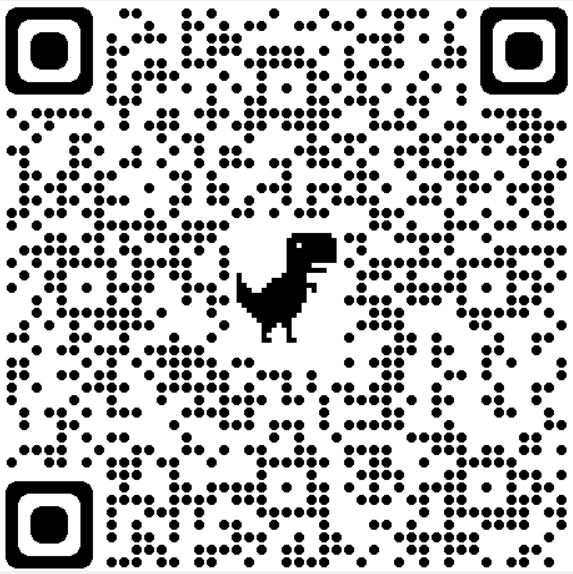
The coefficients of friction can be calculated empirically since:

$$\mu = {}^{F}/_{F_N}$$

where F_N is the force of the object onto the surface and F is the force required to move it.

However, there are many tables that exist that describe the static and dynamic friction forces for a combination of materials.

One such table is:
https://piping-designer.com/index.php/properties/878-tables/2718-friction-coefficient-of-materials-table



From the table of coefficients of friction

- Question 1: What is the static force required to move a 100 Kg wooden box standing on a concrete floor?
- Question 2: What is the static force required to move 200 g of polystyrene on a steel surface?
- Question 3: What do you observe about the difference between the STATIC and SLIDING coefficients of friction?
- Question 4: Which material has the lowest static coefficient of friction?
- Question 5: What do you observe about the STATIC and the SLIDING coefficient of friction for TEFLON and what does it suggest?

Sliding Bearings

Sliding Bearings

- The term sliding bearing refers to bearings where two surfaces move relative to each other without the benefit of rolling contact.
- Sliding bearings can be used in both linear and rotary application. In general, when used in rotary applications, the bearing may be called any one of the following:
  - SLIDE
  - PLAIN
  - SLEEVE
  - **JOURNAL**
  - SHELL
  - BUSH

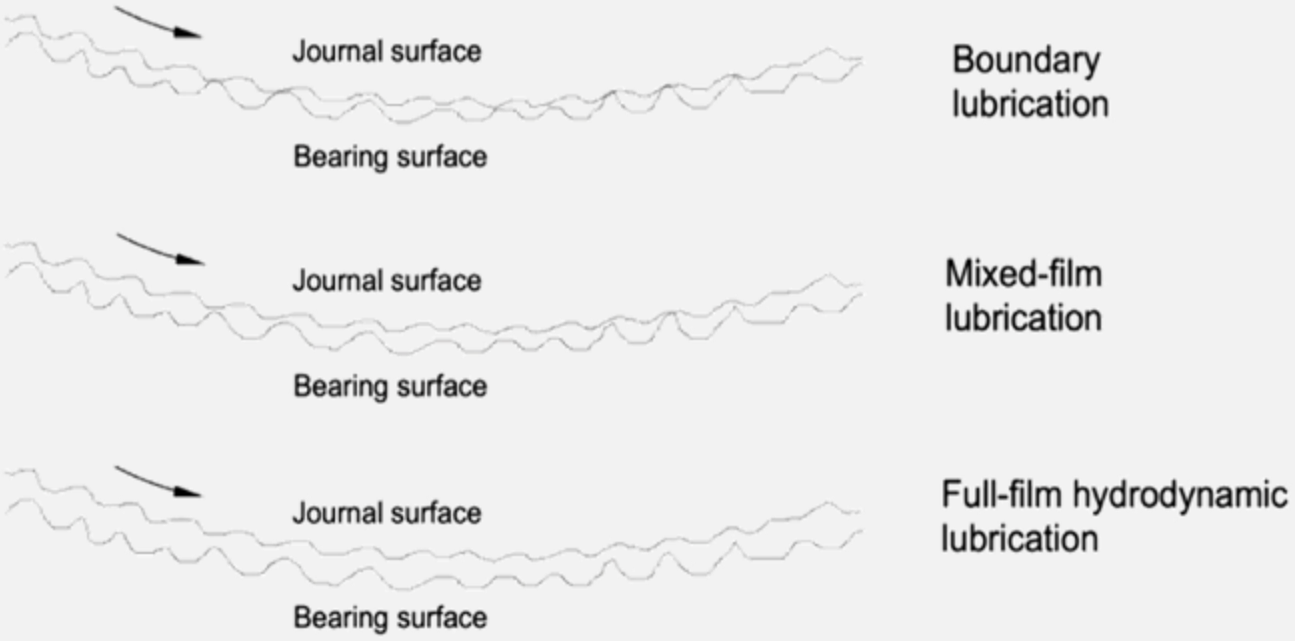
* The ‘Journal’ bearing is sometimes considered to be a complete structure

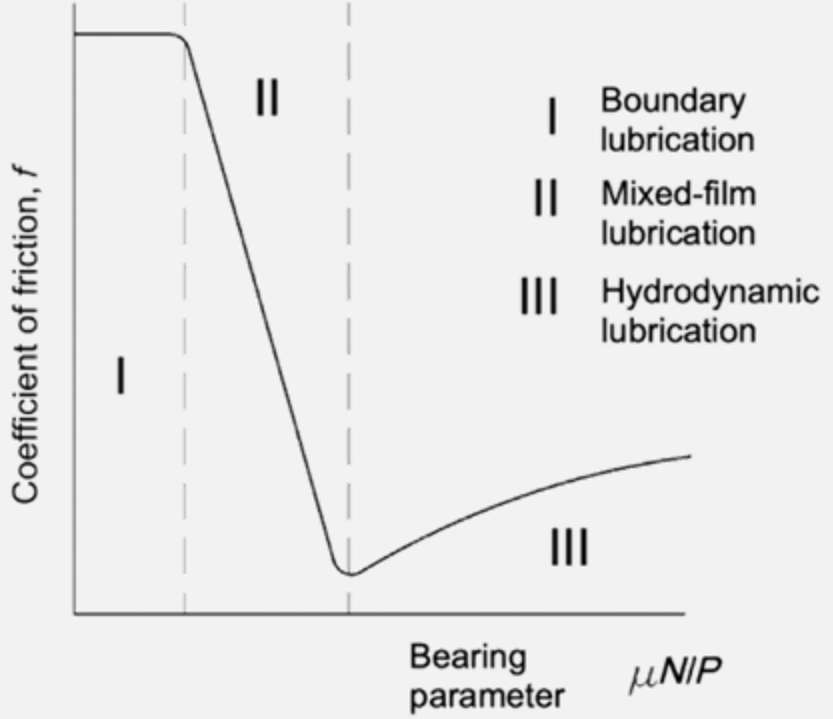
Sliding Bearing Materials

These bearings are placed between **shafts** and **housings** to reduce friction, wear and to facilitate rotary and/or translation motions. These bearings can be made from many different materials but some of the most common are:

- Bronze (An alloy of copper and approximately 12% of other elements)
- Brass
- Graphite
- Babbitt (an alloy of both hard and soft materials)
- PTFE
- Sintered types (Reconstituted elements for porosity).

Sliding Bearing Lubrications





Typical coefficients of friction for a boundary-lubricated bearing are between approximately **0.05 and 0.1**. By contrast, the coefficient of friction for a rolling element bearing is typically of the order of **0.002**.

Sliding Bearings – Pros and Cons

Advantages of sliding bearings:

- Operational noise is low
- Cheap
- Small space requirement

Disadvantages (in general):

- High friction between mating surfaces resulting in low energy efficiency
- Susceptible to damage from impurities in lubricant
- Have stringent lubricant requirements

Special Rotary Sliding Bearings

Jewel Bearings (Synthetic rubies)

What are the properties of Jewel bearings:

- Low friction
- Thermally stable
- High hardness (low wear)
- The bearing is stronger than the shaft

Where are they used?

- Watches

- Compasses

- Precision Instrumentation

Sliding/Plain bearings in a linear application

Advantages:

- They can be self lubricating and therefore maintenance free
- Low friction
- Contaminant particulates do not adhere to the bearing
- Resistant to corrosion
- Low noise
- Light weight
- Safe in specialist environments (depends on composite)

Were are they used?

Not all slide bearings are cylindrical

e.g. The dovetail linear slide

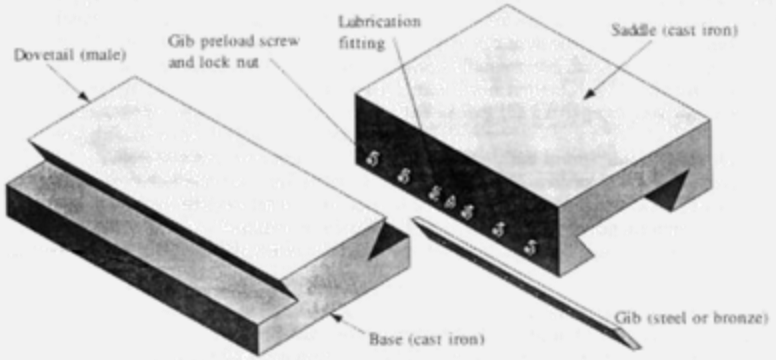


Figure 2-3. Dovetail Box Way

Advantages:

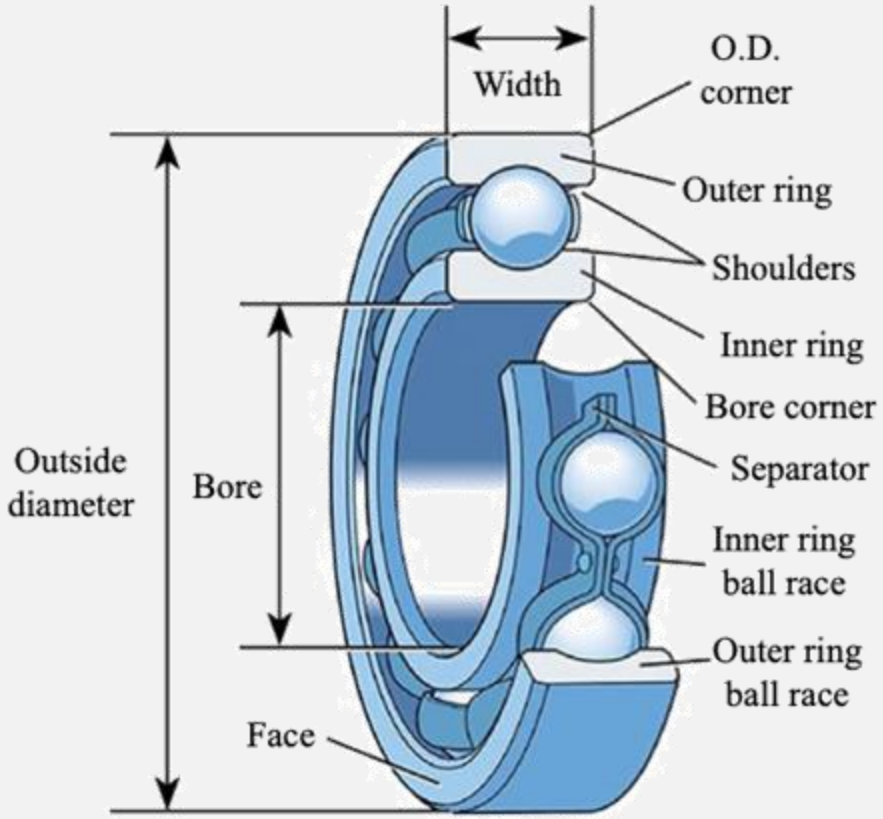
- Adjustable tension
- Precision can be defined by adjustment

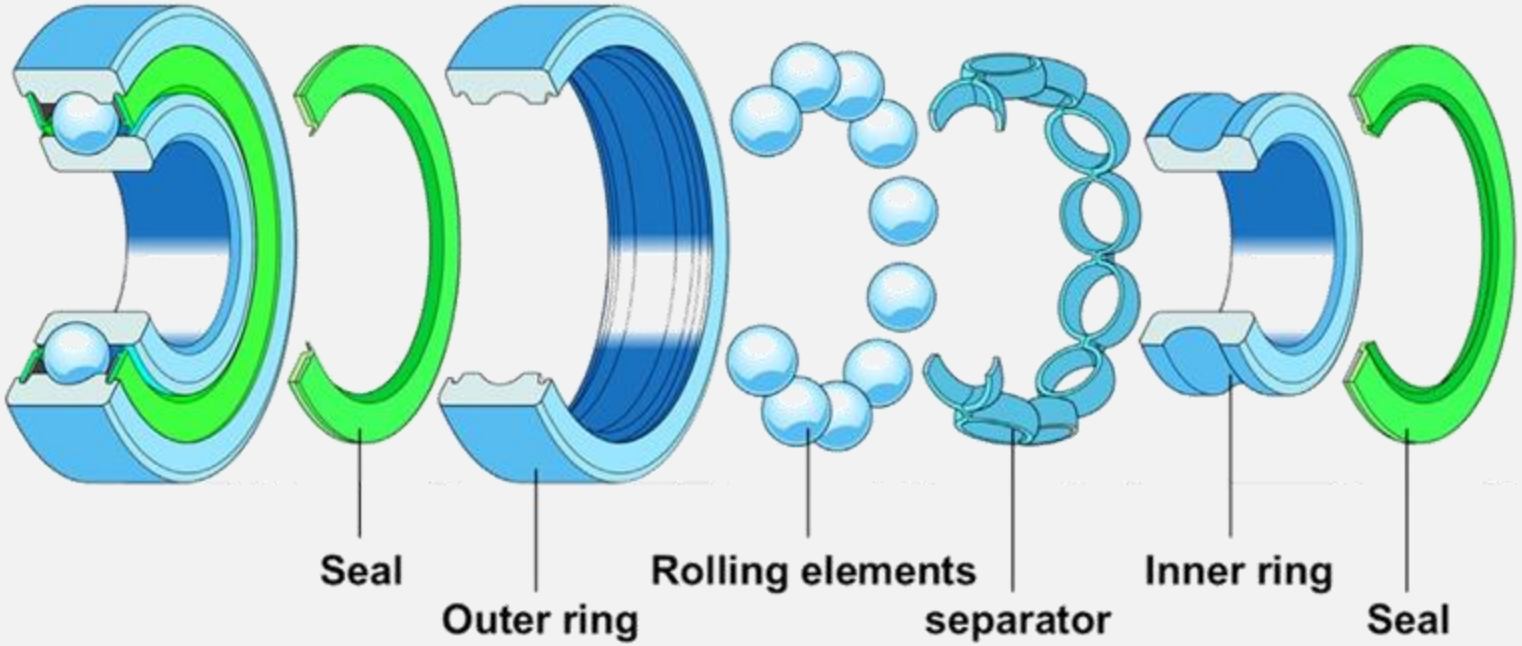
Disadvantages:

- Regular maintenance
- Undefined f_s

Rolling Bearings

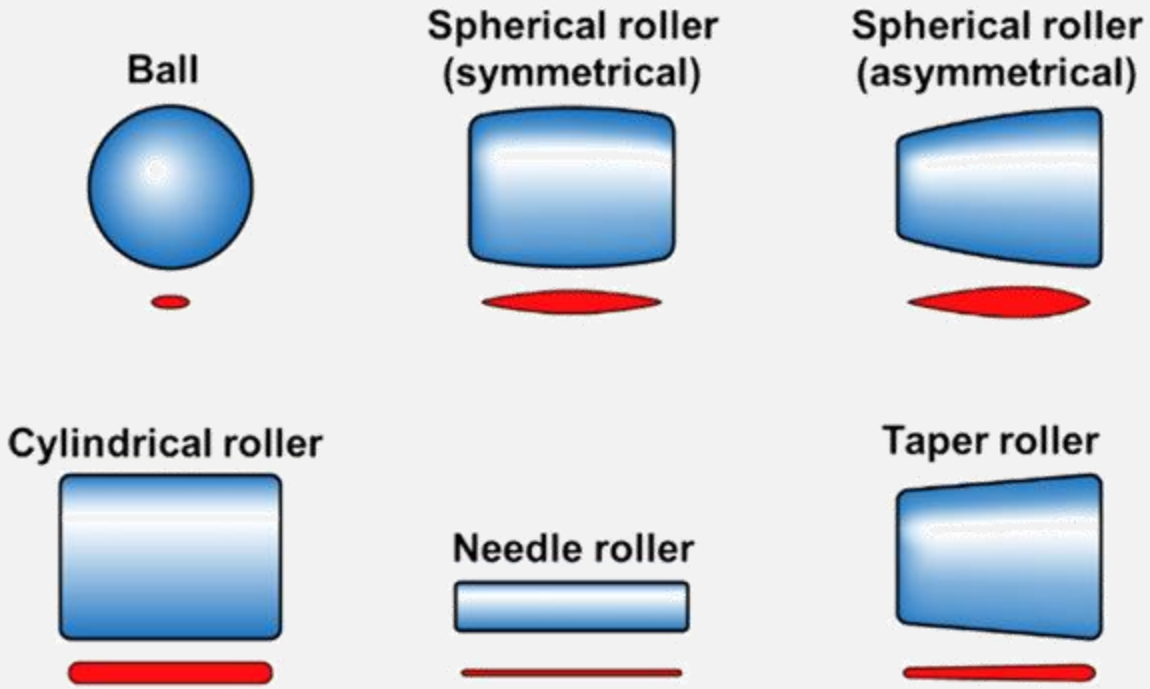
The essential parts of a rolling bearing

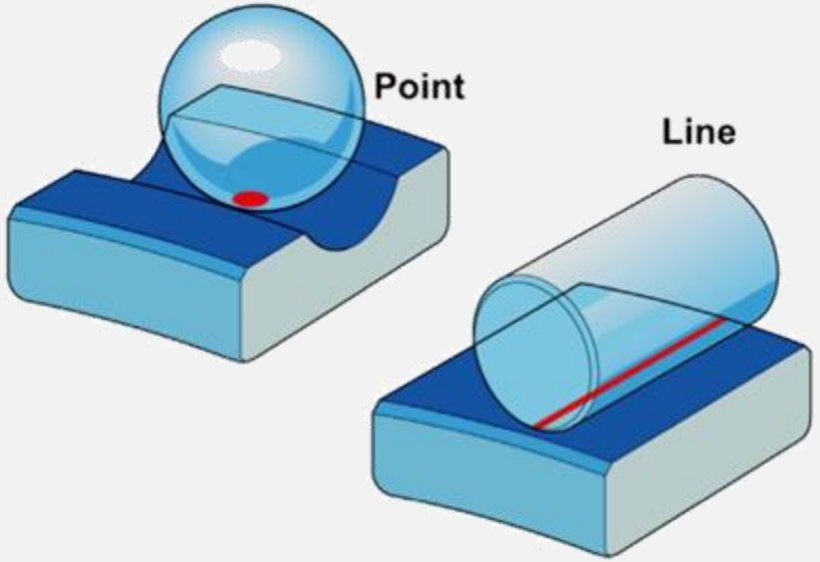




Types of rolling elements

- The main difference between rolling elements is the contact area between rolling elements and inner ring. **Load capacity?**



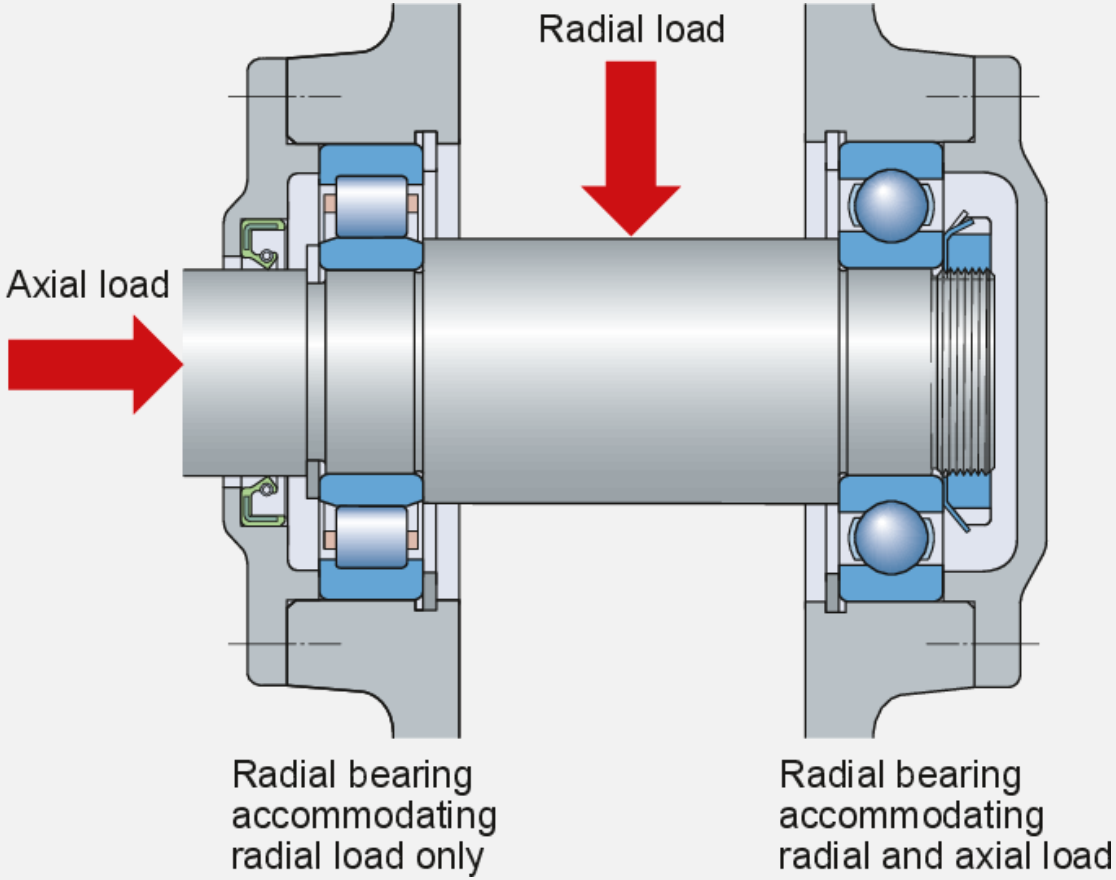


Bearing loading

Before we move on we need to be aware of application loading i.e. the direction of the forces on the bearing.

There are two types of loading:

- AXIAL/THRUST load
- RADIAL load



Rolling Bearings Types

- There are two types of rolling bearings i.e. BALL or ROLLER and each has a grouping type i.e.
  - RADIAL (loads perpendicular to the shaft) or
  - THRUST/AXIAL (loads perpendicular to the axis of the shaft)

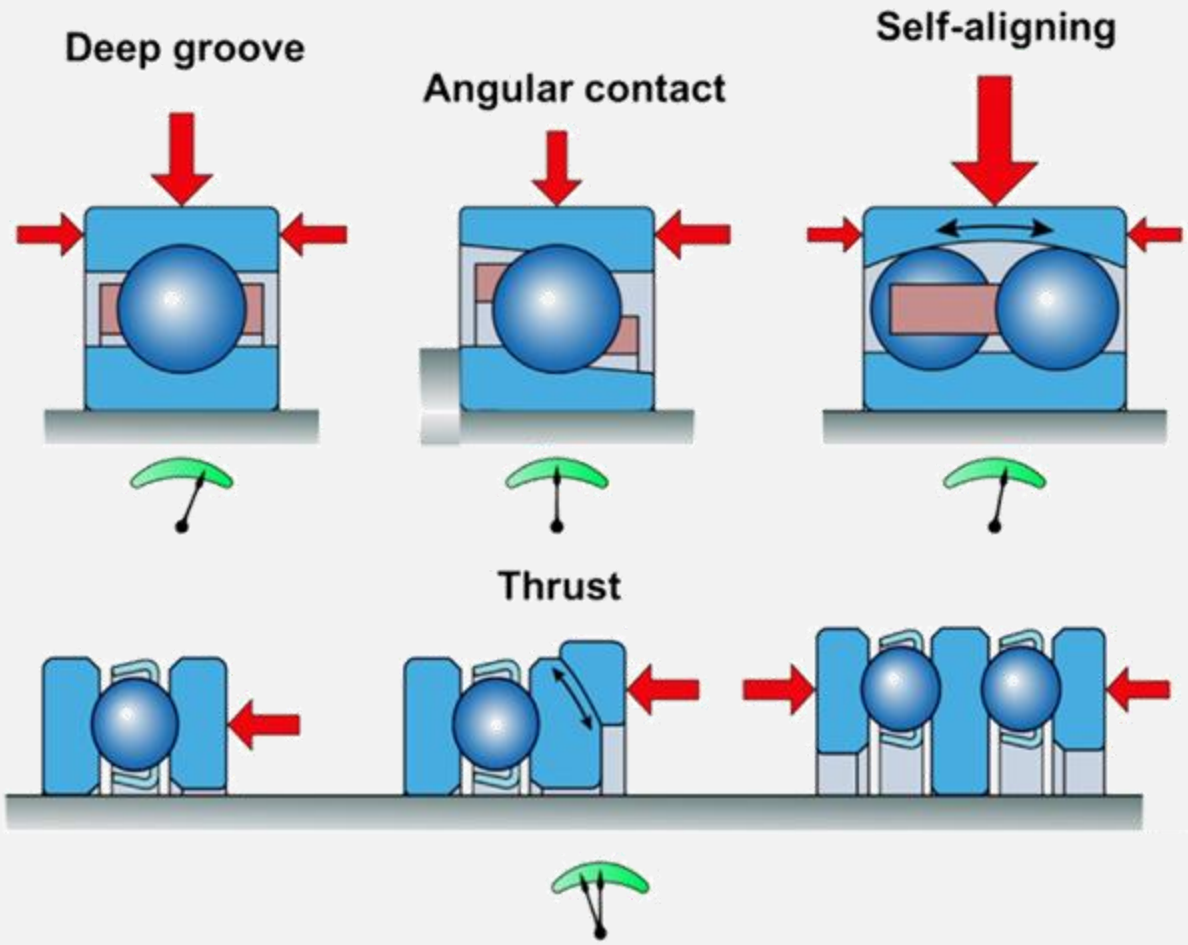
BALL (RADIAL)

BALL (THRUST)

ROLLER (RADIAL)

ROLLER (THRUST)

Bearing Loading



Special Variants (Part 1)

Spherical Roller Thrust Bearing

Advantage:

- Help with misalignment

Disadvantage:

- Expensive to produce

Tapered Roller Bearing

Advantage:

- Cheaper to produce than spherical bearings

Disadvantage:

- Do not facilitate misalignment

Generals uses:

- Moderate speed applications
- Heavy duty
- Combination loads
- Often used in pairs
- Common use on vehicle wheels

Special Variants (Part 2)

Needle Radial Bearing

Applications:

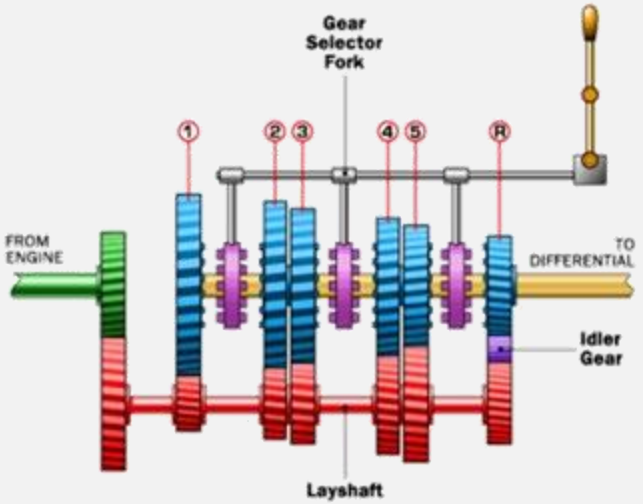
- Planetary gears
- Universal joints
- Constant mesh gears

Advantages:

- Low profile
- Lightweight
- Higher load capacity
- Relative Low cost

Disadvantages:

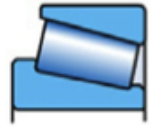
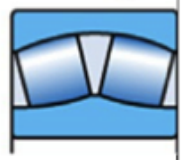
- Cannot be guided accurately
- High friction
- Low speed



For more information on bearings see the following link:

https://www.ntnglobal.com/en/products/catalog/pdf/2203E_a01.pdf

Comparison between the types of rolling bearings

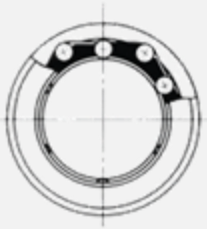
Bearing Type / Characteristics	Deep groove ball bearings	Angular contact ball bearings	Cylindrical roller Bearings	Needle roller Bearings	Tapered roller bearings	Self-aligning roller Bearings	Thrust ball Bearings
							
Load carrying capacity Radial load Axial load	↑ ←	↑ ←	↑ ← (3)	↑	↑ ←	↑ ←	←
High speed rotation (1)	☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆☆	☆☆☆	☆☆	☆
Low noise/ vibration (1)	☆☆☆☆	☆☆☆	☆	☆			☆
Low friction torque (1)	☆☆☆☆	☆☆☆	☆				
High rigidity (1)			☆☆	☆☆	☆☆	☆☆☆	
Allowable misalignment for inner/outer rings (1)	☆					☆☆☆	★
Non-separable or separable (2)			○	○	○		○

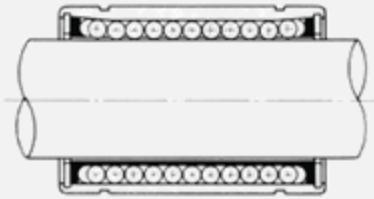
(1) ☆ The number of starts includes the degree to which that bearing type displyes that particular Characteristics
★ Not applicable to that bearing type
(2) ○ Includes both inner ring and outer ring are detachable
(3) Some clyndrical rollar bearings with rib can bear an axial load

Where sliding and rolling meet: The Linear roller bearing

Advantages:

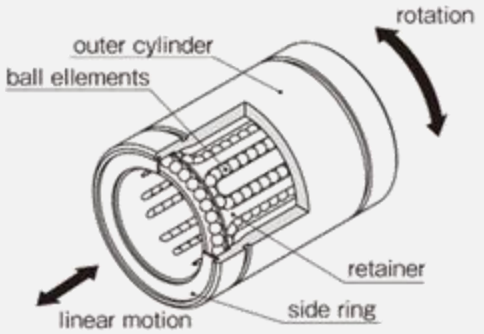
- Reduces the risk of ‘Stick-Slip’ (increased static friction due to angular forces), since static and kinetic friction are virtually the same



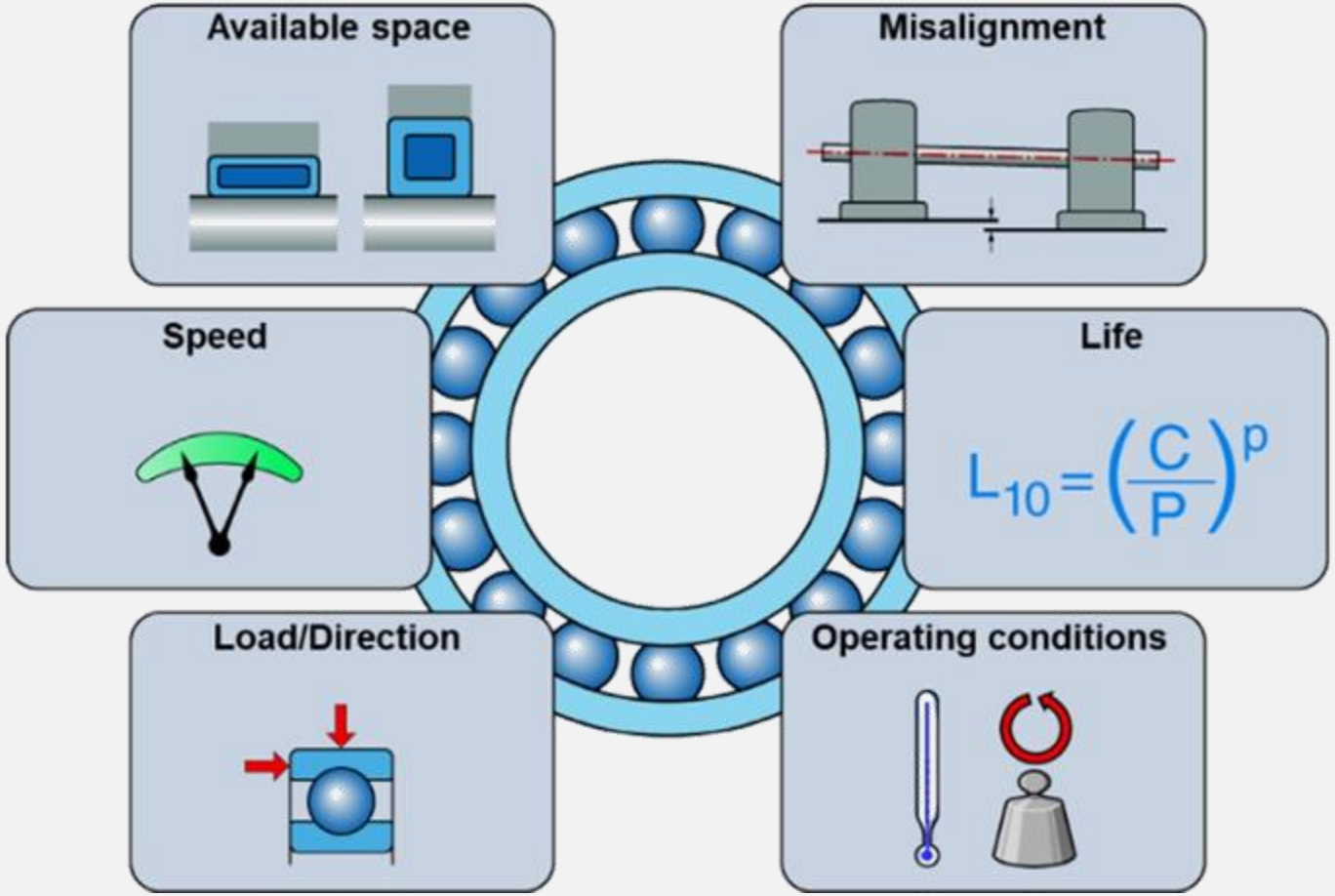


Disadvantages:

- Expensive to produce
- Larger profile
- Can cause shaft damage through wear



Bearing selection



Quick note on mounting free bearings

PILLOW BLOCKS
(with rolling bearings installed)
(used to support sliding and rolling bearings)

SPLIT PILLOW BLOCK

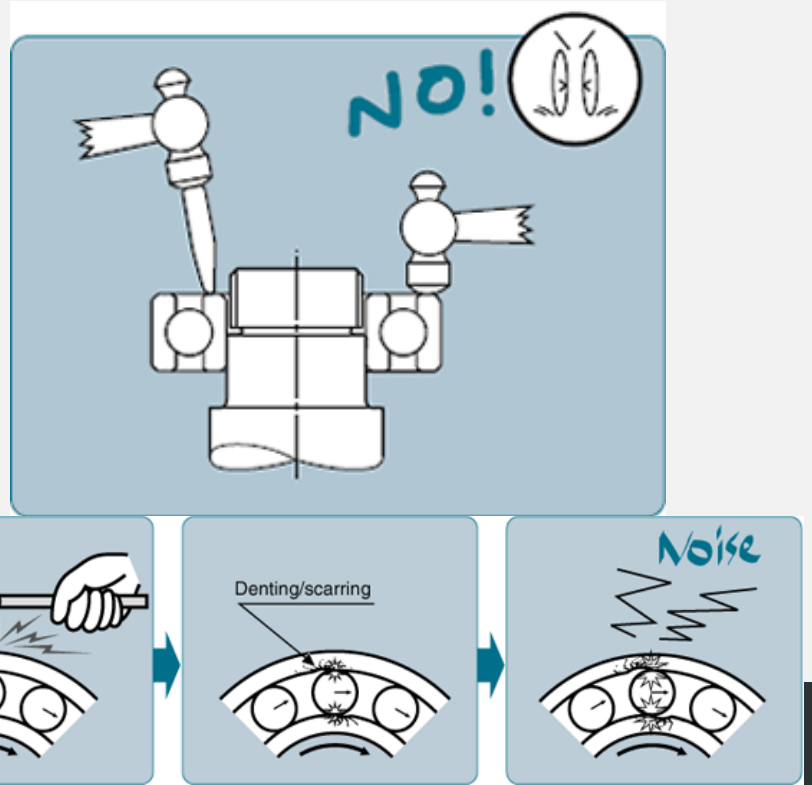
What are the advantages and disadvantages of this block relative to the normal pillow block?

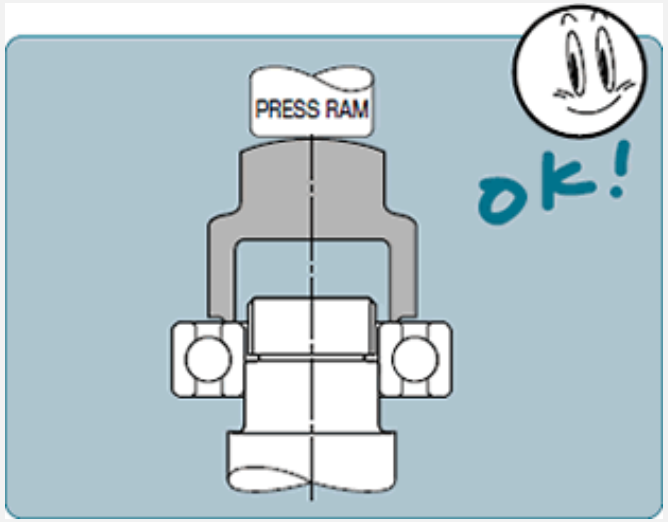
Advantage:
- Easy to remove the shaft

Disadvantage:
- More expensive to make
- Larger than standard block

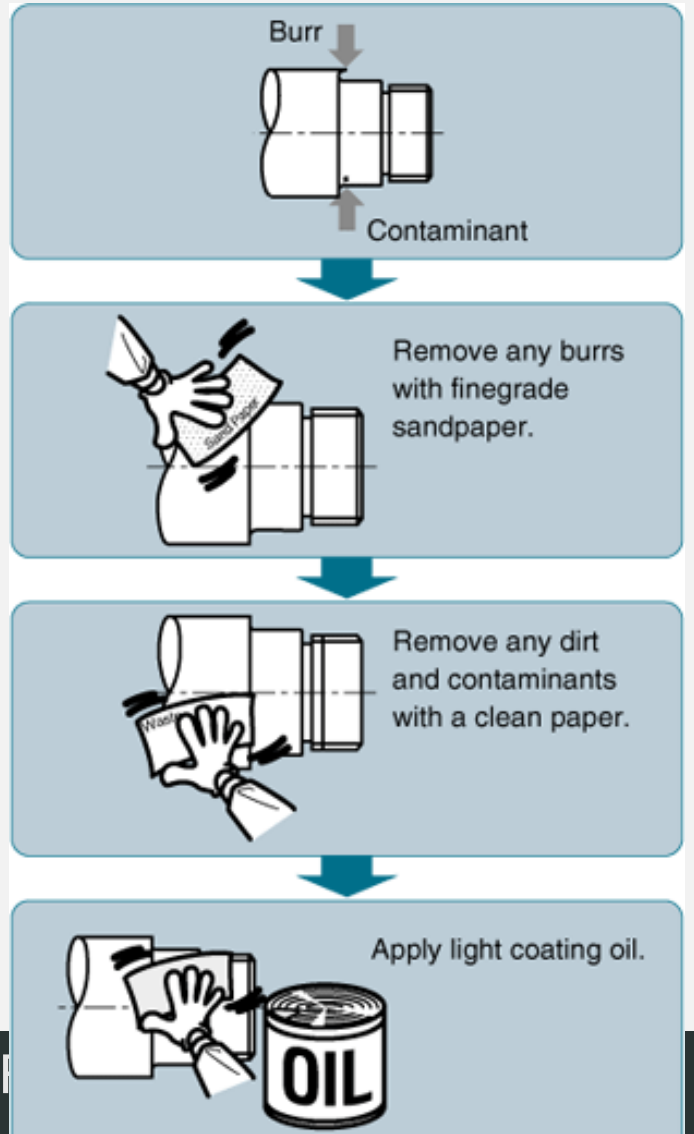
Mounting a bearing

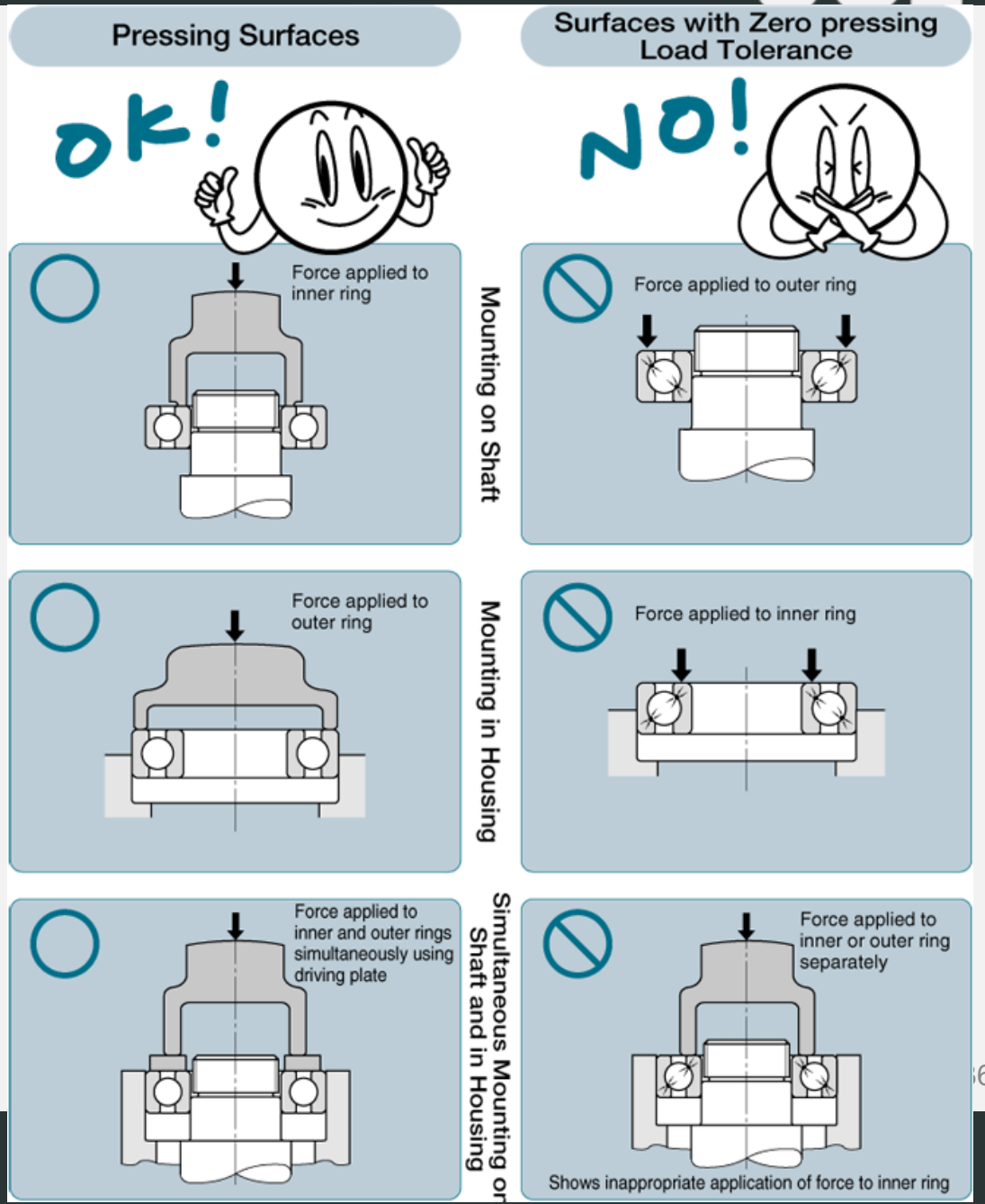
Mounting bearings using a hammer causes damage due to sharp impacts. Please mount press fit bearings using a pressing arbour or other designed to provide a uniform face.





Preparation and mounting

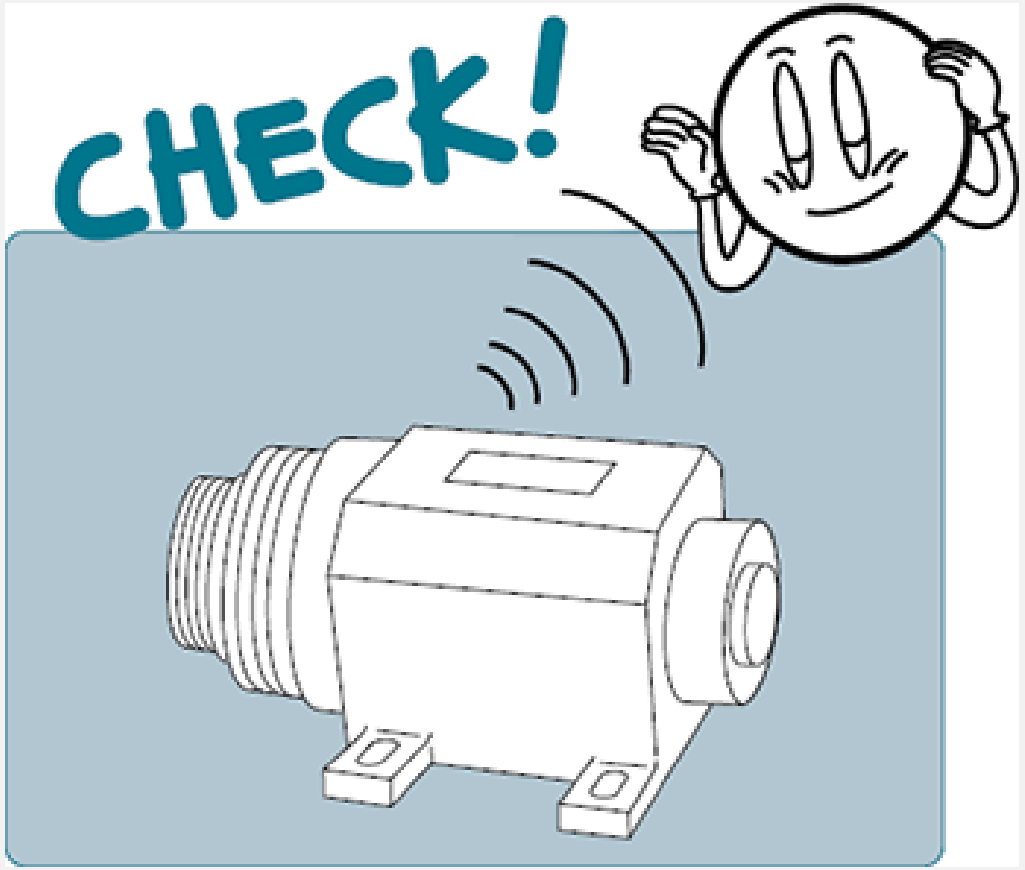


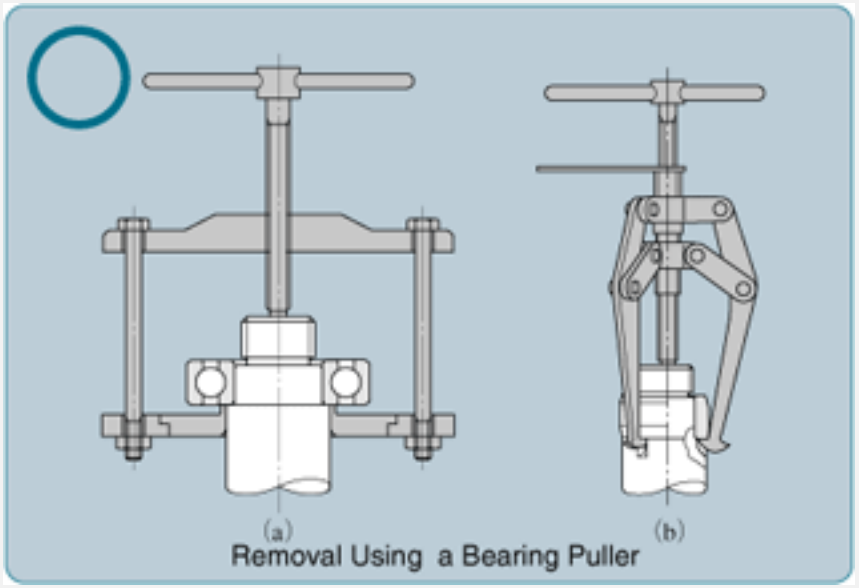


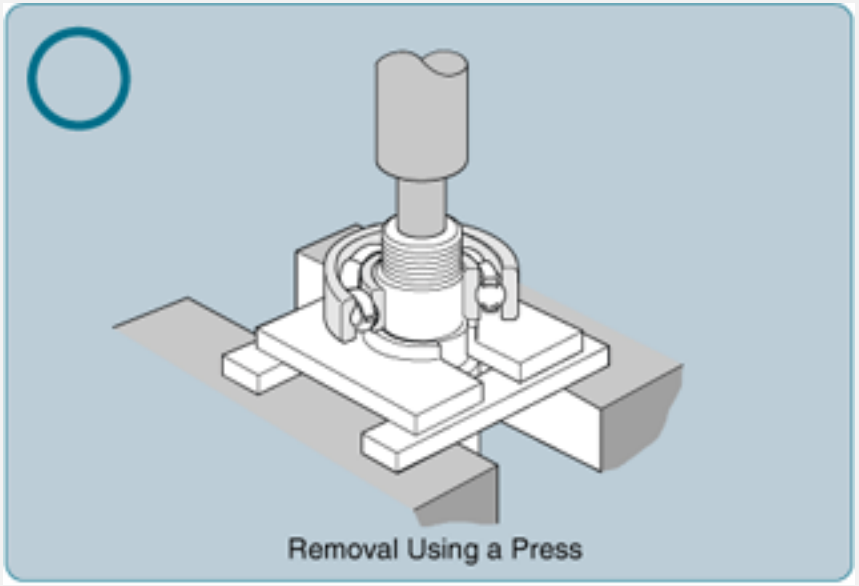
Recommended Fits

Operating conditions	Load condition	Example application	Recommended fits
Rotating inner ring Stationary outer ring Constant load direction	Rotating load on inner ring Stationary load on outer ring	Belt drives	Interference fit for the inner ring Loose fit for the outer ring
Stationary inner ring Rotating outer ring Constant load direction	Stationary load on inner ring Rotating load on outer ring	Conveyer idlers Wheel hub bearings	Loose fit for the inner ring Interference fit for the outer ring
Rotating inner ring Stationary outer ring Load rotates with the inner ring	Stationary load on inner ring Rotating load on outer ring	Vibrating applications Motors	Interference fit for the outer ring Loose fit for the inner ring
Stationary inner ring Rotating outer ring Load rotates with the outer ring	Rotating load on inner ring Stationary load on outer ring	Gyratory crusher Merry-go-round	Interference fit for the inner ring Loose fit for the outer ring

After mounting and removal







Discussion

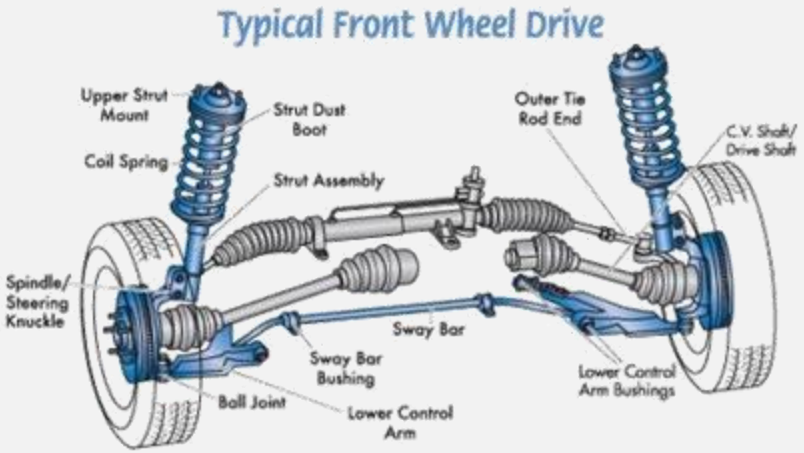
What type of bearings would you use in the following applications and why?

Hand router for wood

Dial indicator

Skateboard

3D printer



Front wheel drive