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Rolling Bearings and the Forces Generated in Them

Tovashov Rustam Xo'jaxmat o'g'li
Doctor of Philosophy in technical Sciences, docent.
Karshi engineering-economic institute

Abstract: This article presents formulas for calculating the forces generated in rolling bearings, which are widely used in all areas of production.

Keywords: mechanical, bearing, thought, element, geometric, kinematic, parameter, length, diameter.

Introduction. Bearings with rolling elements are considered to be one of the main parts widely used in rotating parts in all branches of production, as well as in agricultural production. Rolling bearings are divided into types according to the conditions of operation and the loads applied to each element. Therefore, since agricultural machines work in field conditions, it is important to correctly choose the rolling bearings used in them and to calculate the forces generated when choosing their parameters.

Research method. Rolling bearings are a widely used component in machinery. In terms of structure, rolling bearings consist of two grooved rings (inner and outer), rolling elements (balls or rollers) located between the rings and, in some cases, a separator that serves to separate and guide them (Fig. 1).

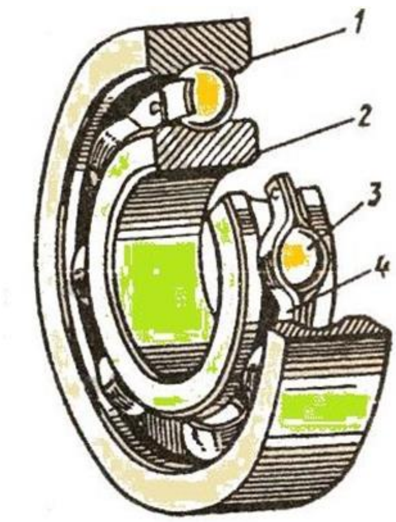

Figure 1. The structure of rolling bearing: 1- outer ring; 2- internal people; 3- rolling element ball or roller; 4- separator.

Advantages of rolling bearings:

- ➢ The value of the coefficient of friction in a rolling bearing is small;
- ➢ low friction force and the amount of heat generated in it;
    - the initial torque of the shaft is small compared to the sliding bearing (5...10 times);

- easy maintenance and simple lubrication system. For example, bearings with closed sides are lubricated during preparation and do not require additional lubrication during the service life;
- the possibility of standardization allows to produce many bearings and reduce their cost.

Disadvantages of rolling bearings:

- due to its non-separable structure, in some cases it is not possible to install it on shafts (for example: crankshafts);
- larger radial dimensions (diameter) compared to sliding bearings;
- short service life (because the value of the contact voltage is high);
- work with noise when moving at high speed (so the speed is limited);
- low ability to work in vibration and impact loads;
- it is not possible to work in water and dangerous environments. Because bearing parts are made of steel, there is a possibility of rusting.

Research results and discussions. Under the influence of radial forces, the rolling elements of rolling bearings are uneven, that is, half loaded and half unloaded (Fig. 2). Using the equilibrium condition, it is possible to determine the distribution of the impact force between the spheres:

$$F_r = F_0 + 2F_1 Cos\ \gamma + 2F_2 Cos\ (2\gamma) + \dots + 2F_n Cos(n\gamma),$$

here $\gamma = 360 / z$ – the angle between the spheres; z – number of balls.

The force acting on each sphere can be determined as follows:

$$F_1 = F_0 Cos^{3/2}\gamma,\ F_2 = F_0 Cos^{3/2}\gamma\ \dots\ F_n = Cos^{3/2} n\gamma.$$

Putting the found values in equilibrium condition

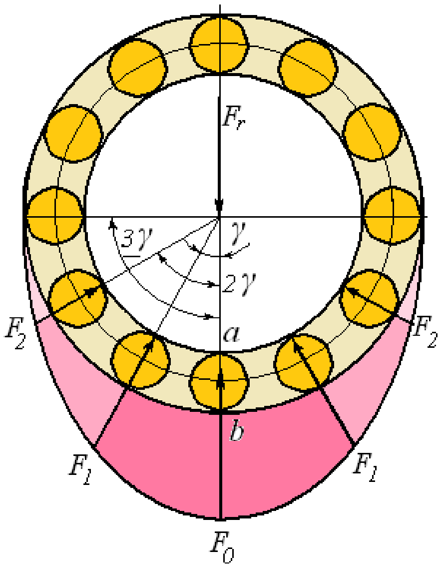

Figure 2. Scheme for determining the maximum load acting on the rolling element.

$$F_r = F_0\ (1 + 2) \sum Cos^{3/2} n\gamma$$

we get the expression From this we determine the value of the largest force:

$$F_0 = k\ F_r\ / z;\quad k = z / (1 + 2) \sum Cos^{3/2} n\gamma.$$

In this case, it is necessary to achieve an effect with a alternating cycle of contact voltage.

Once the values of the applied forces are determined, contact stresses, which are one of the main causes of failure of the bearing details, can be found (not presented here). In order for the rolling bearings to work well, it was recommended to ensure the rotation of the inner ring.

To study the kinematics of a rolling bearing, we use a velocity plot for a bearing detail with a rotating inner ring (Fig. 3). Accordingly:

$$V_0 = V_1 / 2 \,,\; V_1 = \omega D / 2.$$

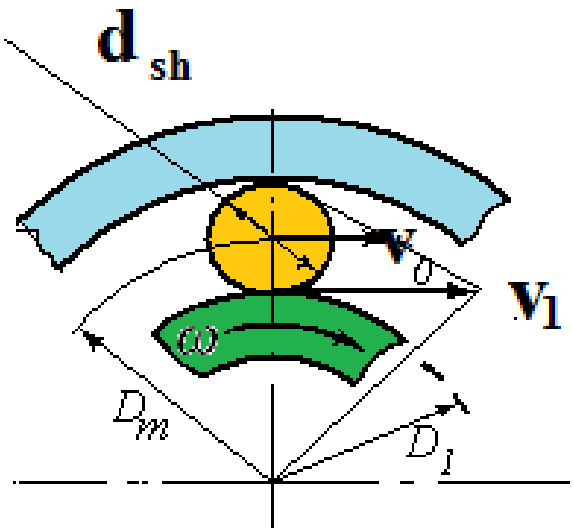

Figure 3. Kinematics of a rolling bearing.

The frequency of rotation of the ball (or roller) around its axis:

$$\omega_{sh} = 2\,(V_1 - V_2)\,/\,d_{sh} = 0{,}5\,\omega\,D_1 / d_{sh}\,.$$

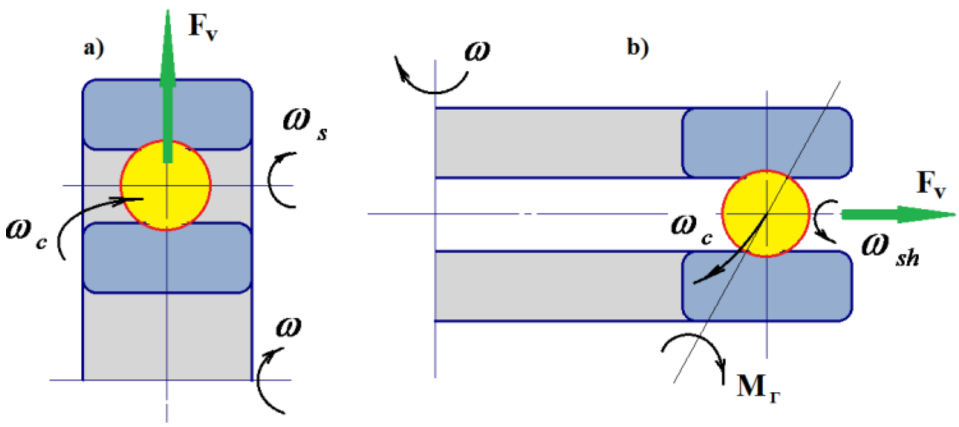

Figure 4. Schematic diagram of rolling bearing dynamics.

The frequency of rotation of the separator is equal to the frequency of rotation of the ball around the shaft axis, i.e

$$\omega_c = 2\,V_0 / d_{sh} = 0{,}5\,\omega\,D_1 \,/\, (D_1 + d_{sh}) \approx 0{,}5\,\omega\,. \quad (1)$$

Therefore, the separator rotates with an angular velocity equal to half the angular velocity of the shaft according to the rotation of the shaft.

It can be seen from formula (1) that the angular velocity of the separator depends on the size of the ball.

Dynamics of rolling bearing. Each ball or roller of the bearing is compressed by the centrifugal force (Fig. 4) from the center of the outer ring.

$$F_v = 0{,}5 m \omega_c^2 D_m$$

where: m is the mass of the ball and the roller.

Selection of bearings according to dynamic and static load capacity. Under the influence of alternating voltage, the surfaces in contact are exhausted and are the main reason for their decay. Currently, the calculation of the durability of rolling bearings is based on two methods:

- according to the static load capacity so that there is no residual deformation;
- in order not to collapse due to fatigue, according to the dynamic load capacity.

In practice, rolling bearings are not considered in the design of machines, but are selected from the table according to the standard, based on the consideration of the force acting on the support and other necessary factors. Because the bearing capacity is calculated for any bearing.

Static load capacity of rolling bearings. Rolling bearings used in crane hooks, self-rotating cranes, jacks and similar machines and mechanisms move around their axis with $P < 1\ \text{min}^{-1}$ during operation. Such bearings are calculated according to the static load capacity.

The value of the static equivalent load for grooved radial, grooved and roller radial-support bearings is determined as follows:

$$R_0 = X_0 F_r + Y_0 F_0$$

where X_0, Y_0 are coefficients taking into account radial and longitudinal forces.

Installation of bearings on shafts and housings. The main detail is the outer and inner rings of the bearing when transferring bearings to shafts and housings. All changes to dimensions are made at the cost of resizing the shaft or housing. For the outer ring of the bearing, the hole system for the inner ring of the shaft system is adopted.

When transferring bearings to a shaft or housing, its mode of operation and type are of great importance. In this case, the greater the load, the smaller the limit of the size of the shaft and the body, and it should be transferred with a high viscosity (in nodes with a large number of revolutions, this viscosity is compared to low-density bearings, and radial-support bearings have radial gypsum is installed in relation to the bearings).

Conclusion. One of the most important factors in the selection and calculation of rolling bearings, which is one of the details widely used in rotating parts of agricultural machines, is to take into account the balance states and the dynamic and static forces generated in it.

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