Bearings, load, accuracy

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Bearings

Bearings are called machine components that allow relative rotary motion related components. They are divided into two large groups - on **sliding** and **roller** bearings. Sliding bearings are inserted soft cases resistant to sliding friction, roller bearings have embedded elements overcoming friction roller.

Roller bearings have the following advantages:

- Rolling resistance is less than friction – Roller bearings are therefore higher efficiency.
- Easy to use – They are suitable for higher speeds.
- Longer life because there is no frictional wear.
- They are produced in completely enclosed design with a lubricated, which will last for the lifetime of bearings.

- The disadvantage is higher noise and vibration compared to sliding bearings.

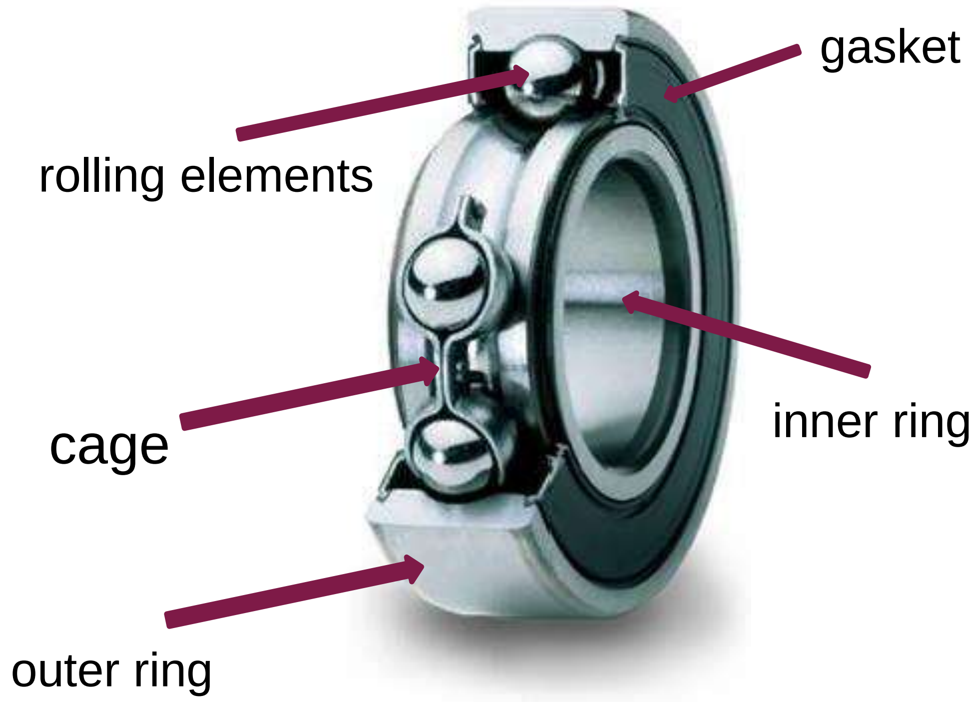
Characteristics of rolling bearings

For rolling bearings are applied load is transmitted through the rolling elements. Rolling elements roll almost without a slip. Friction during startup is for rolling bearings very small compared with the friction during acceleration sliding bearings.

Roller bearings are standard machine components.

The roller bearing is composed of:

- inner ring
- outer ring
- rolling elements
- cages (some bearings absent)
- gasket (may or may not be)



Types of rolling bearings

Division according to the transmitted load :

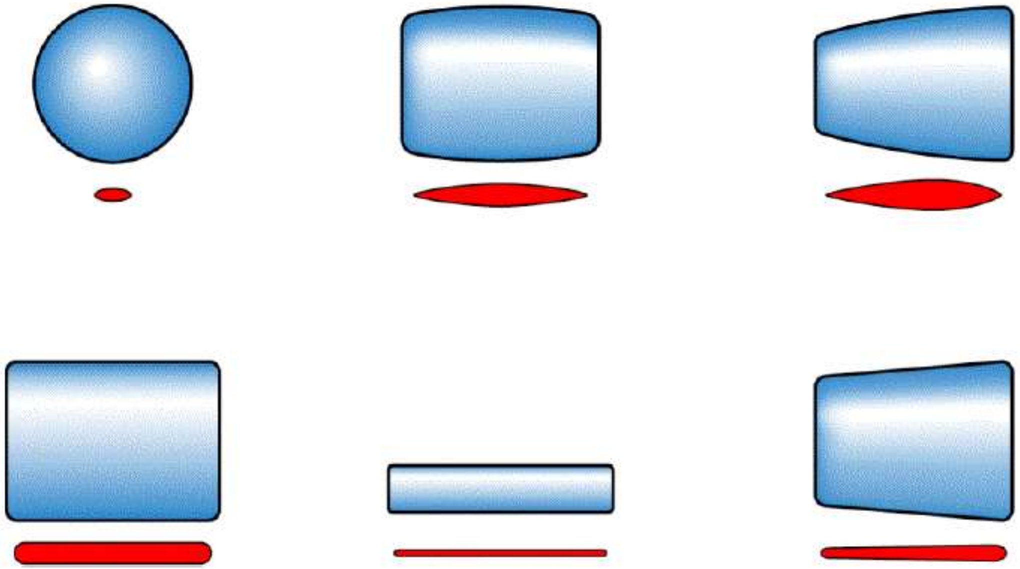
- radial
- axial
- combined (can carry both radial and axial loads)
- torque load

Division according to the shape of the rolling elements :

- ball bearings
- cylindrical roller bearings
- tapered roller bearings
- spherical roller bearings
- needle roller bearings

Division according to contact the rolling element raceway:

- point
- line



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Materials for rolling bearings

Materials for rolling bearings can be divided into materials used to manufacture the rollers and rings and other materials for cages.

Materials for the production of rolling elements and rings:

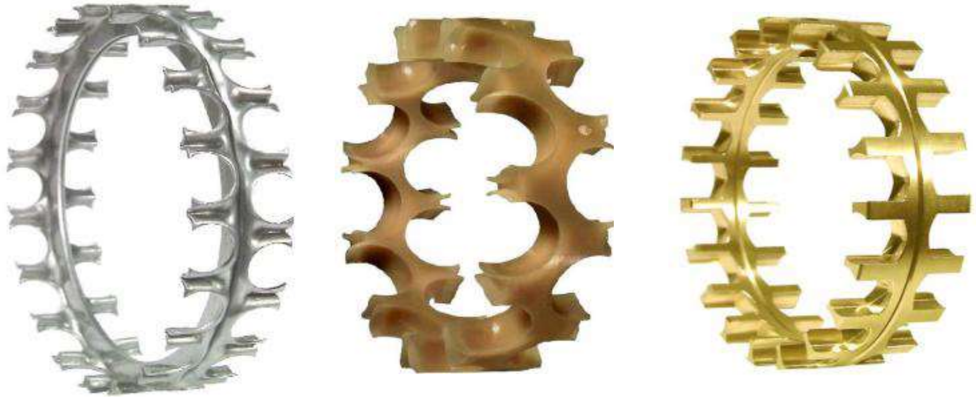
- Bearing steel
- Hardenable steel
- Induction-hardening bearing steel
- Case hardened bearing steel
- Stainless steel bearing
- Steel for high temperature
- Ceramic materials (silicon nitride Si_3N_4)

Materials for the manufacture of cages :

- Steel
- Solid brass
- Brass sheet
- Polyamid

Hybrid bearings are bearings with different material rolling elements (ceramic - silicon nitride) and rings (steel).

All-ceramic bearings have made ceramic rolling elements and rings.



Examples of the material of cages

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Ways of supporting shafts in roller bearings:

The shafts are arranged so as to prevent their axial displacement, yet allow them to expand due to the heating operation. We also have to reckon with manufacturing inaccuracies. For the designer, this means that some of the edges of the bearings must keep unsecured and free sliding.

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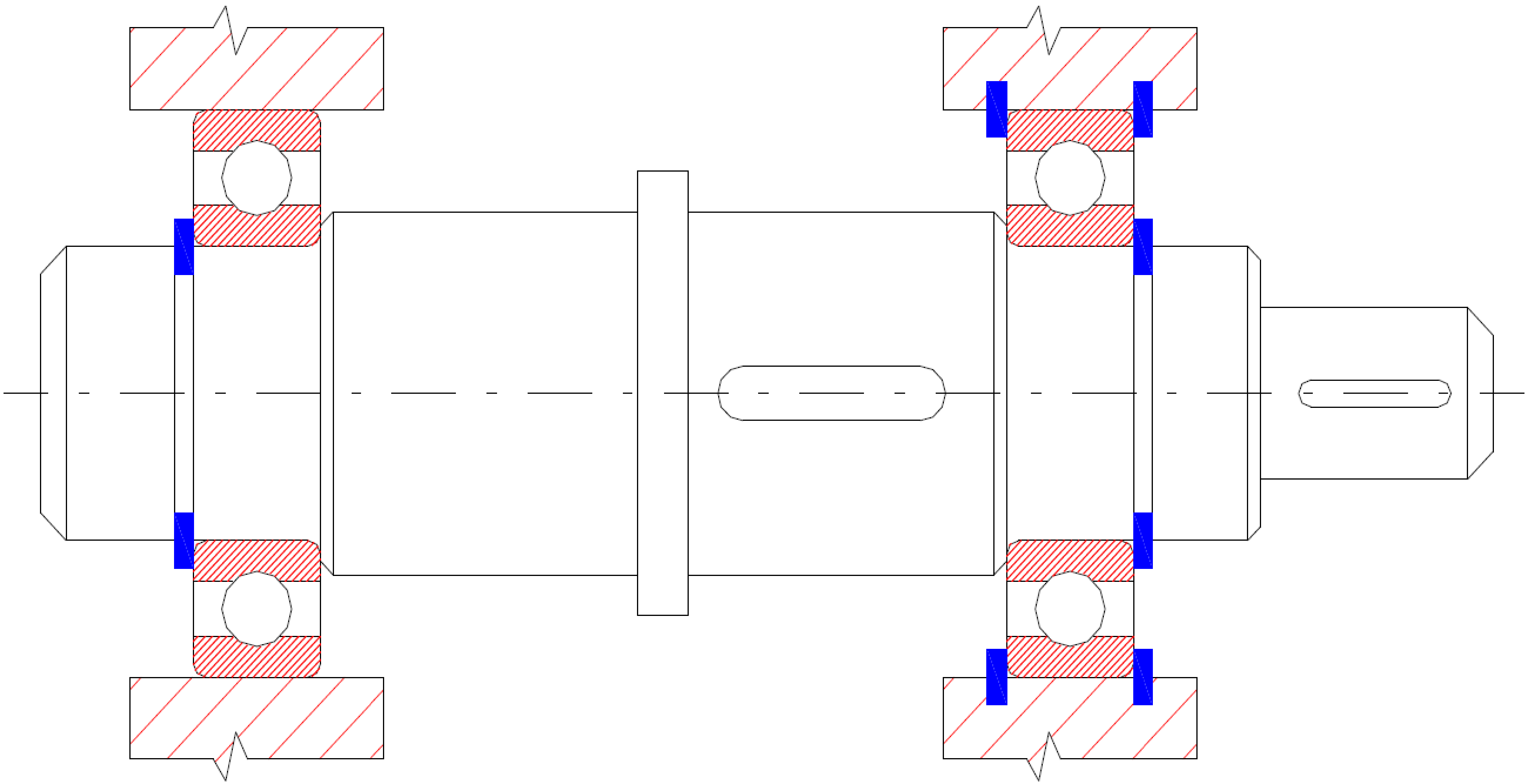
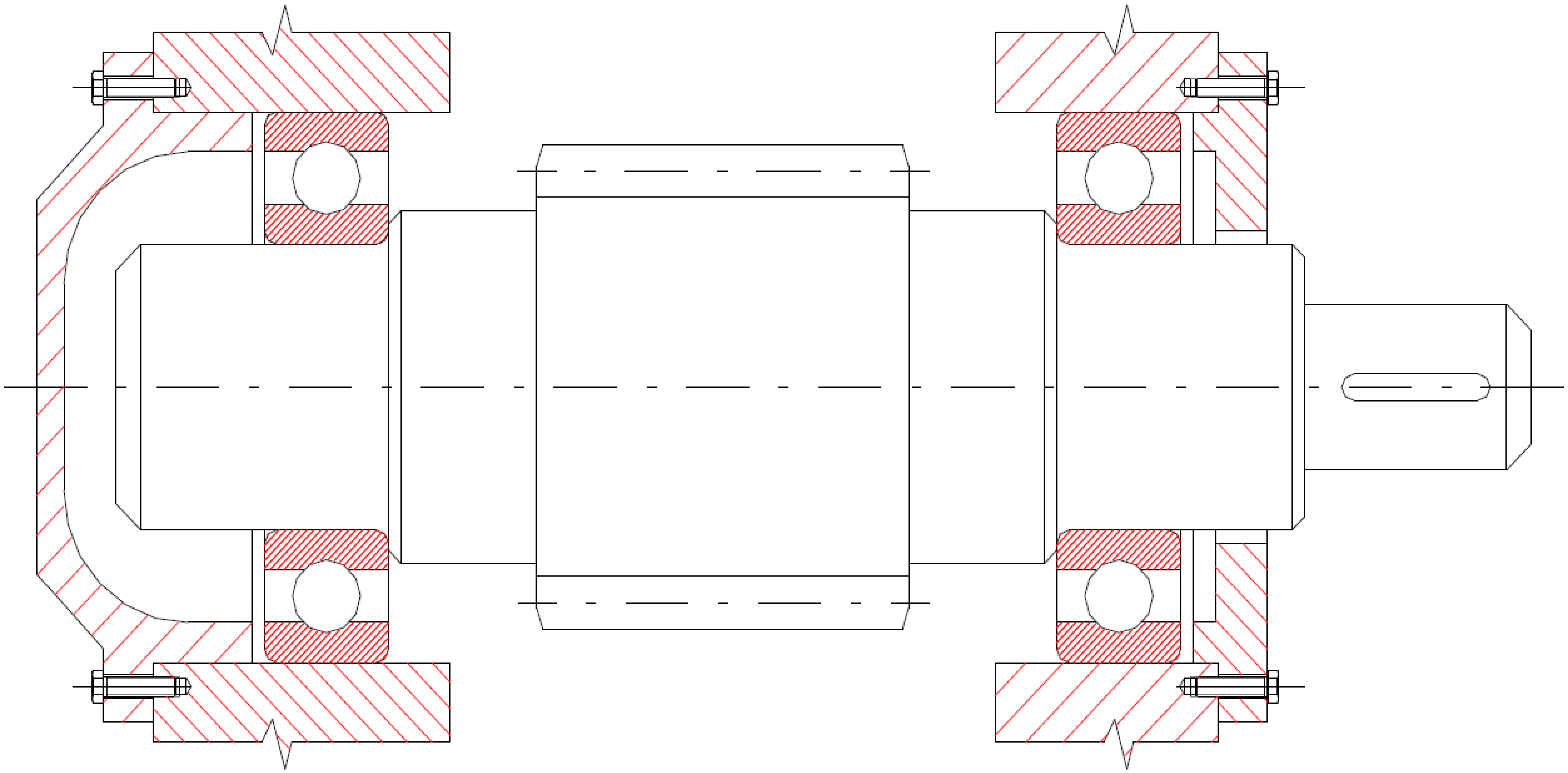
One bearing is firmly mounted (right) and one of the floating (left) bearing. Free bearing has a certain possibility of lateral displacement.



Suporting so-called "over the ball" is the demanding production accuracy. The outer rings of the bearings are available to some small lateral clearance to the bearings allows a certain lateral displacement.



Definition of terms for the calculation of roller bearings

Equivalent static load P_0

It is the load (radial or axial), which causes the same maximum load of a rolling element as the actual load.

Equivalent dynamic load P

It is hypothetical variable load (radial or axial) which has the same influence on the durability as the actual load acting on the bearing.

The basic dynamic load rating of bearings C

It is the load at which the bearing reaches the basic durability 1000000 rpm. It is used to calculate the bearing life, which is dynamically loaded.

Basic static load rating C_0

It is a tension that will produce in the middle of the most heavily loaded contact points between the rolling element and the orbits of permanent deformation of 0.0001 diameter rolling element.

Durability L

It is defined as the number of revolutions or the number of operating hours at a given speed of rotation, which bearing performs before they manifest the first signs of fatigue (valid for a minimum of 90% of the bearings of the test group).

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Calculation of rolling bearings

Statically loaded roller bearings

Equivalent static bearing load F_0

$$F_0 = X_0 \cdot F_r + Y_0 \cdot F_a$$

F_r – radial force acting on the bearing

F_a – axial force acting on the bearing

X_0 - The coefficient of static load (radial)

Y_0 - The coefficient of static load (axial)

X_0 and Y_0 are given by the manufacturer.

Static safety bearing is given by the formula

$$k_0 = \frac{C_0}{F_0}$$

Calculation of static load (k_0) we always perform, and regardless of the operating speed. Is performed even when the bearing does not rotate at all or, conversely, when it is constantly in motion.

Dynamically loaded bearings

Calculation of dynamic load rating of rolling bearings are used to determine their lifecycles. The value is expressed in millions rpm or hours of operation. Like in the case of static load ratings we are counting equivalent dynamic load F, ie. Those radial and axial loads, which has the same effect on the life of the bearing as the actual running load.

In the formula for this device we will meet again with several coefficients that are searching CSN or in mechanical engineering tables. We need to make a few preliminary calculations.

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It is first necessary determine the ratio of the axial bearing load F_a and static load capacity C_o.

$$\frac{F_a}{C_0}$$

Then, in the mechanical engineering tables (Table X and Y values), we find the line, stating their closest value of this ratio. On the same line, the rightmost subtract coefficient **e**. This factor evaluates the influence of axial force on the bearing.

Then we calculate the ratio between the two loading forces :

$$\frac{F_a}{F_r}$$

The calculated value is compared to coefficient e. In case it is smaller, the influence of axial forces is negligible and typically we substitute X = 1 and Y = 0.

In the case that the value is greater, the influence of axial forces is significant and values of X and Y must be traced in the table.

Equivalent dynamic bearing load is then calculated from the formula :

$$F = V \cdot X \cdot F_r + Y \cdot F_a$$

Dynamic load coefficient **X** (radial) and **Y** (axial) are supplied by the manufacturer and their searching is described above. Rotation factor **V** is given by the manufacturer, and has in most cases a value of 1.

Only for point load bearing inner ring with single-row deep groove ball, cylindrical, spherical and tapered roller has a value of 1,2.

Then it is necessary to calculate the **basic rating life L**, which is usually expressed in millions of revolutions. It's such a life, that type of bearings that can withstand 90% of these bearings.

For ball bearings formula:

$$L = \left(\frac{C}{F}\right)^{3}$$

For cylindrical, spherical, ball and needle bearings, then apply a slightly modified formula :

$$L = \left(\frac{C}{F}\right)^{\frac{10}{3}}$$

where **C** is the basic dynamic load rating indicated by the manufacturer. It is the bearing load indicated by the manufacturer at which 90% of the tested bearings reaches the lifetime 1,000,000 revolutions. We can be found in the tables of engineering.

If you need to know the life of the bearings in operating hours L_h, use the following conversion using rpm – **n**:

For ball bearings:

$$L_h = \frac{10^6}{60 \cdot n} \cdot \left(\frac{C}{F}\right)^3$$

For other types:

$$L_h = \frac{10^6}{60 \cdot n} \cdot \left(\frac{C}{F}\right)^{\frac{10}{3}}$$

This is again a lifetime of hours that last 90% of the bearings of this type. To bearing could be used, this value must be higher than the required service life.

In addition, the manufacturer specifies the maximum speed $\mathbf{n_{max}}$, which can be operated bearing. It must be observed.