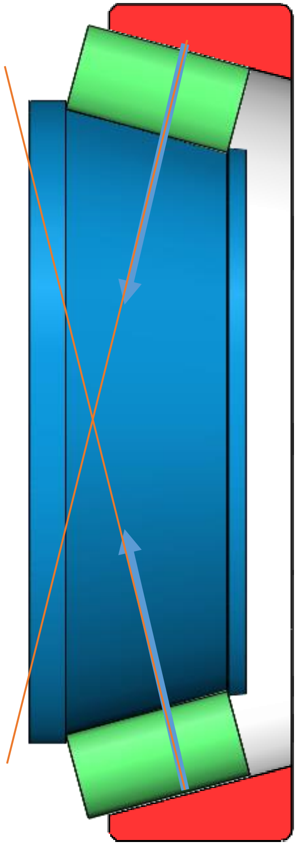
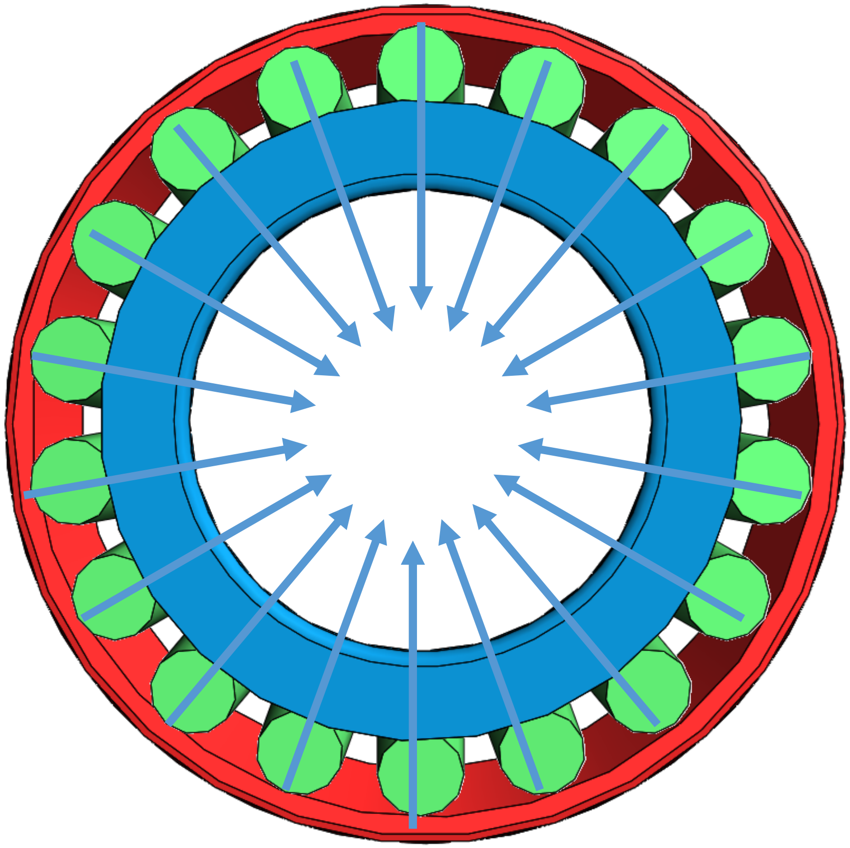
Design and size angular contact bearing arrangements

Angular contact bearings

General description

Architecture of angular contact bearings

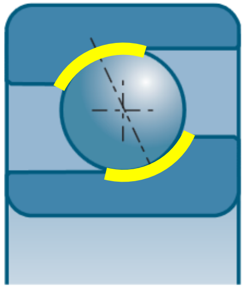


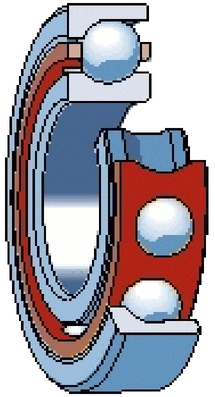


Load support on a cone, unilateral actions → axial load transmitted **in a single direction**, determined by mounting

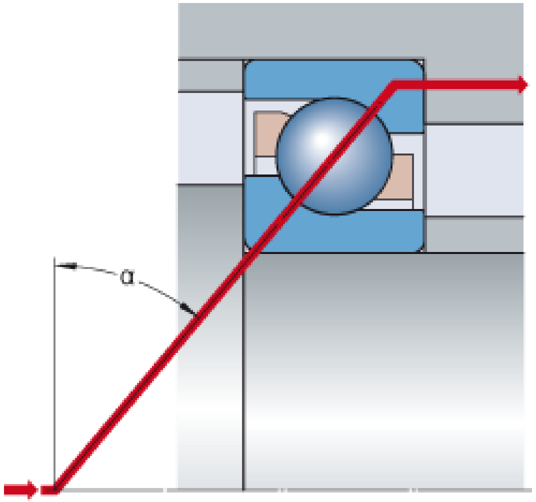
Angular contact bearings

raceways





Gap between the two raceways



Contact angle

Contact angle = angle between the load direction (between the 2 contact points) and the radial direction

- Typical bearing: α = 40 °
- Precision bearing: α = 15° ou 25°

- ✓ Support axial loads
- ✓ Axial load in a single direction
- ✓ Equivalent to a unilateral spherical joint

Angular contact ball bearings

Characteristics

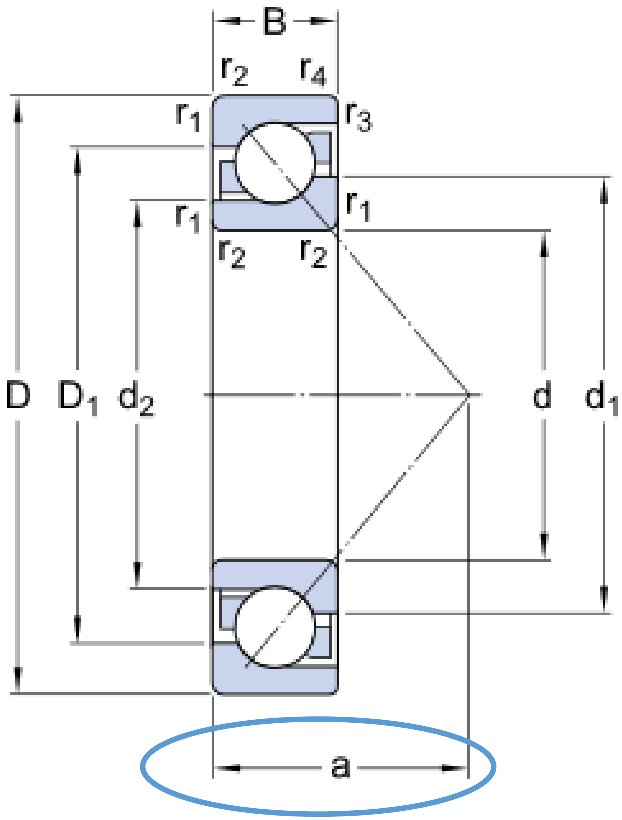
Mounted by pairs in opposition

Rings cannot be separated

Large number of balls → large load capacity

Axial load increases with loading angle

Permissible misalignement: 1 to 2’



Applications

Vertical axis electrical engines
Car front wheels …

Tappered roller bearings

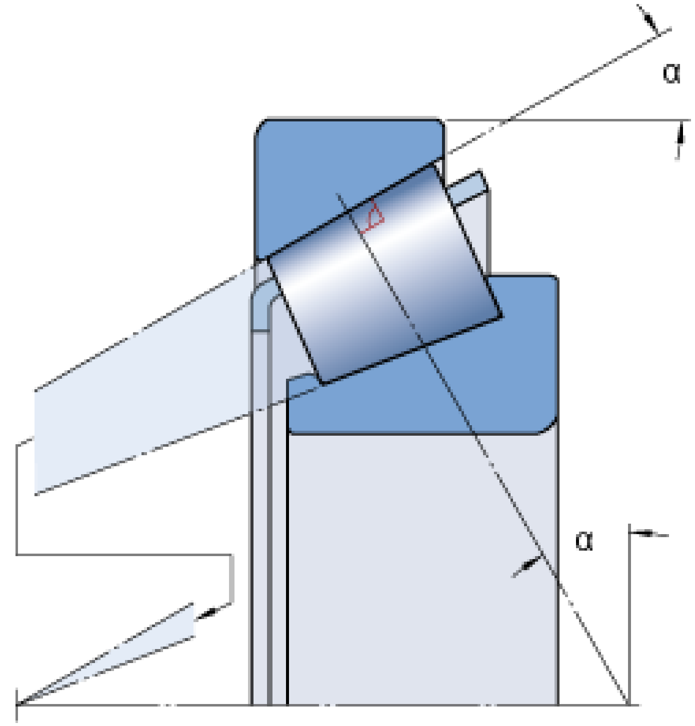
Description

Rollers and raceways are cone portions

Rollers and raceways are slightly rounded

All cones have the same apex to ensure rolling and limit sliding

Linear contact



- ✓ Designed for combined loads
- ✓ Axial force transmission on a single direction
- ✓ Equivalent to a unilateral spherical joint

Roulement à rouleaux coniques

Characteristics

Mounted by pairs in opposition

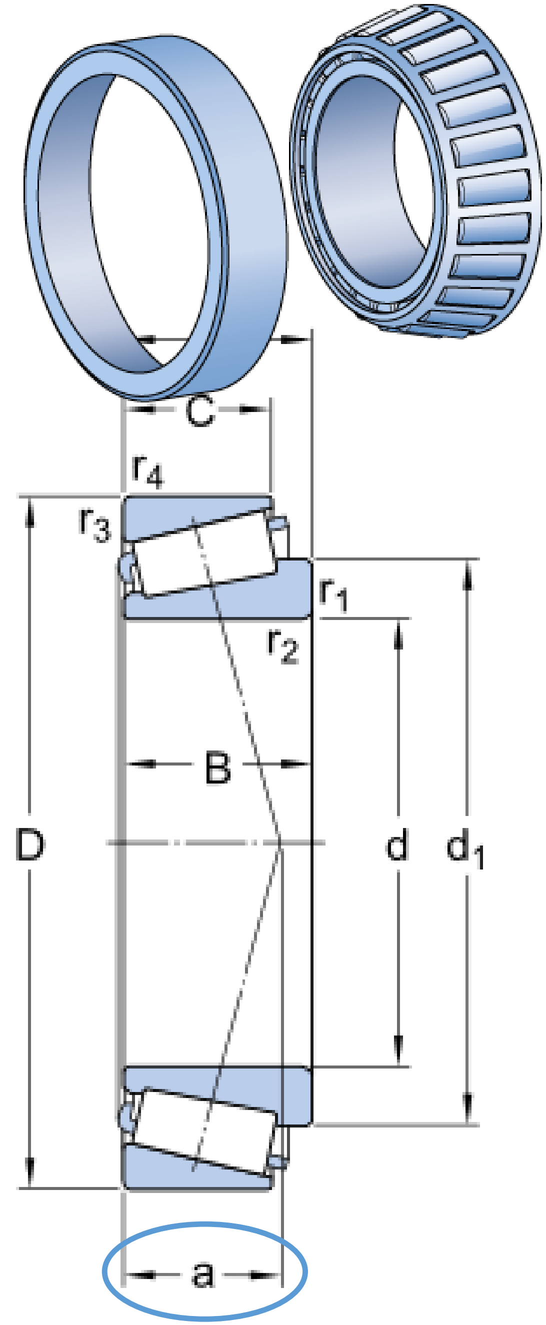
Rings can be separated

Linear contact→ large load capacity

Load capacity increases with loading angle

Permissible misalignement: 1 to 4'

Shaft and housing must be really coaxial

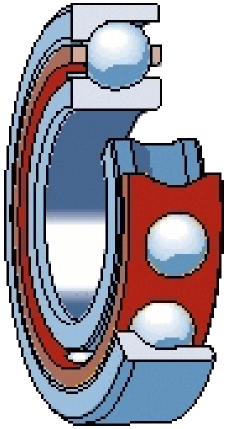


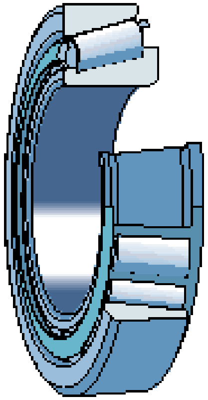
Applications

Car back wheels

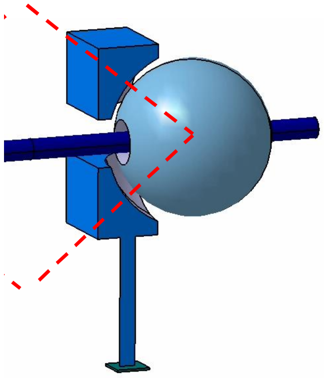
Reducers …

Mounting





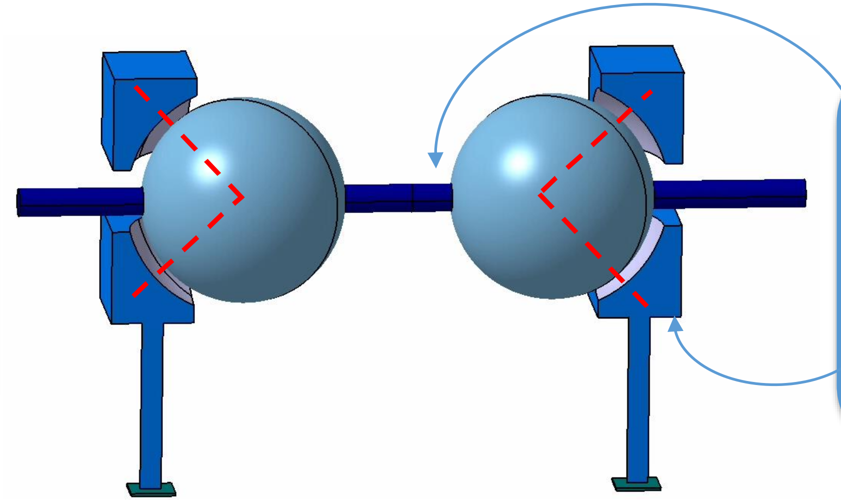
1 complete rotation + 2 limited rotations (permissible misalignement) + axial locating in a single direction



« Half » spherical joint

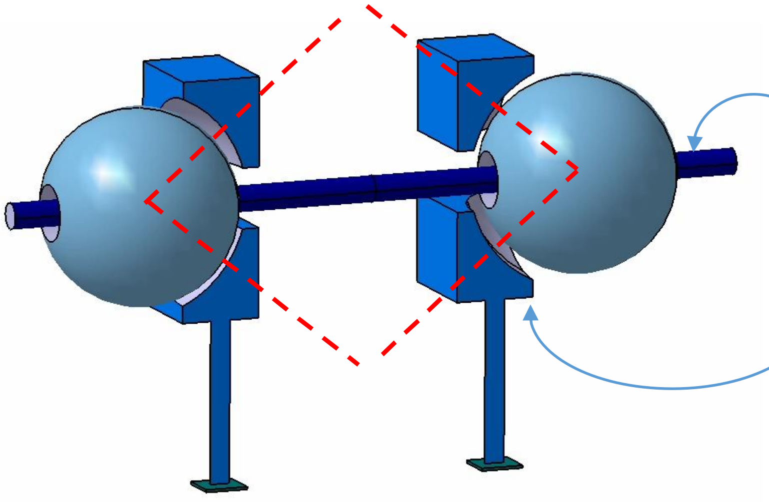
Revolute joint

X mounting = face-to-face mounting
Load centers are closer
Shaft is more rigid



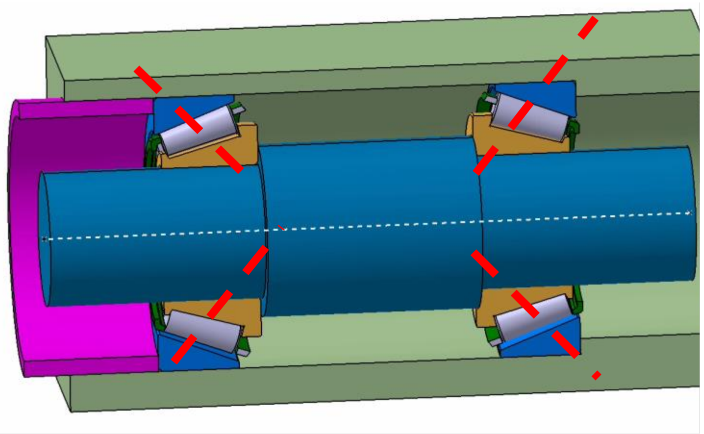
Locating:
- Inside on the shaft
- Outside in the housing

O mounting = back-to-back:
Load centers are distant
Assembly is more robust to external radial forces



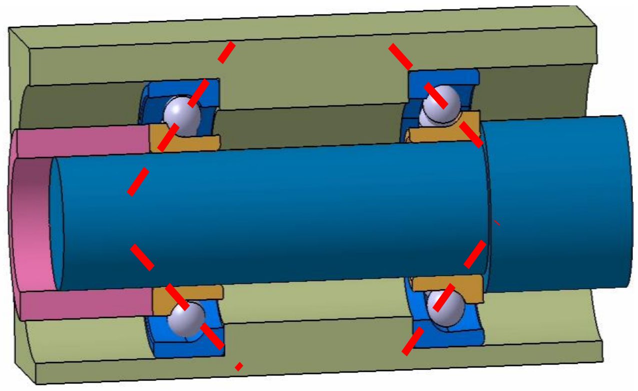
Locating
- Outside on the shaft
- Inside in the housing

Consequences on mounting



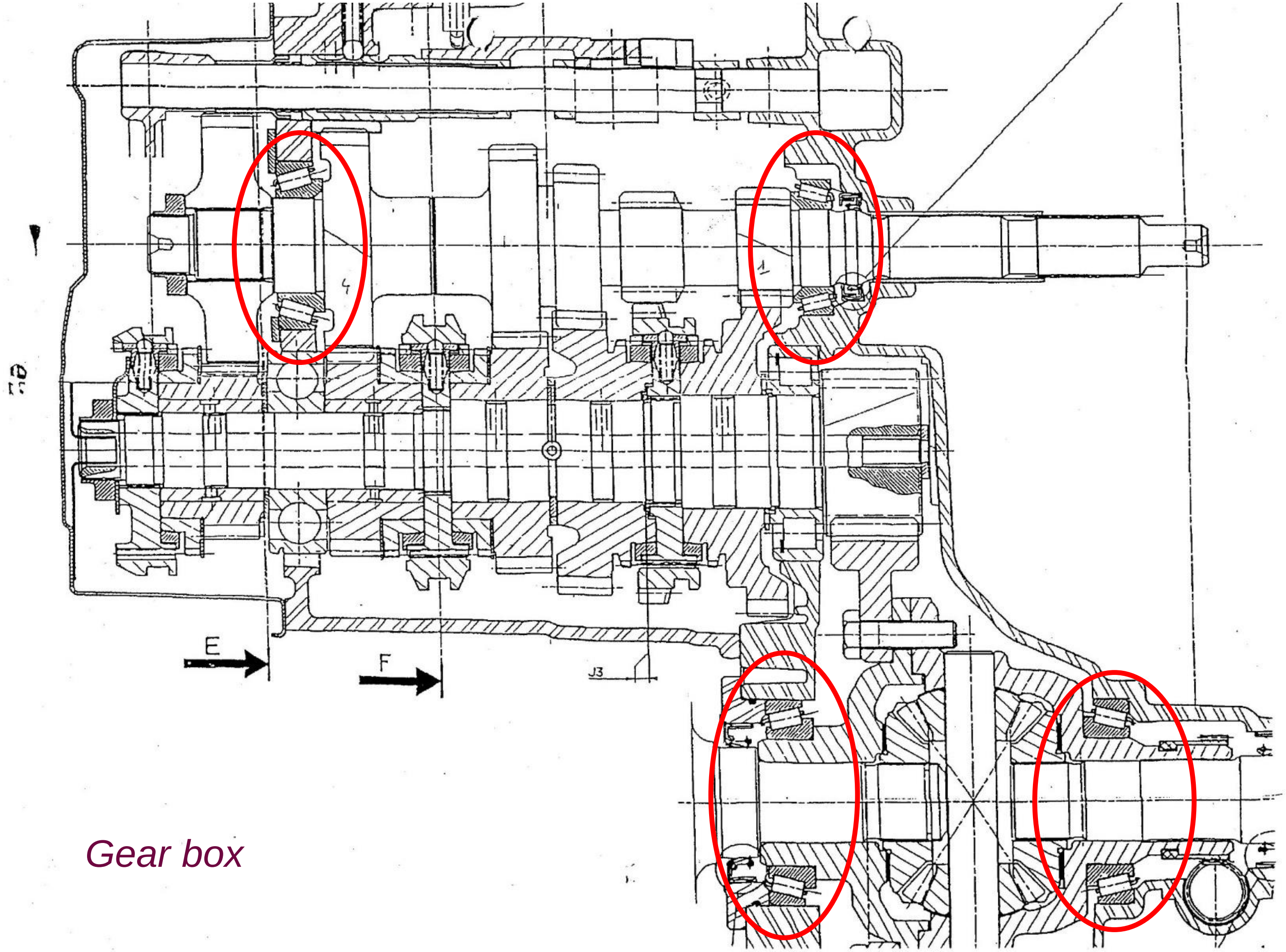
- Internal (inside) locating preferably by a shoulder
- Rings with interference fits preferably mounted on shoulders

⇩



- X mounting (face to face) better when shafts rotates with respect to the load direction
- O mounting (back to back) better when housing rotates with respect to the load direction

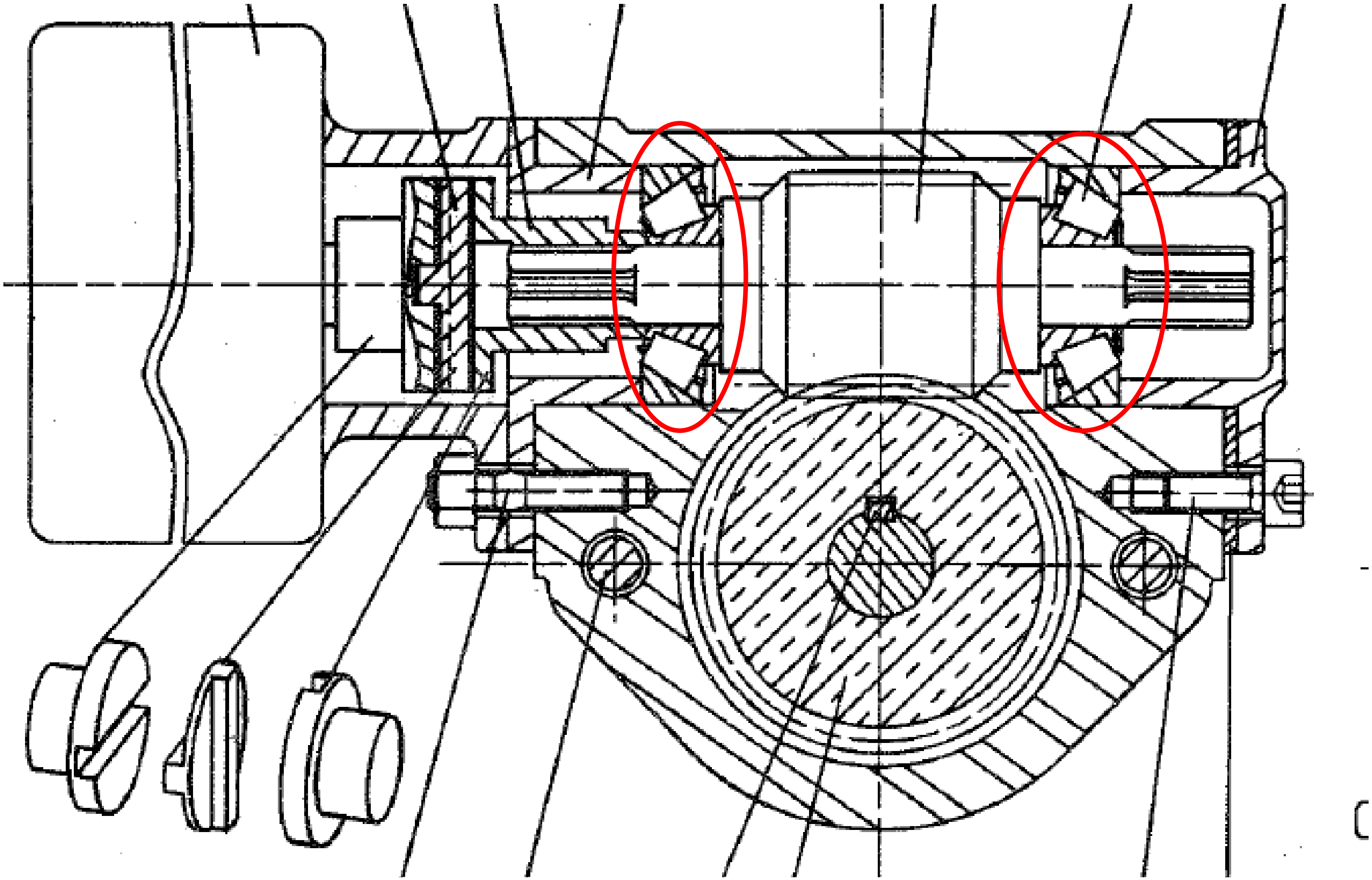
Examples



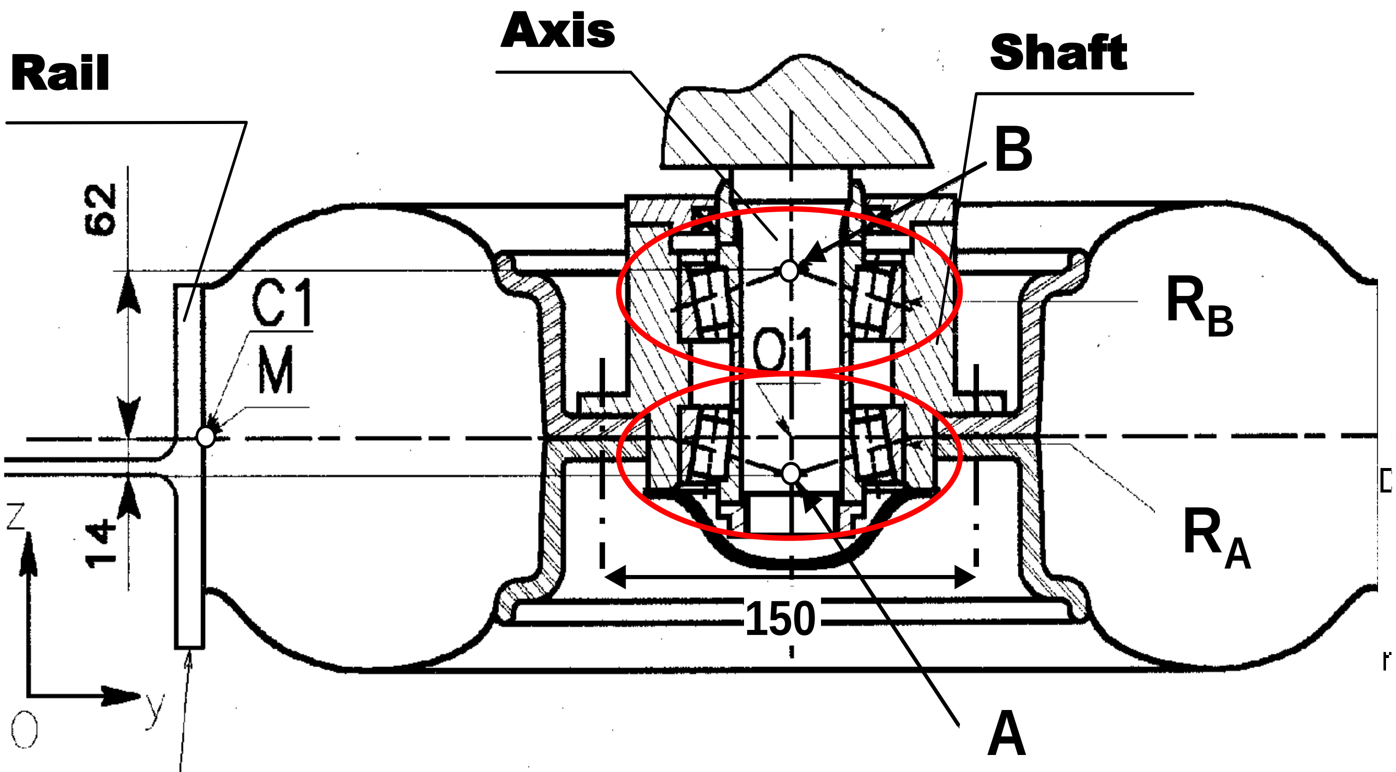
Gear box

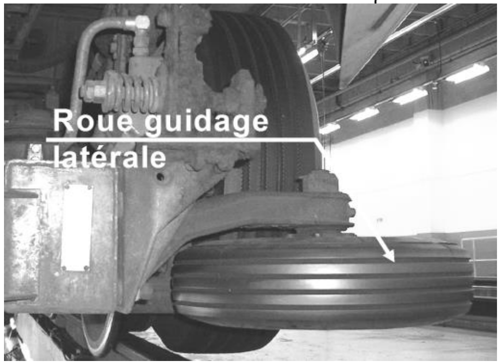
Examples

Electrical linear actuator



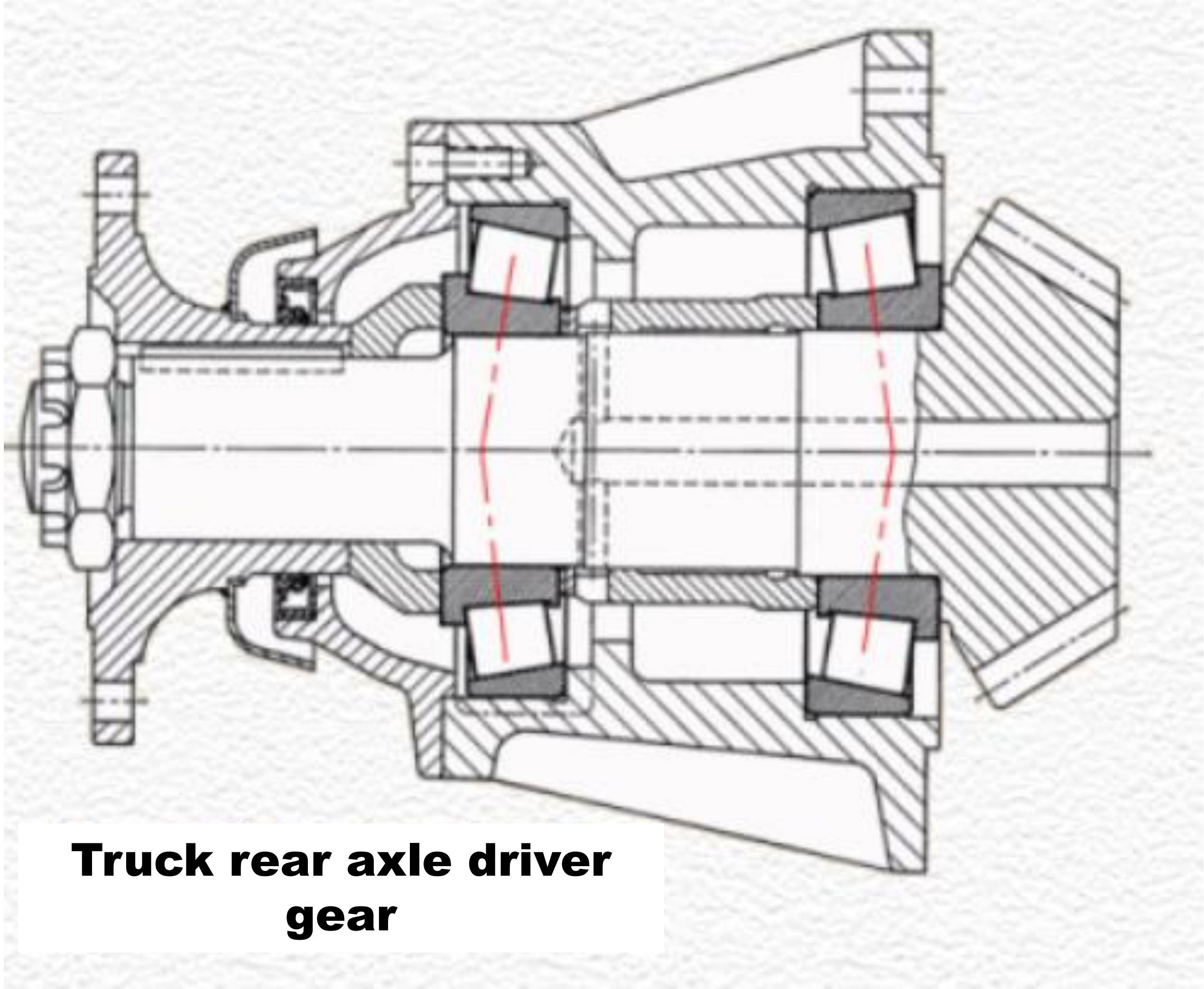
Examples





Guiding wheel for the subway

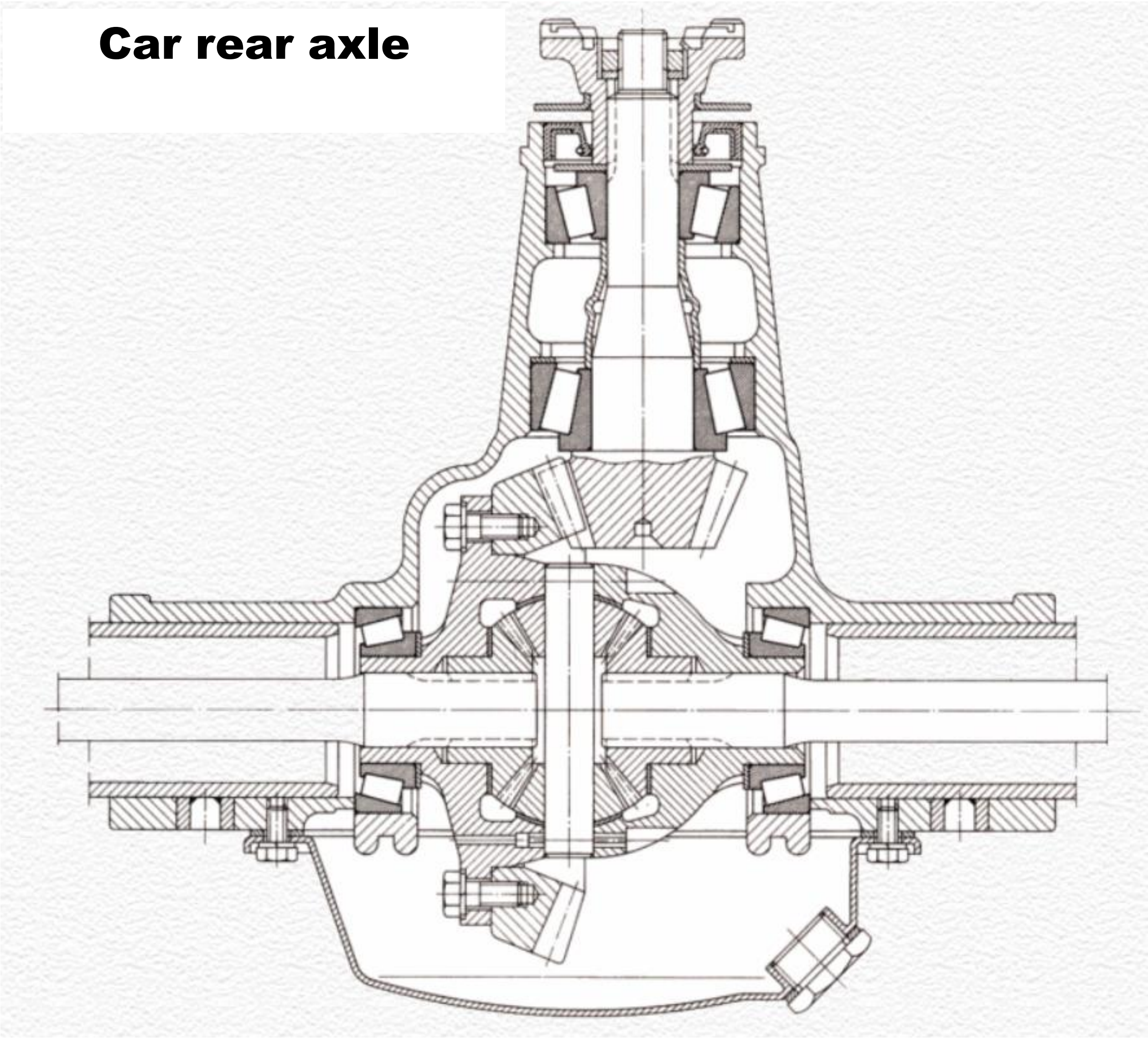
Examples



Truck rear axle driver gear

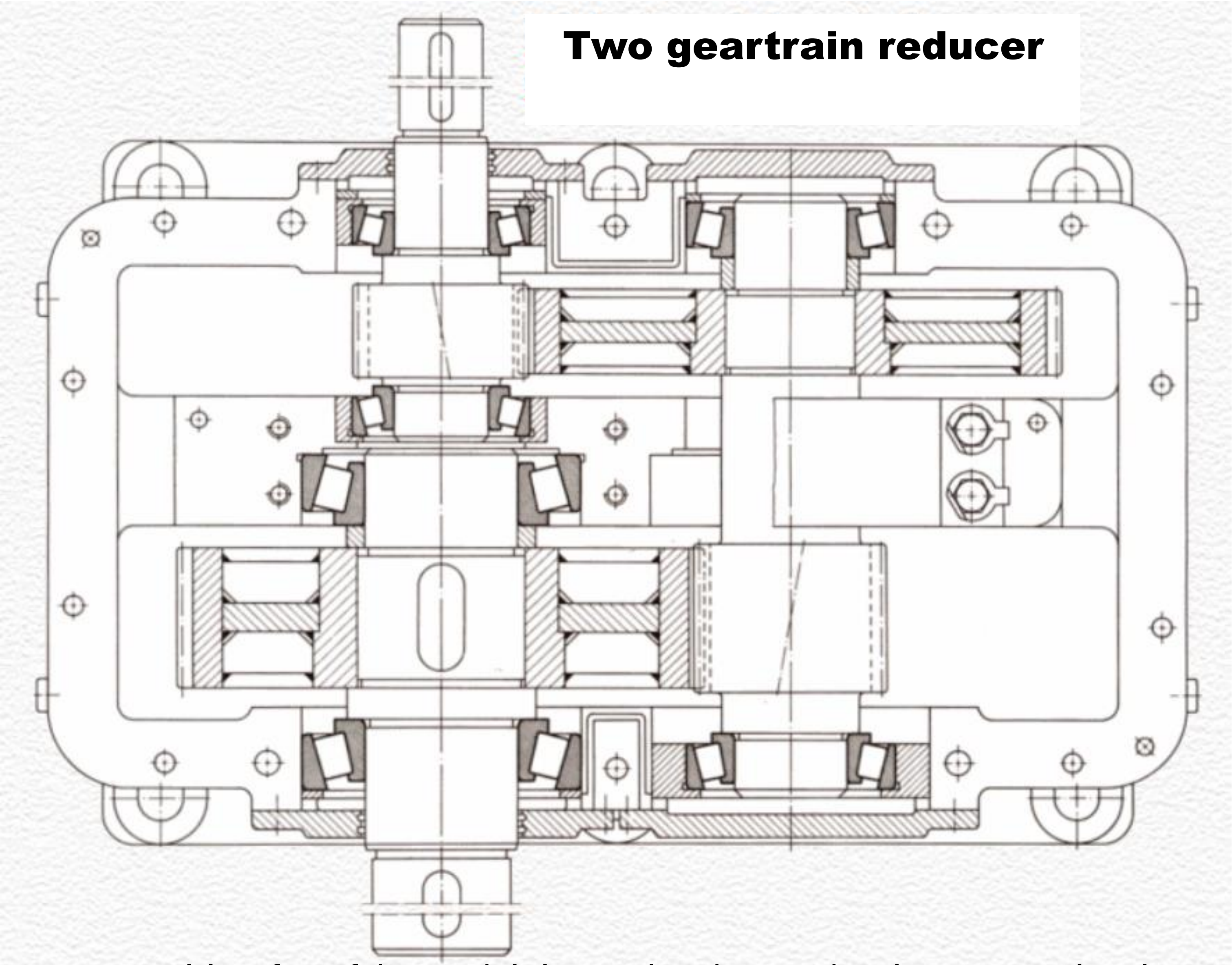
http://barreau.matthieu.free.fr/cours/Liaison-pivot/pages/roulements-2.html

Examples



http://barreau.matthieu.free.fr/cours/Liaison-pivot/pages/roulements-2.html

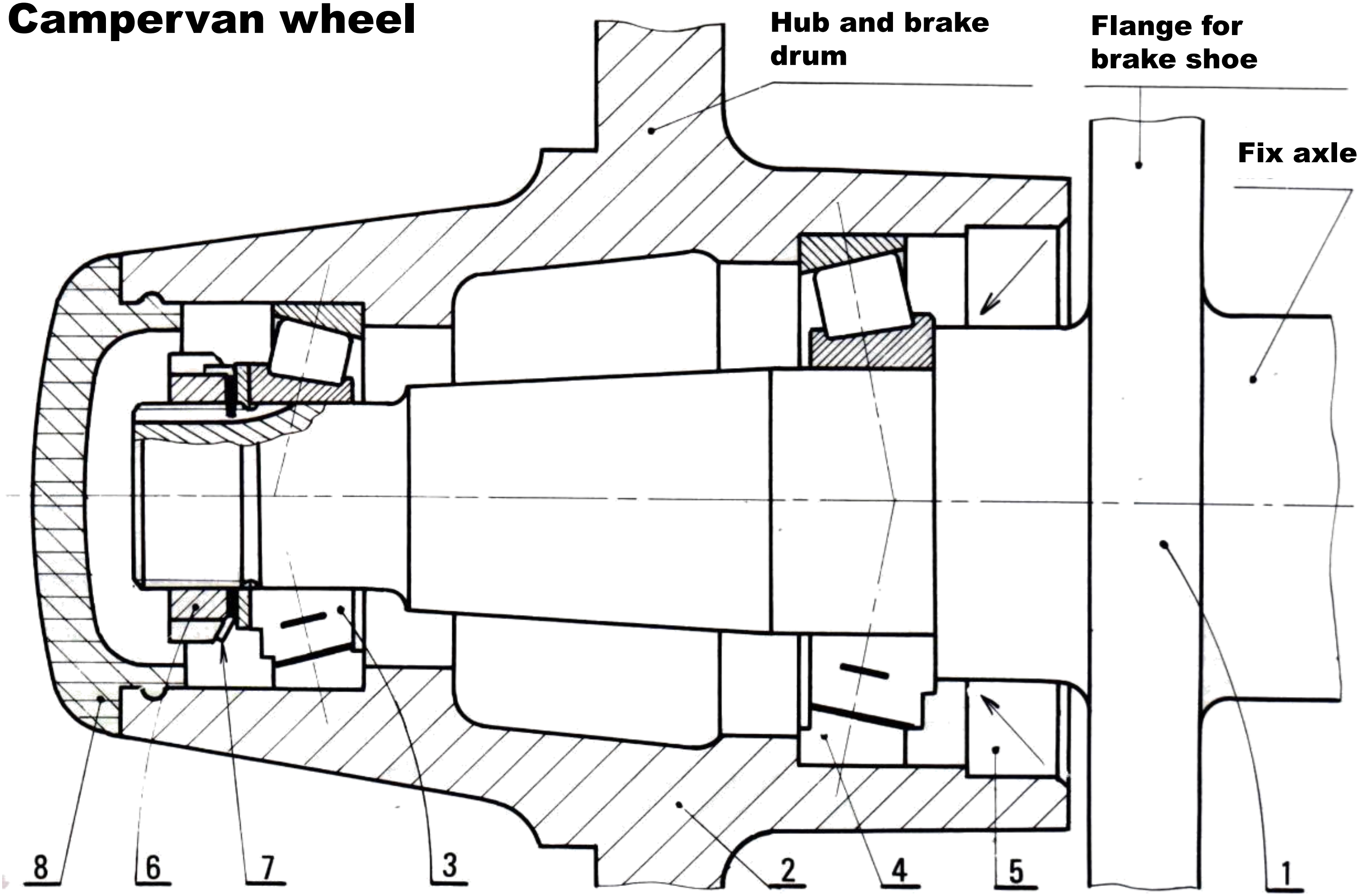
Examples



http://barreau.matthieu.free.fr/cours/Liaison-pivot/pages/roulements-2.html

Examples

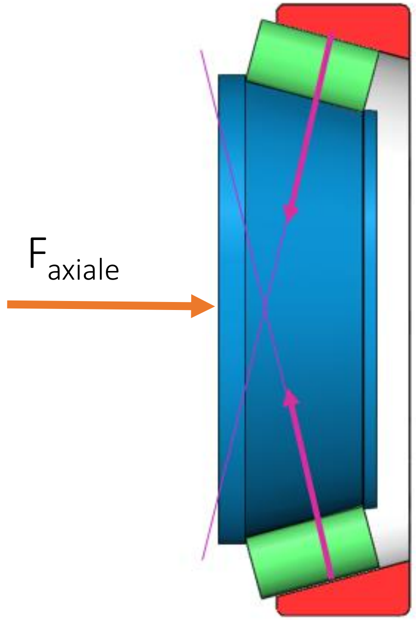
Campervan wheel

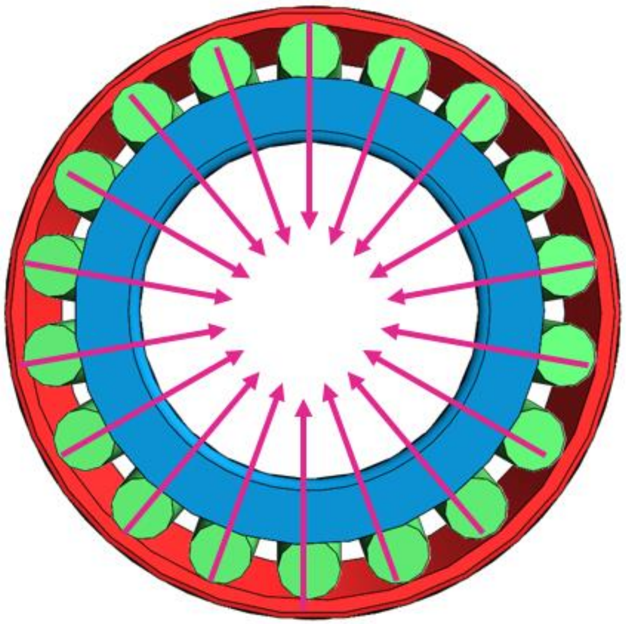


Loading angular contact bearings

Axial load

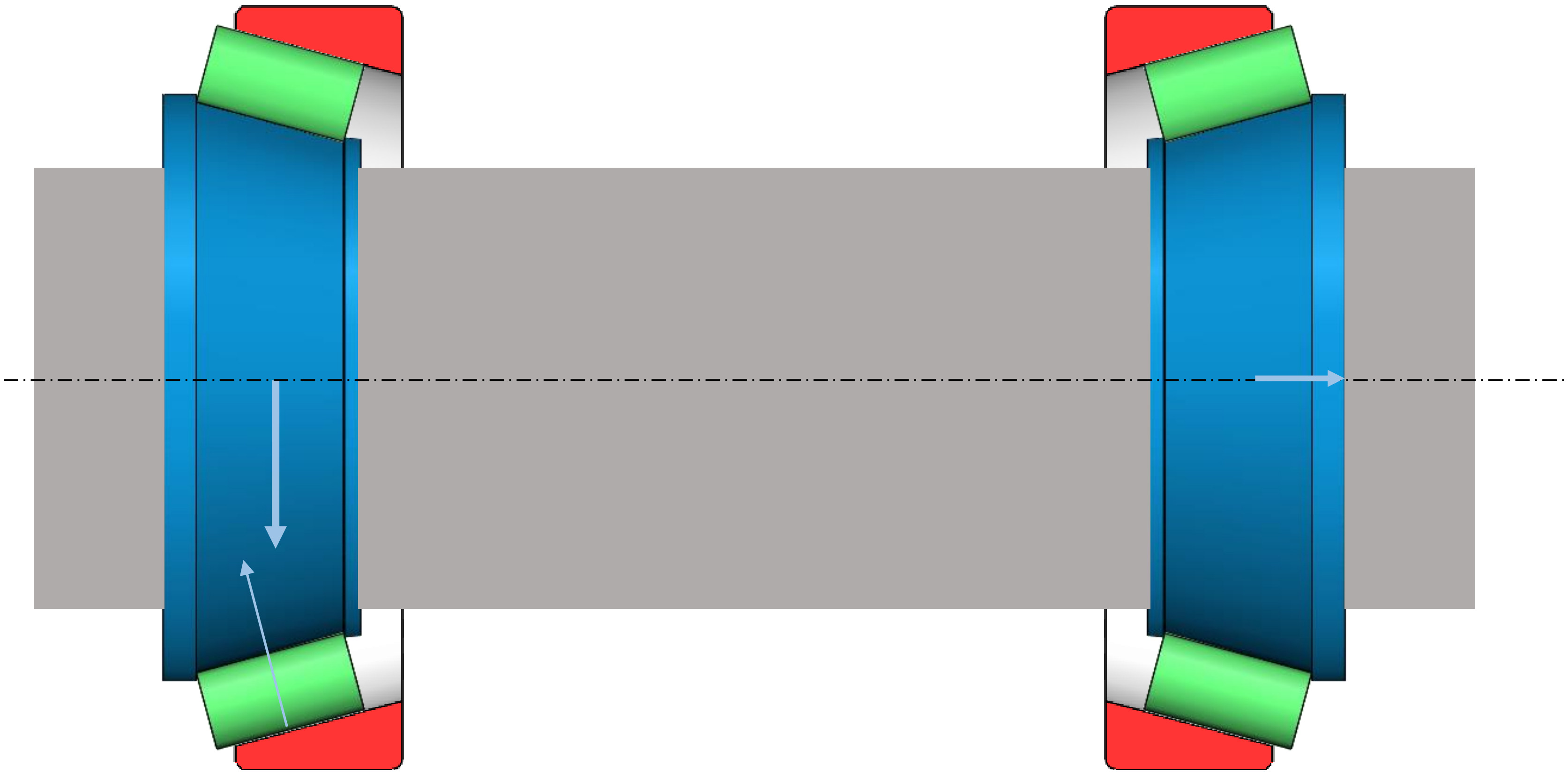
Contact loads on a cone





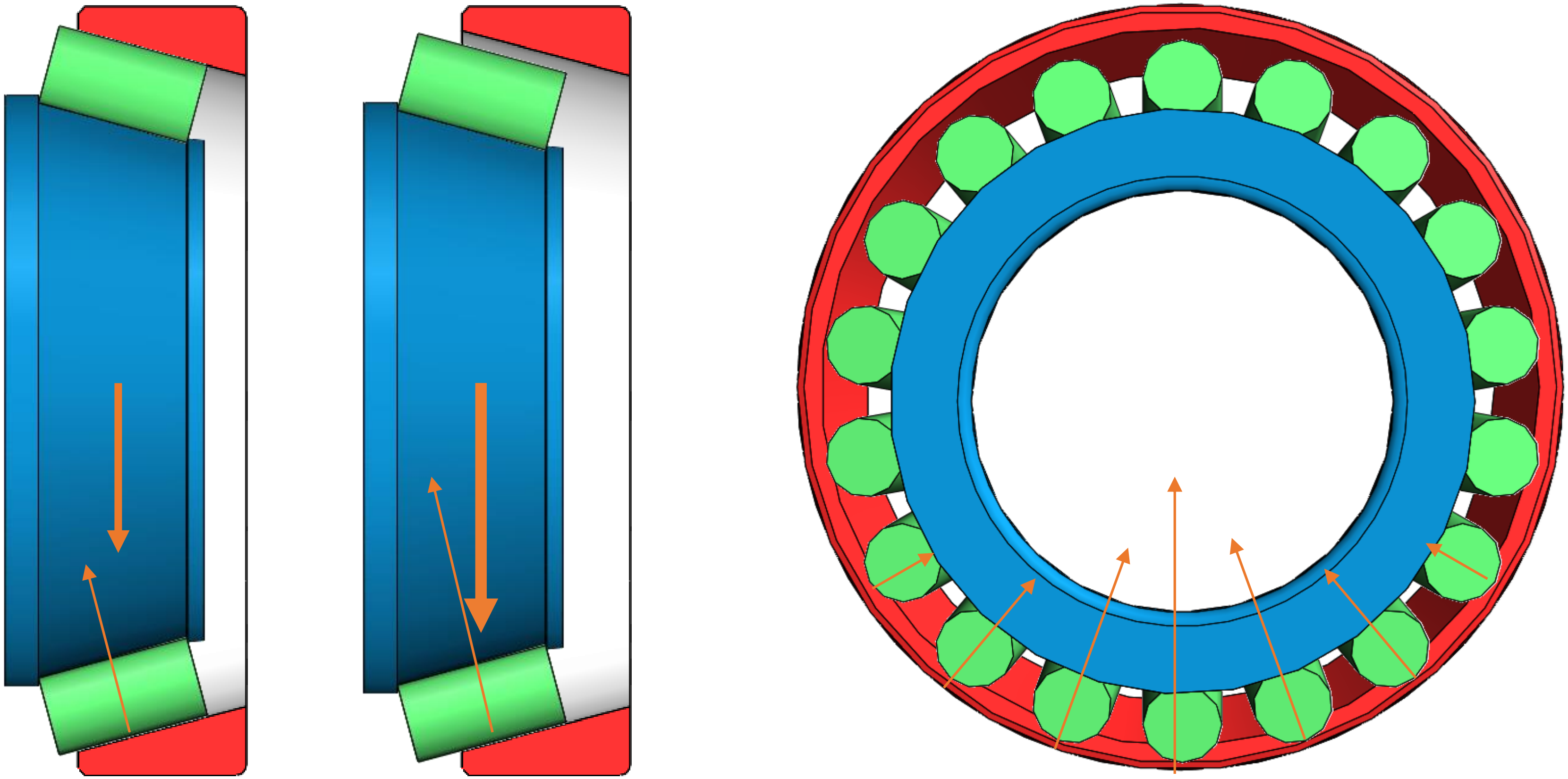
Axial load equally distributed on all rolling elements
Inner ring comes closer to the outer ring

Radial load



Radial load only supported by rolling elements placed along the loading direction
Axial equilibrium requires the presence of the second bearing mounted in the opposite direction.

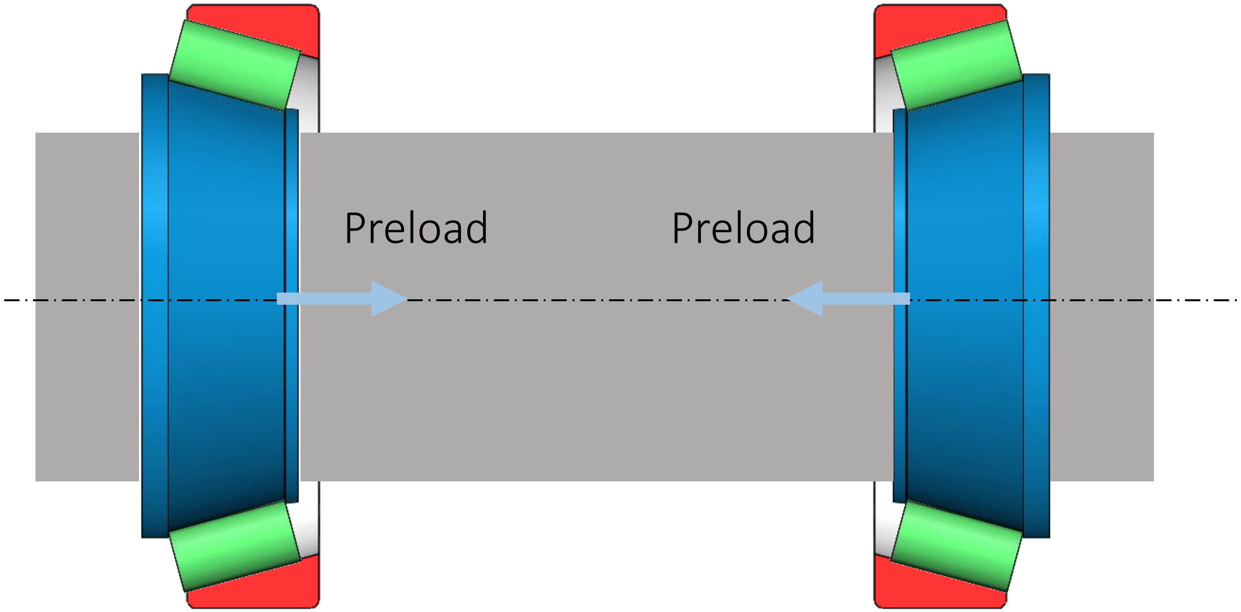
Radial load



Radial load puts apart inner ring from outer ring → fewer and fewer rolling elements support the load→ higher and higher load on those rolling elements

Preload: condition for a good functionning

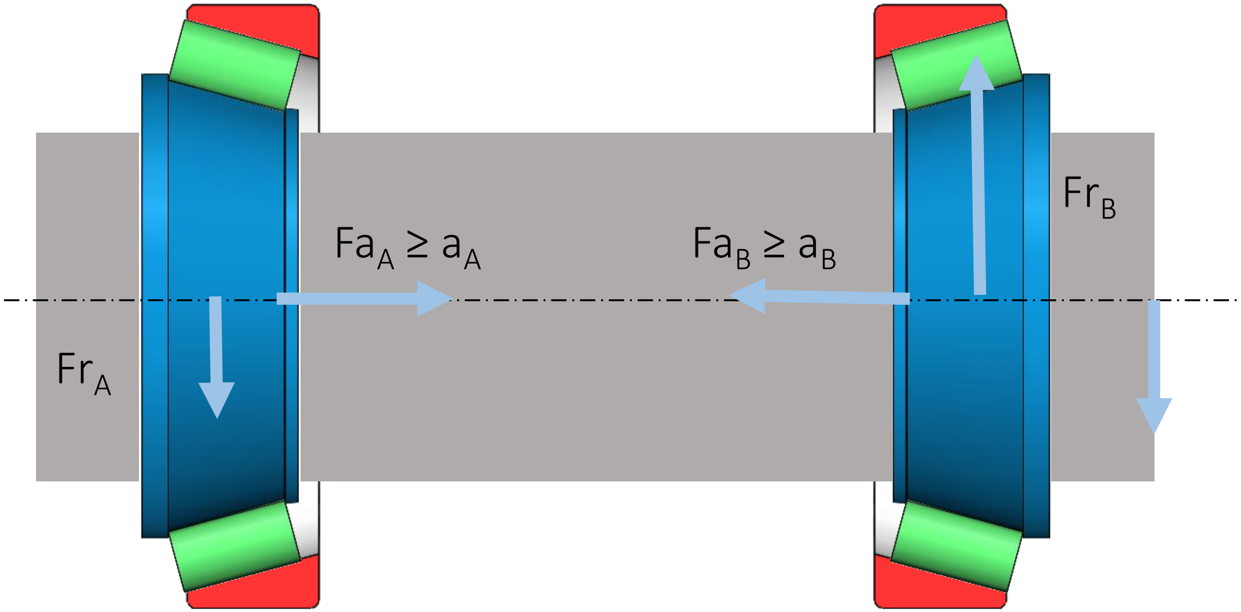
At least half of the rolling elements should support the load



Mounting condition: create an axial preload to bring inner and outer rings closer and increase the number of rolling elements to support the load.

Preload: condition for a good functionning

Preload must ensure that axial load on a bearing is higher than the induced axial load a_i due to external radial load and geometry

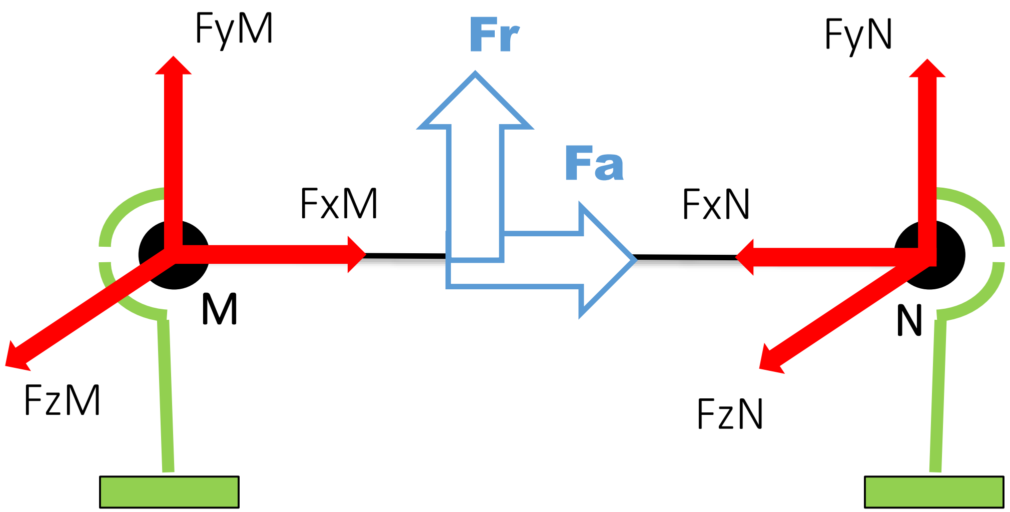


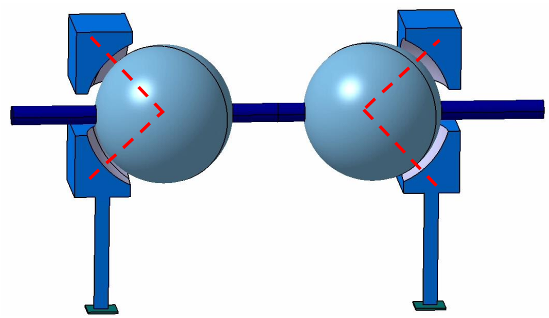
$$a_i = Fr/2Y_i$$

Induced axial load corresponds to the minimum load for half of the rolling elements to be loaded.

Sizing of angular contact bearings

Static equilibrium

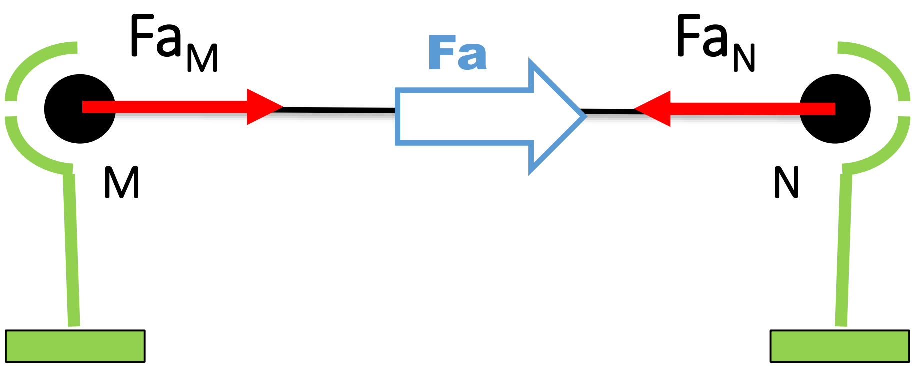




Static equilibrium of the shaft → determine radial loads in bearings (Fy and Fz) BUT NOT the axial loads (Fx)

AXIAL static equilibrium

For sizing, we **assume** that axial load is supported by one bearing and the other supports only the induced axial load.



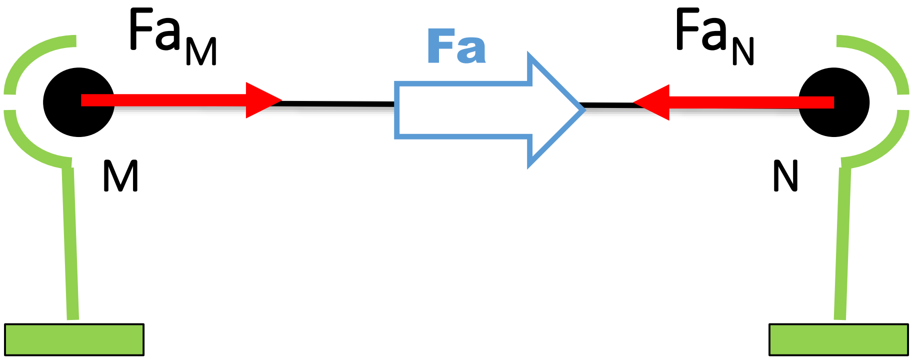
Axial equilibrium:

$$+Fa_M - Fa_N + Fa = 0 \text{ with}$$

$$Fa_M = a_M \text{ et } Fa_N \geq a_N \text{ OR } Fa_M \geq a_M \text{ et } Fa_N = a_N$$

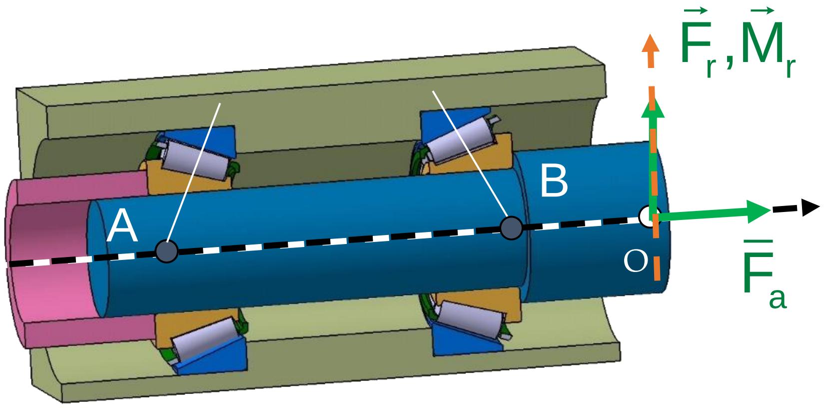
Équilibre statique AXIAL du montage

How to determine which bearing supports only its induced axial load ?



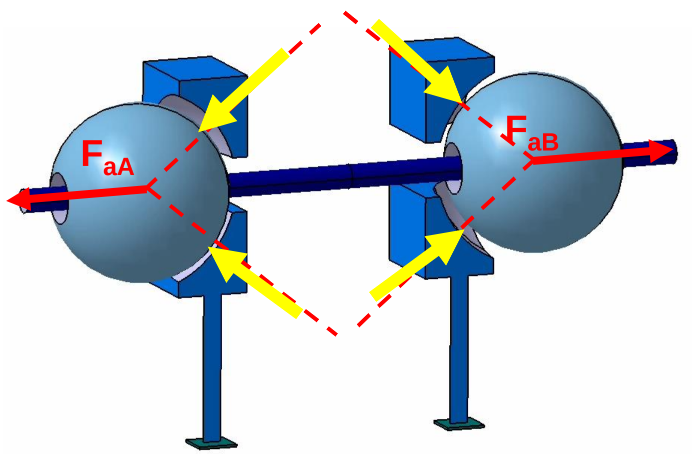
Calculation of axial loads

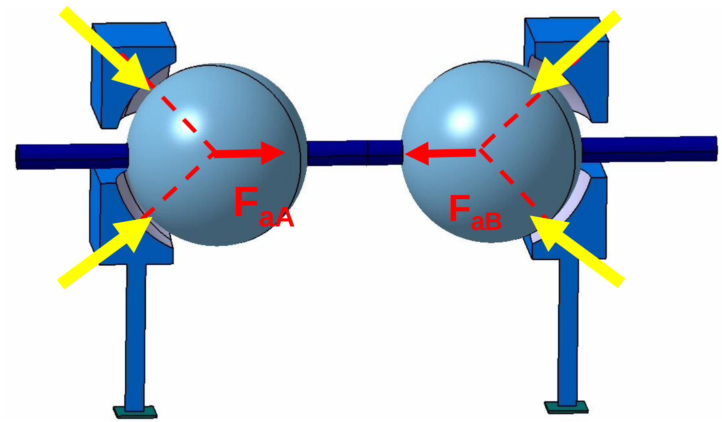
Assuming external loads are on the shaft



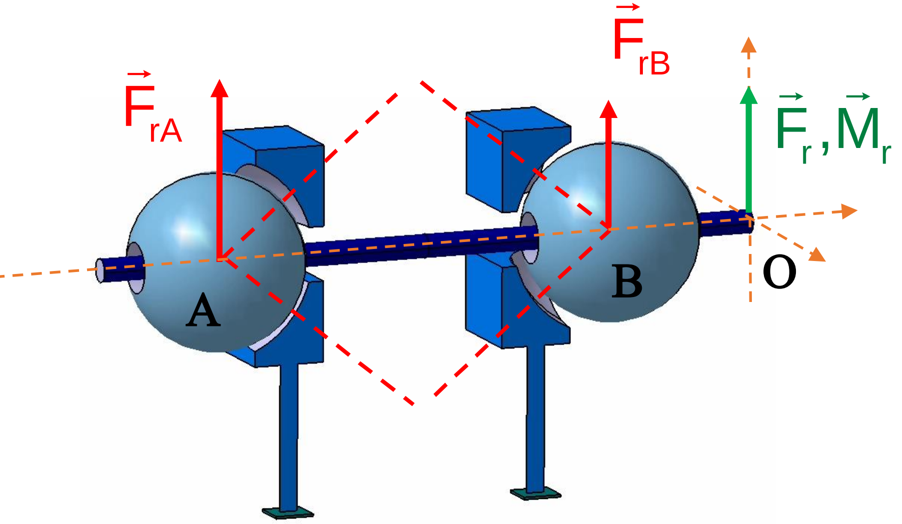
Identify external loads on the shaft
Locate the load centers A and B

Identify the direction of the load exerted by bearings on the shaft

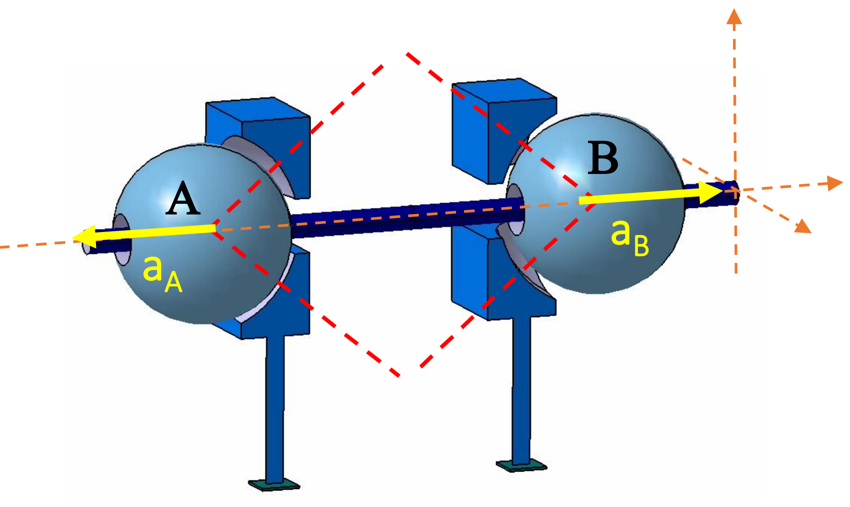




Calculation of axial loads



Loads in bearings are applied at the load center



Write the radial static equilibrium:

$$\vec{F}_r + \vec{F}_{rA} + \vec{F}_{rB} = \vec{0}$$

$$\vec{M}_r + \overrightarrow{AO} \wedge \vec{F}_r + \overrightarrow{AB} \wedge \vec{F}_{rB} = \vec{0}$$

Deduce the norm of radial loads in the bearings:

$$R_A = \left|\vec{F}_{rA}\right|$$

$$R_B = \left|\vec{F}_{rB}\right|$$

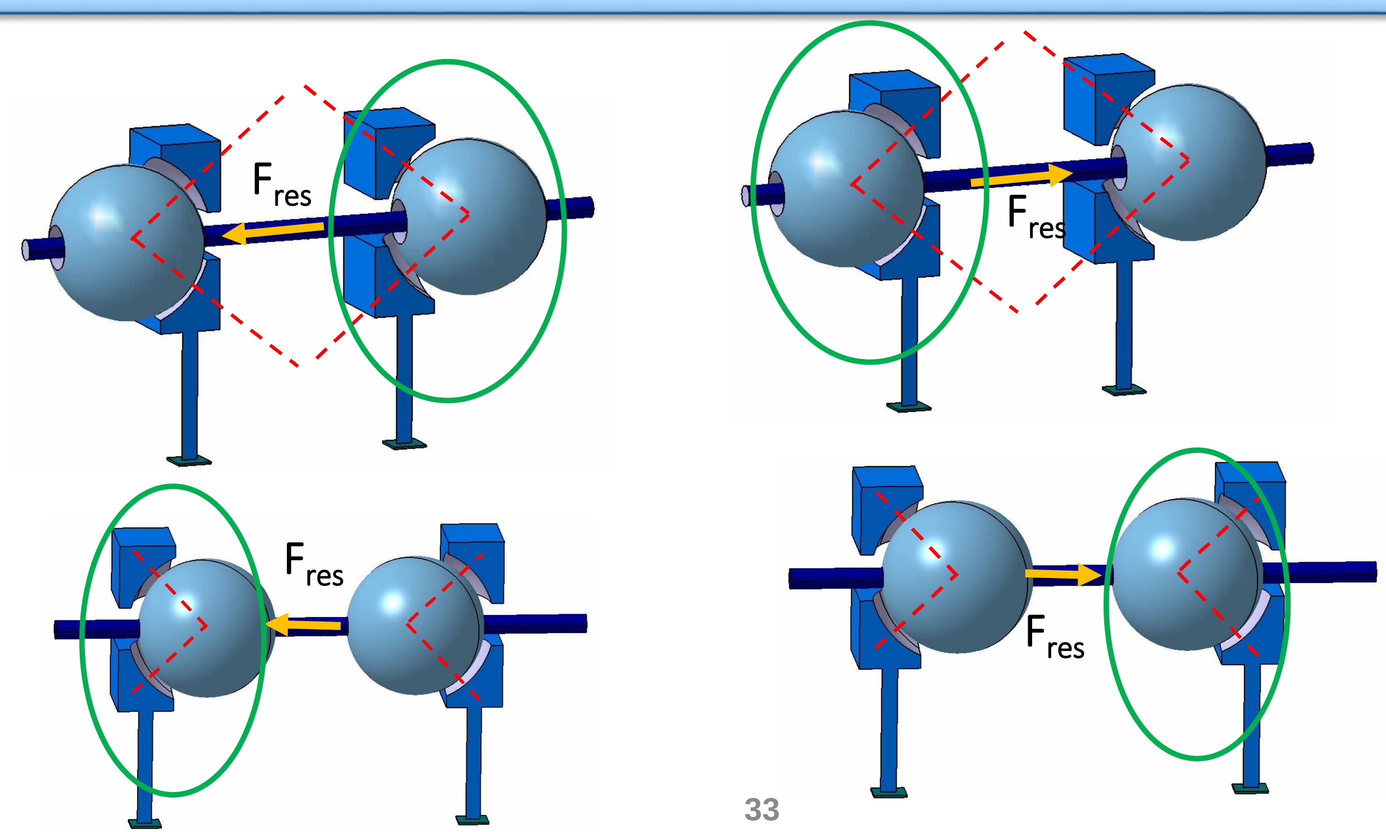
Calculate the norm of induced axial loads:

$$a_A = \frac{R_A}{2.Y_A} \qquad a_B = \frac{R_B}{2.Y_B}$$

Calculation of axial loads

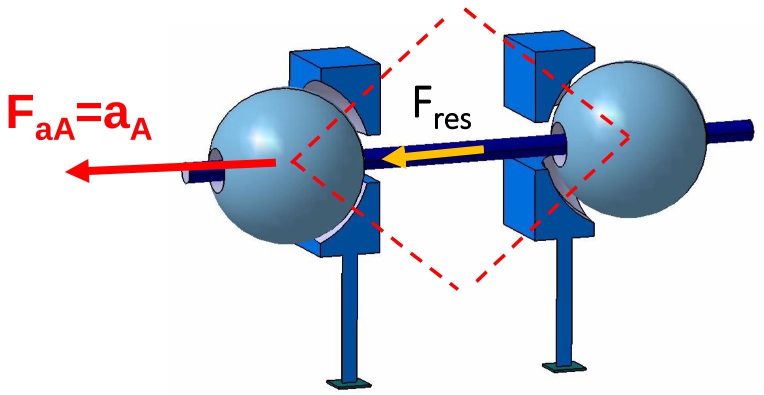
Determine the direction of the resultant axial load: $\overrightarrow{F_{res}} = \overrightarrow{F_a} + \overrightarrow{a_A} + \overrightarrow{a_B}$

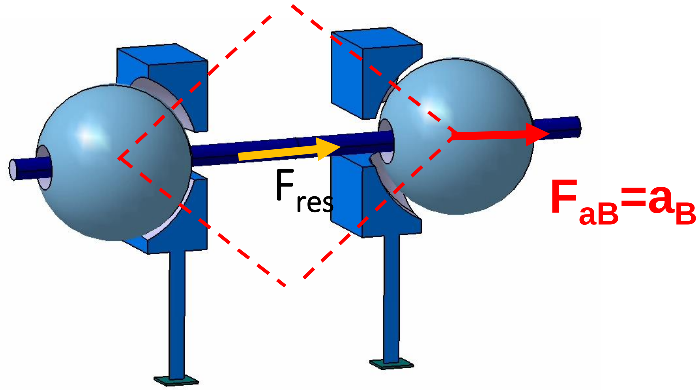
Determine the bearing that can support this load from the load direction

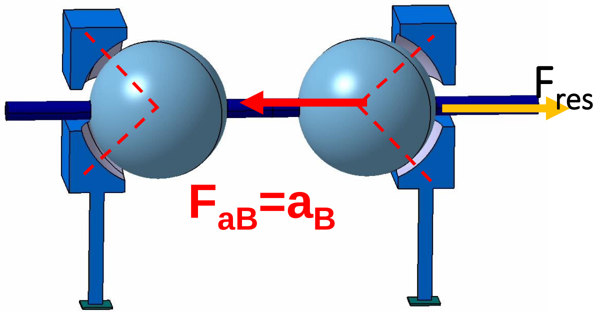


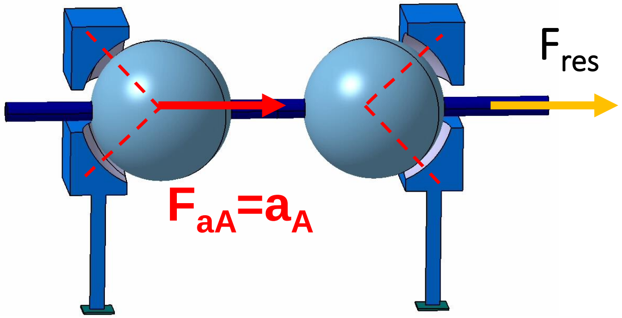
Calculation of axial loads

The other bearing supports its induced axial load only.



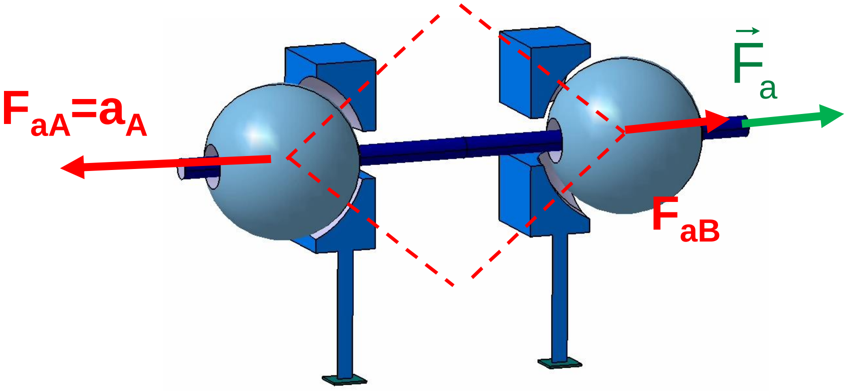




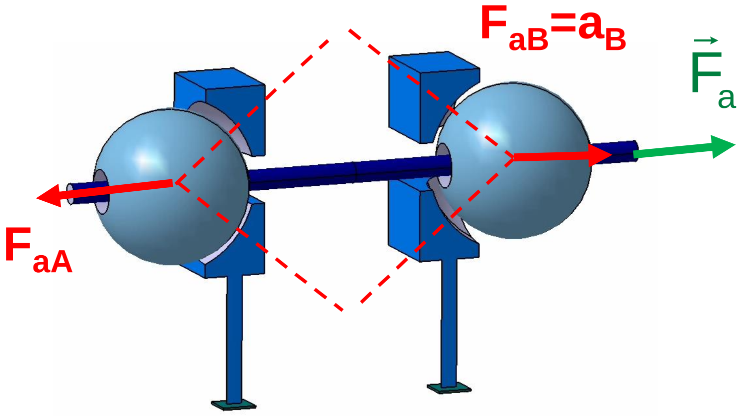


Calculation of axial loads

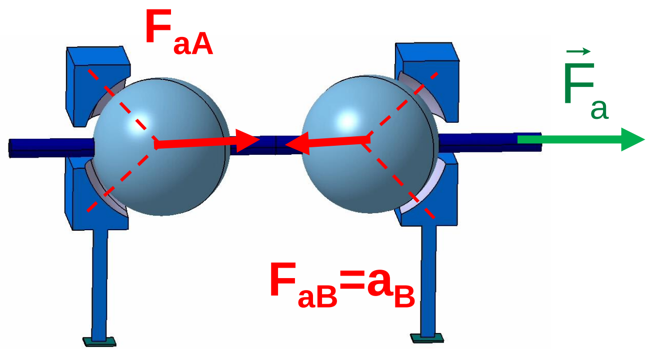
Write the axial equilibrium of the shaft



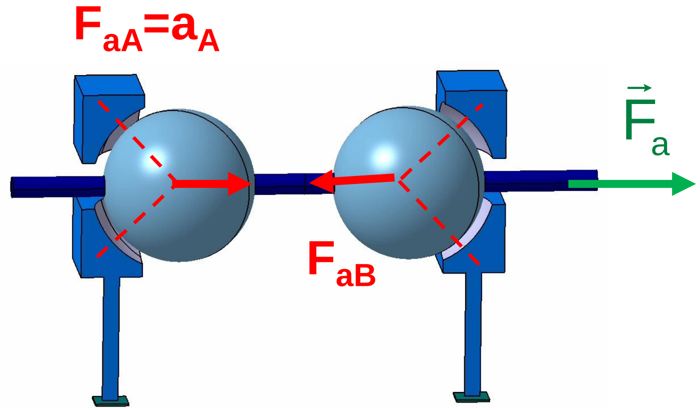
$$-a_A + F_{aB} + F_a = 0 \rightarrow F_{aB} = a_A - F_a$$



$$a_B - F_{aA} + \bar{F}_a = 0 \rightarrow F_{aA} = a_B + F_a$$



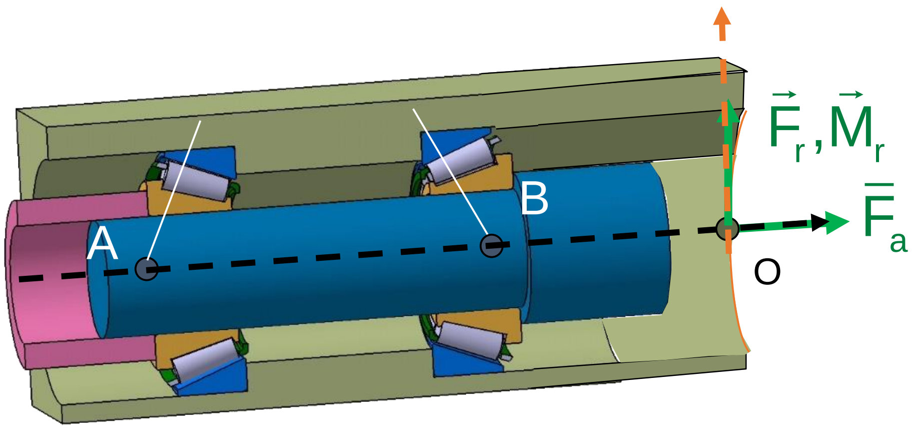
$$-a_B + F_{aA} + F_a = 0 \rightarrow F_{aA} = a_B - F_a$$



$$a_A - F_{aB} + \bar{F}_a = 0 \rightarrow F_{aB} = a_A + F_a$$

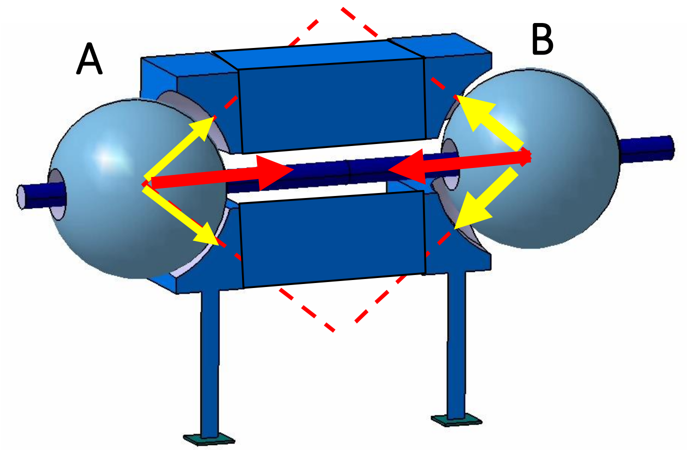
Calculation of axial loads

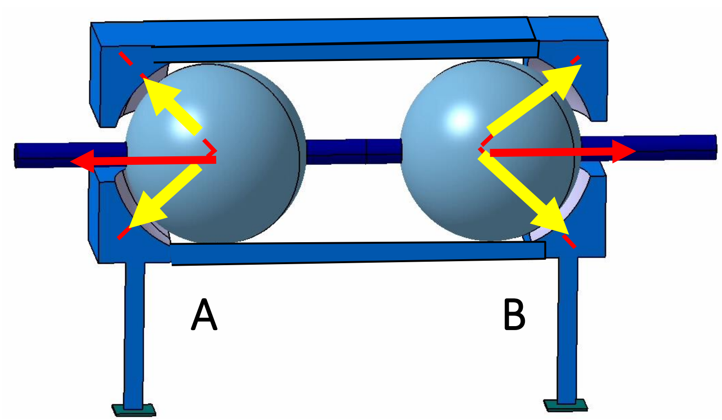
Assuming external loads are on the housing



Identify external loads on the housing
Locate the load centers

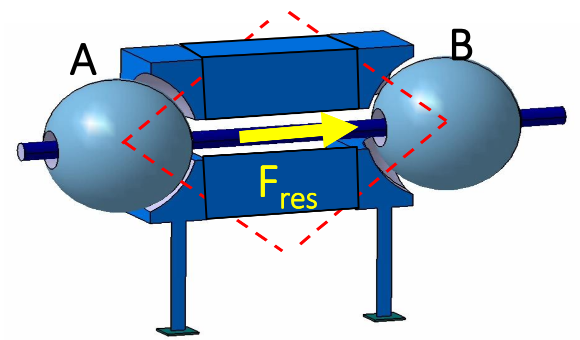
Identify the direction of the load exerted **by** the bearings **on** the housing

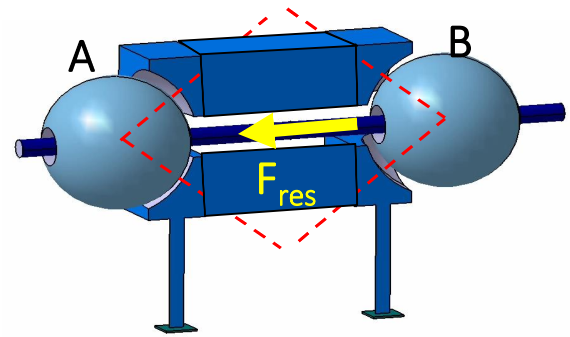


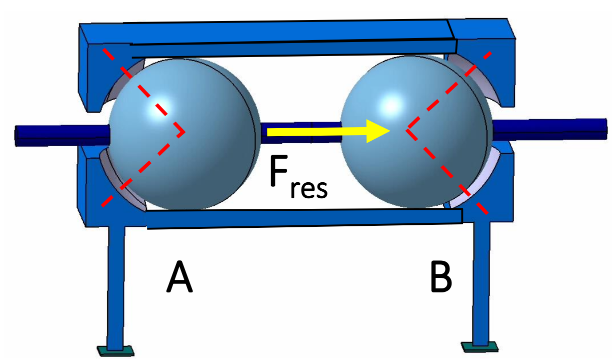


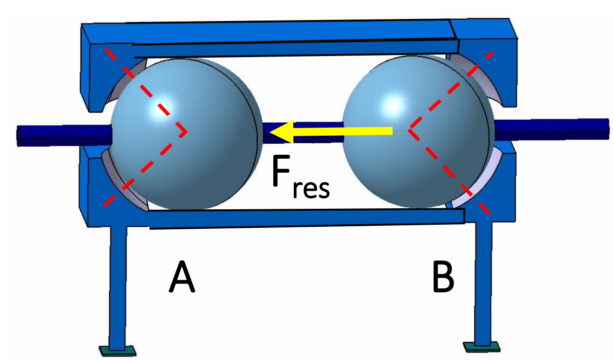
Calculation of axial loads

Proceed the same way









Calculation of axial loads

Take home message :

One bearing supports its induced axial load.

The other supports the external axial load

General method for angular contact bearing sizing

Static equilibrium helps determining axial and radial loads on each bearing.

Proceed as for radial bearings

1. Determine equivalent static bearing load **Po** .
2. Check: $$C_0 > s_0 \times P_0$$

where s_0 depends on loading conditions and **Co** is the static basic load rating,

3. Determine the equivalent dynamic bearing load **P** $$P > P_{min}$$
4. Check it is large enough
5. Calculate the bearing rating life:

$$L_{10} = \left(\frac{C}{P}\right)^n$$

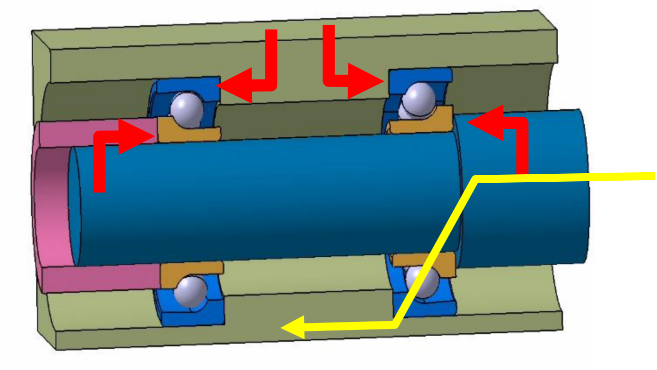
Mounting

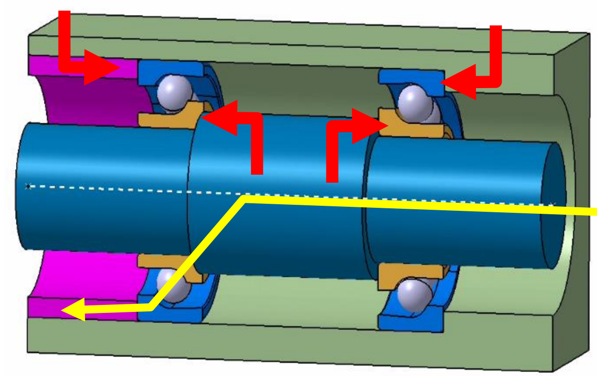
Clearance and preload

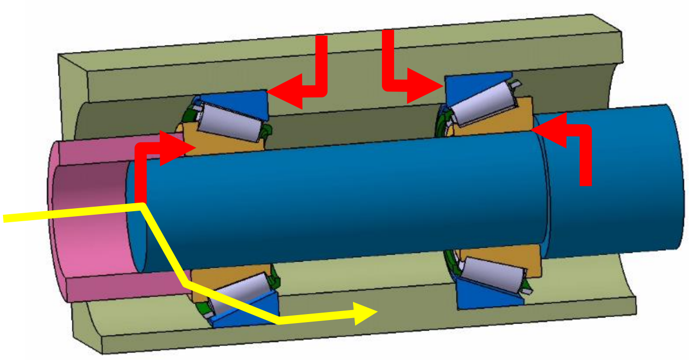
For angular bearing arrangements

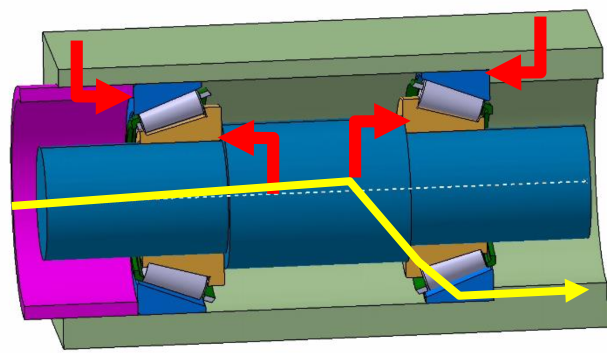
- They are always by pairs

- **Axial locating is done on 4 points which place is determined by arrangement type (X or O)**

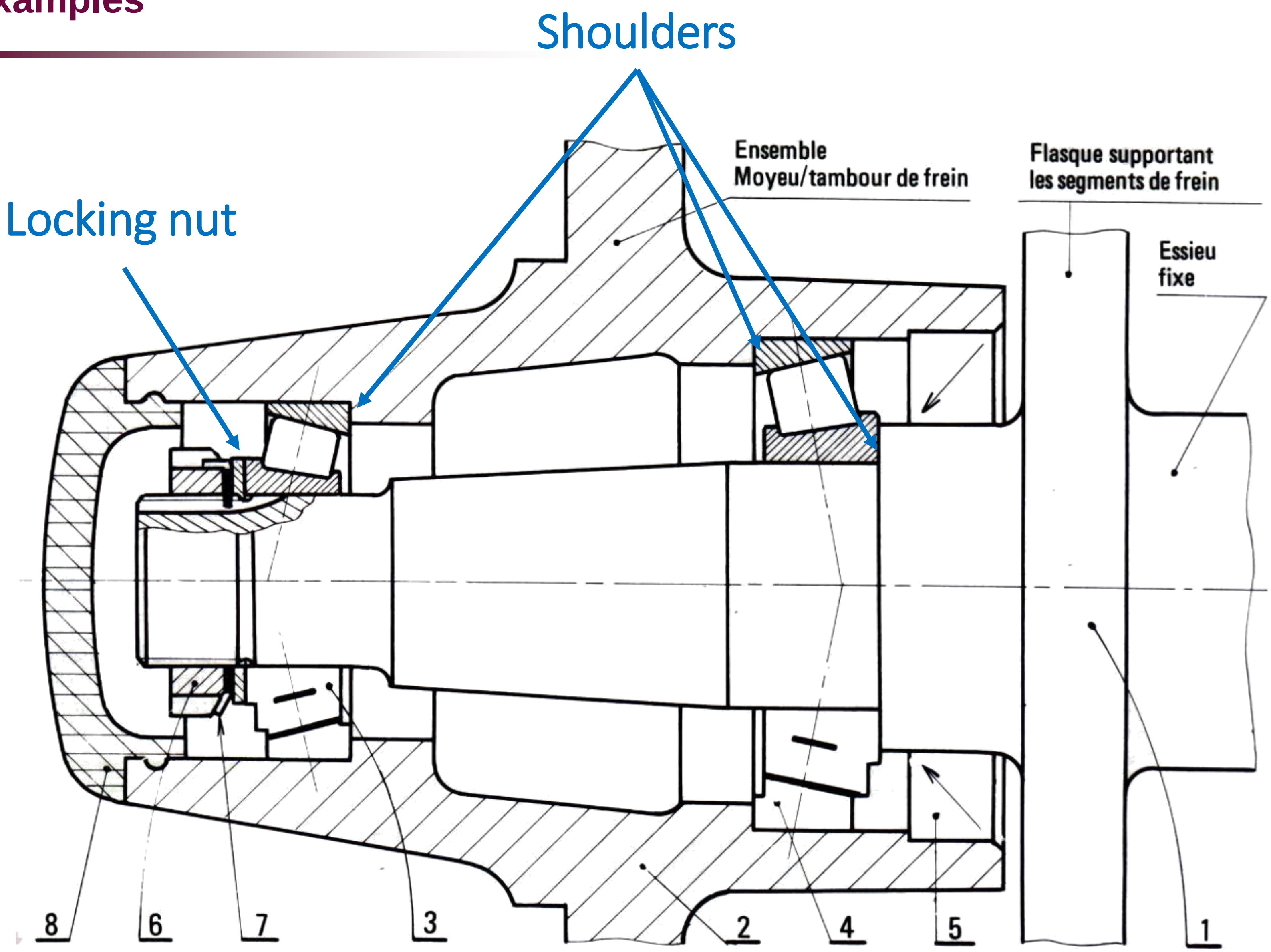






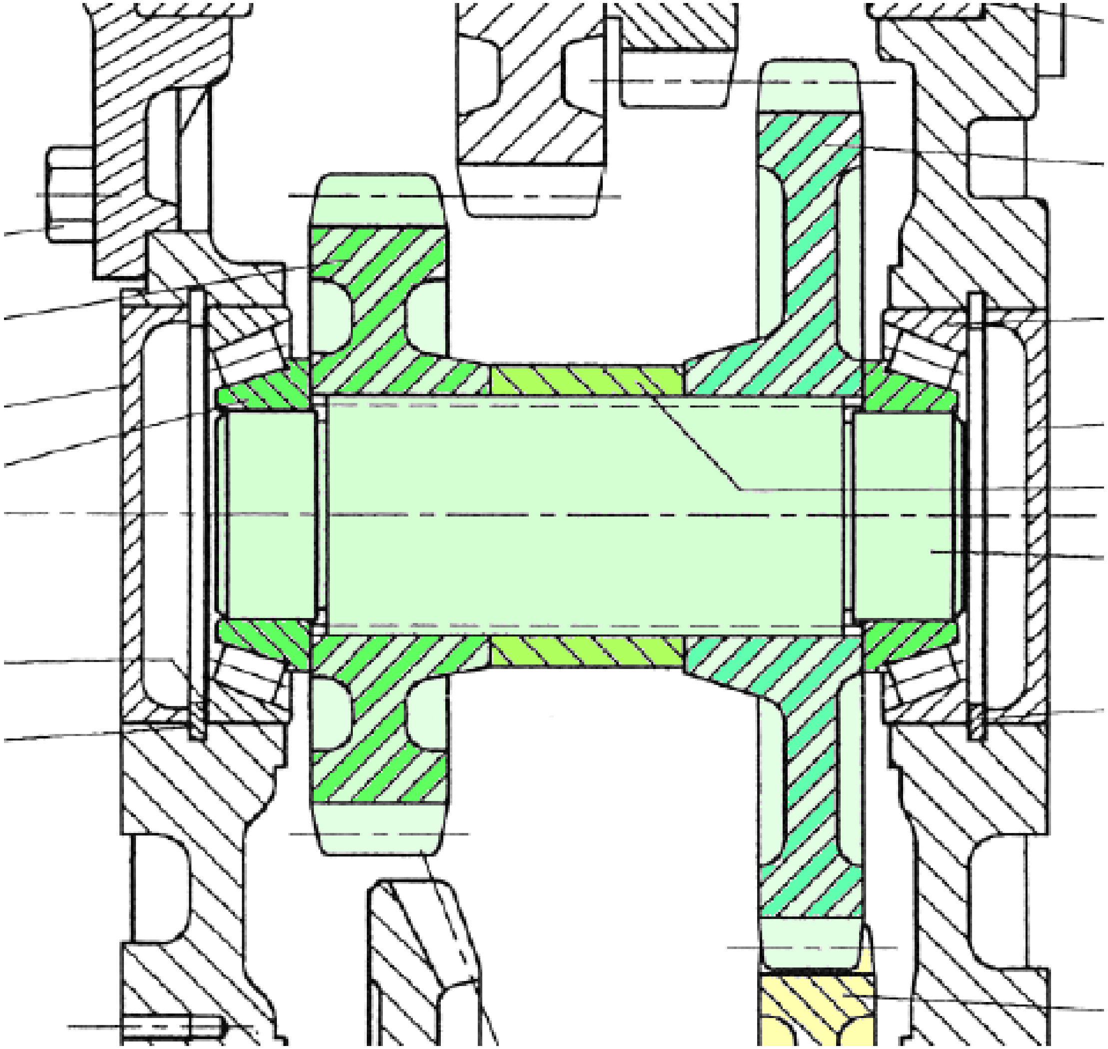


Examples



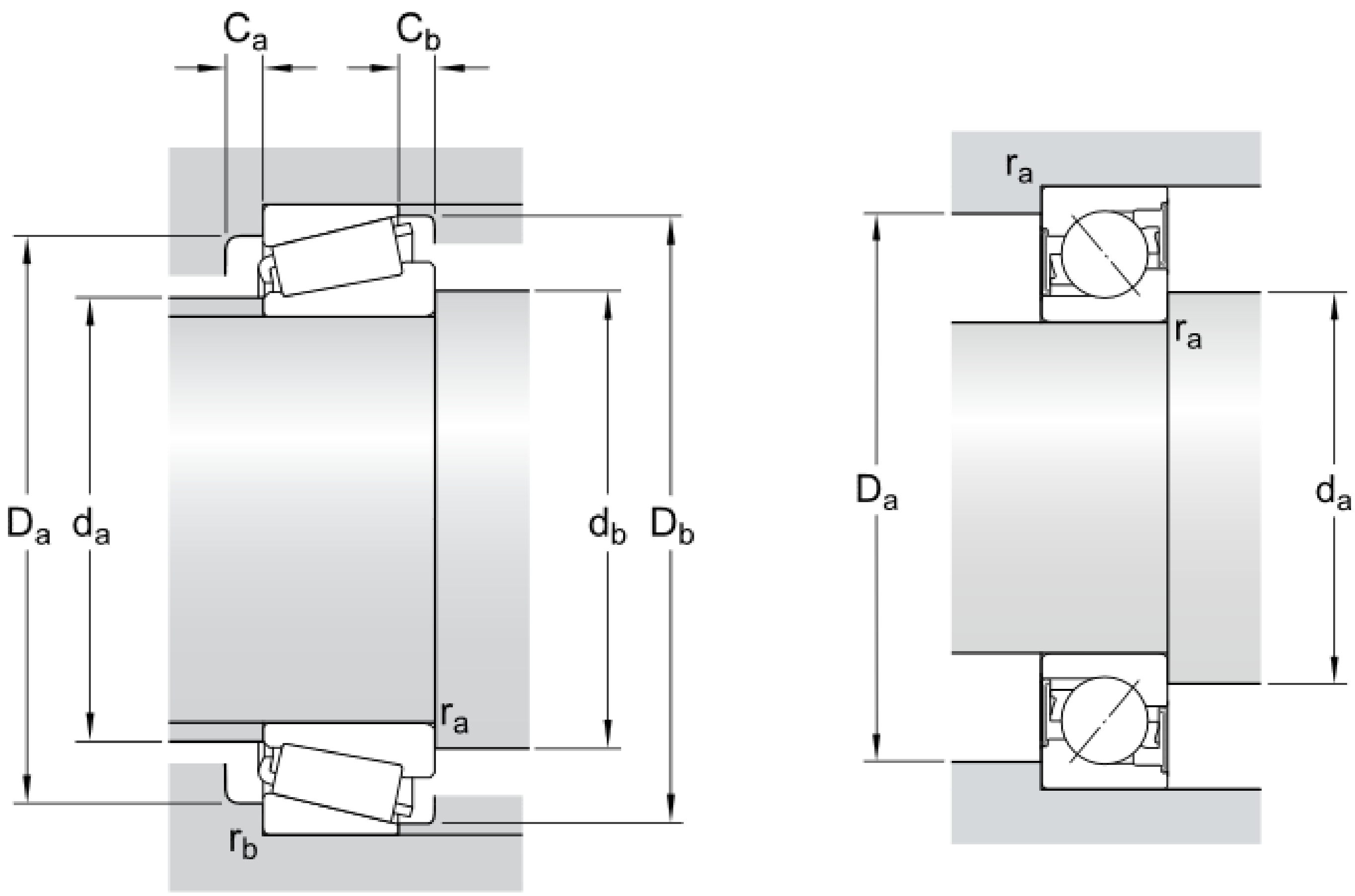
Campervan wheel

Examples



https://pierreprovot.wordpress.com/2008/01/23/sance-de-tp-du-23012008-g2/

Dimensions



Locating radial dimensions are provided by the manufacturer

Preload

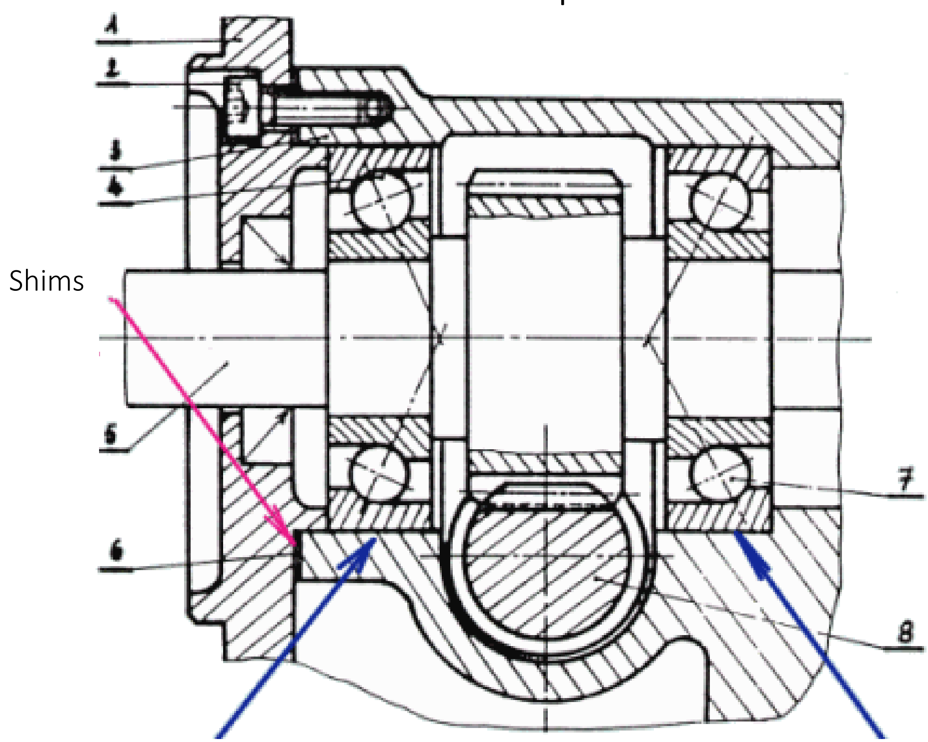
- Requires setting the axial fit by acting on the free ring

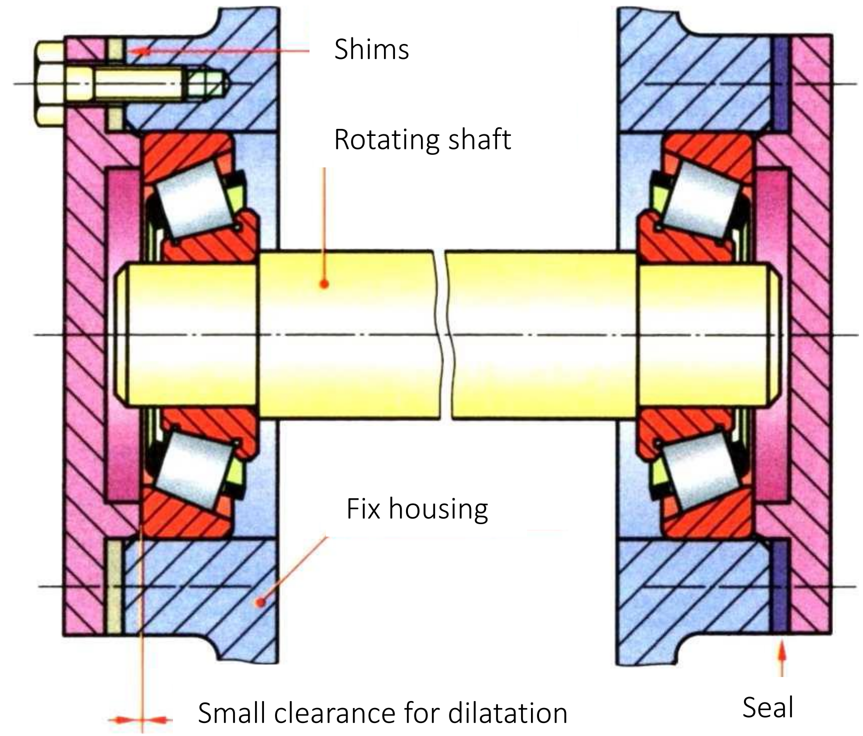
Preload setting - examples

Small shaft – fix load

- Laminated shims

Rack and pinion

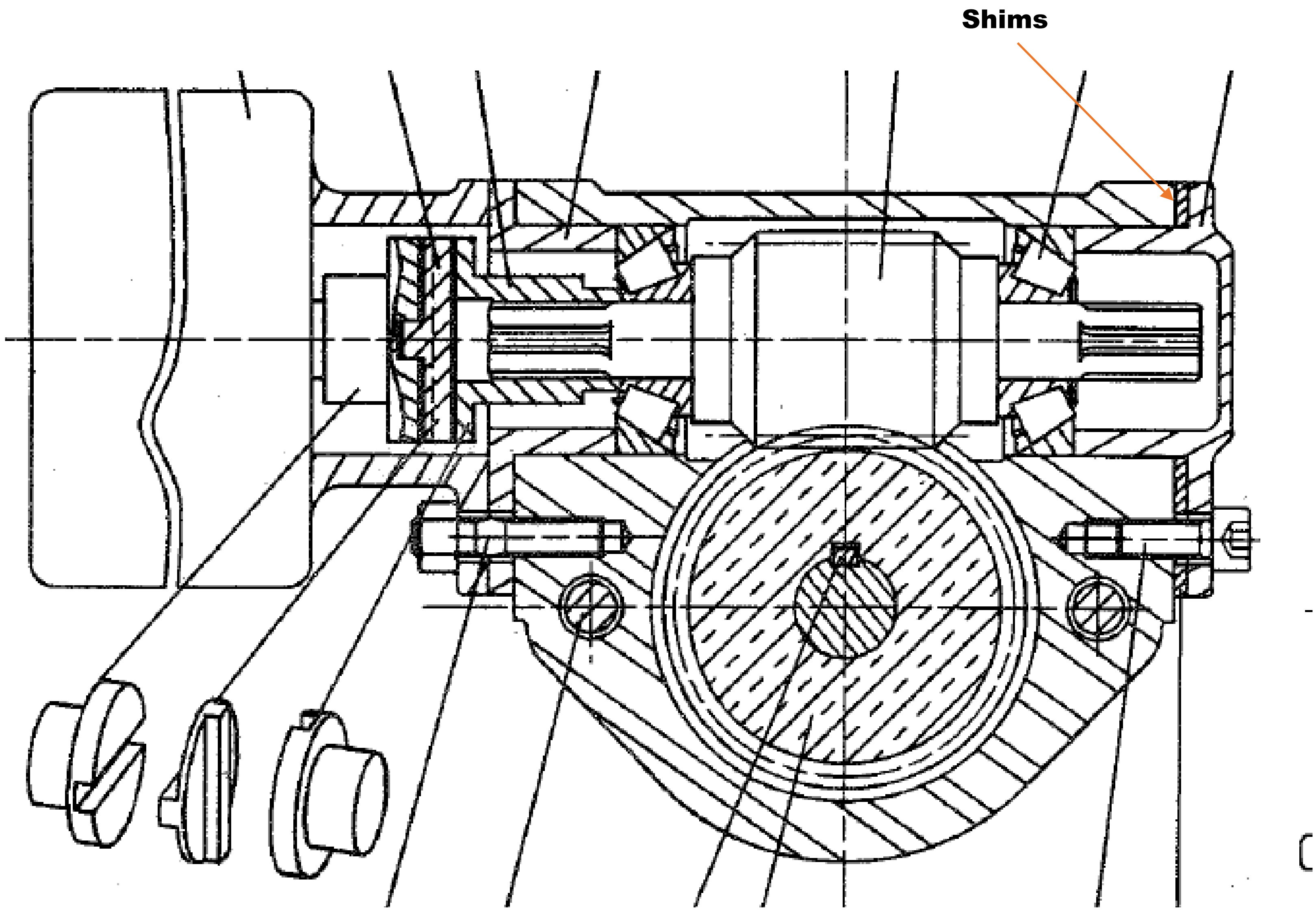




http://joho.monsite.orange.fr/

http://barreau.matthieu.free.fr/cours/Liaison-pivot/pages/roulements-2.html

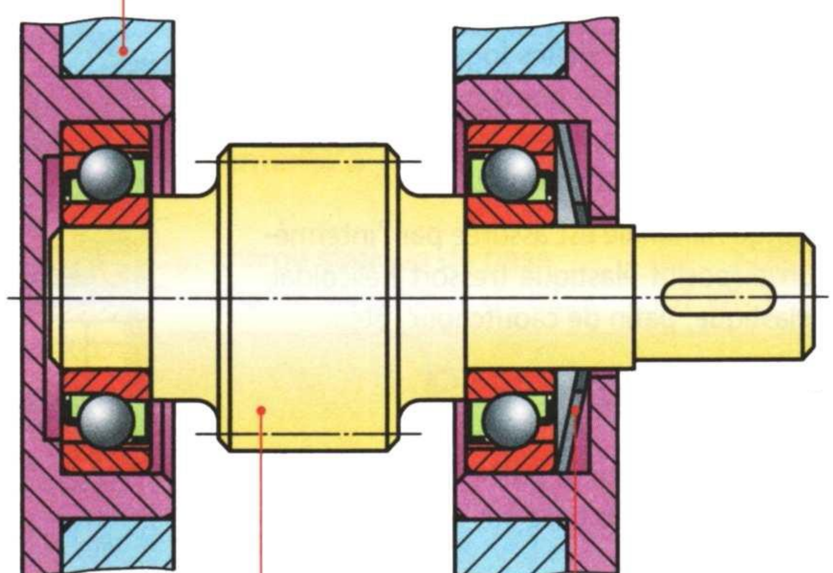
Preload setting - examples

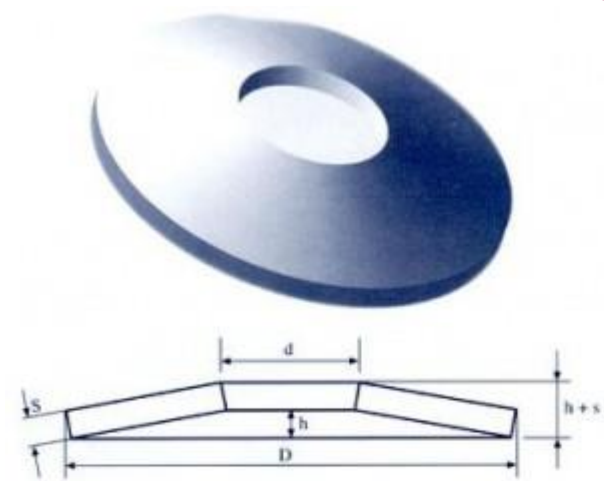


Preload setting - examples

Long shaft – Fix load

- Use springs: spring washer, Ringspann washer, etc.





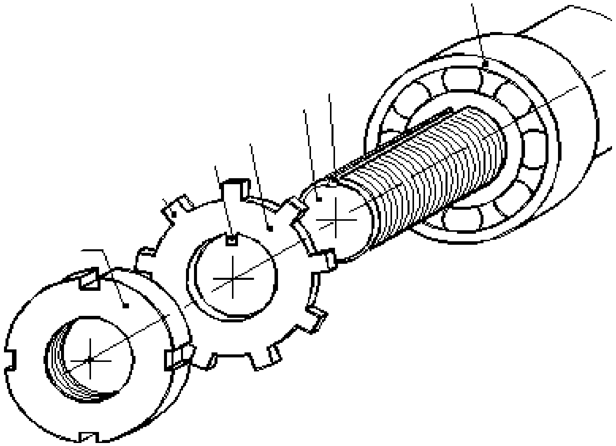
Spring washer

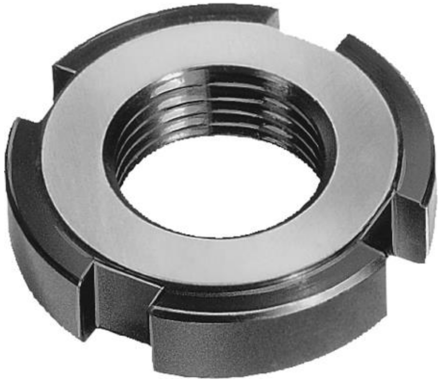
Ringspann washer

Preload setting - examples

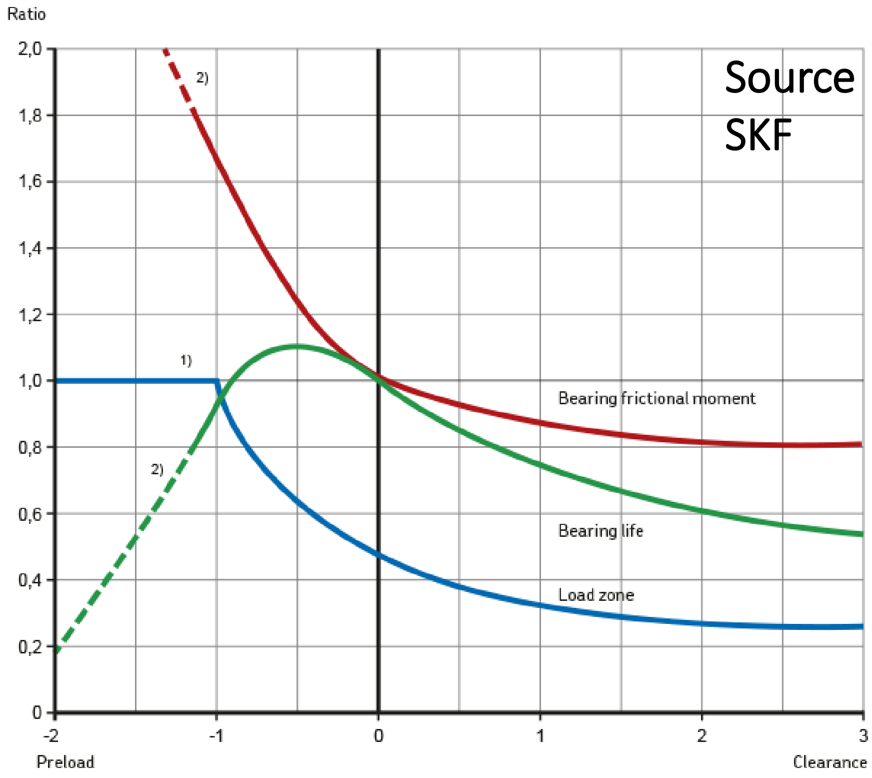
Rotating housing – fix load

- Use a washer and a nut



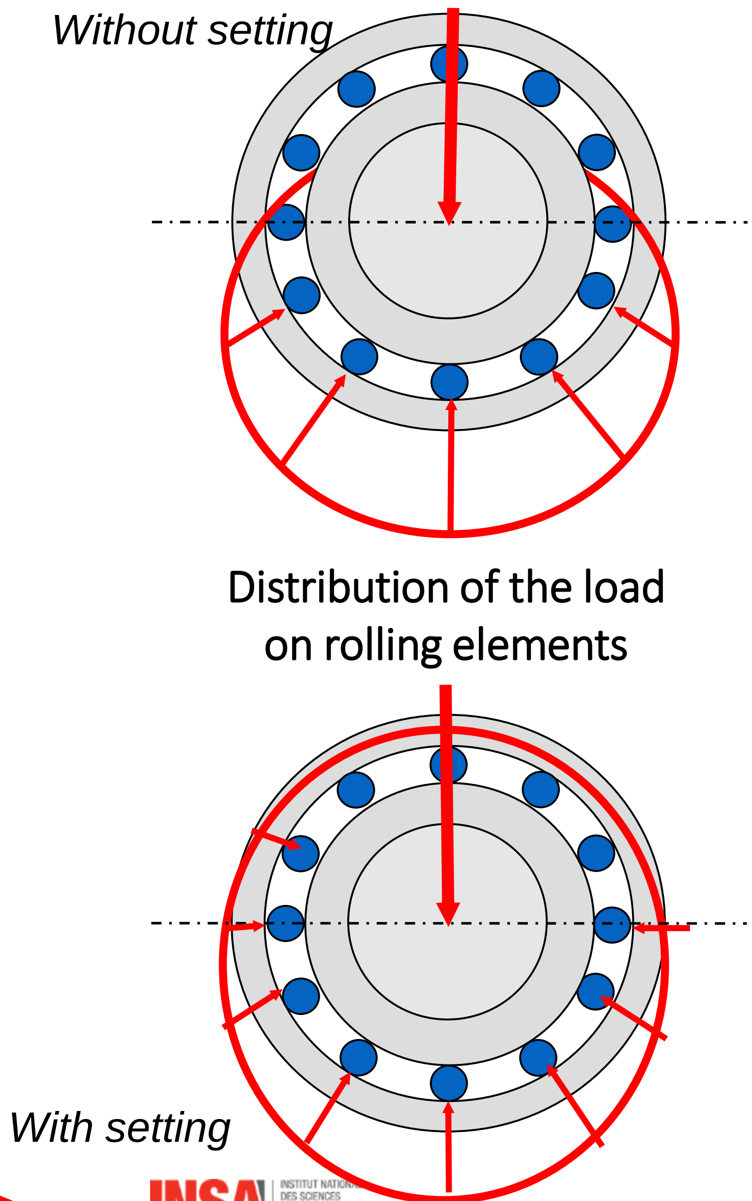


Clearance or preload ?



Clearance or preload is influenced by loading conditions: increase of temperature → dilatation, elasticity, etc

Preload setting



Better distribution of the load on rolling elements

- Better guiding of rolling elements
  → less noise
  → better shaft guiding
- Decreases chocks
  → Increases rating life
- Increases arrangement stiffness
  → Better shaft guiding