5. Loads

5.1 Load acting on the bearing

It is very rare that the load on a bearing can be obtained by a simple calculation. Loads applied to the bearing generally include the weight of the rotating element itself, the load produced by the working of the machine, and the load resulting from transmission of power by the belt and gearwheel. Such loads include the radial load, which works on the bearing at right angles to its axis, and the thrust load, which works on the bearing parallel to its axis. These can work either singly or in combination. In addition, the operation of a machine inevitably produces a varying degree of vibrations and shocks. To take this into account, the theoretical value of a load is multiplied by a safety factor that has been derived from past experience. This is known as the "load factor".

Load acting on the bearing

=Load factor f_w ×Calculated load

Table 5.1 below shows the generally accepted load factors of f_w which correspond to the degree of shock to which the machine is subjected.

5.1.1 Load applied to the bearing by power transmission

The force working on the shaft when power is transmitted by belts, chains or gearwheels is obtained, in general, by the following formula:

$$T = 9550\frac{H}{n},\ 84500\frac{H}{n} \cdots\cdots (5.1)$$

$$K_t = \frac{T}{r} \cdots\cdots (5.2)$$

where,

- T : Torque, N•m, lbf•inch
- H : Transmission power, kW
- n : Number of revolutions, r/min
- K_t : Transmission force (effective transmission force of belt or chain; tangential force of gearwheel), N, lbf
- r : Effective radius of belt pulley, sprocket wheel or gearwheel, m, inch

Accordingly, the load actually applied to the shaft by the transmission force can be obtained by the following formula:

$$\text{Actual load} = \text{Factor} \times K_t \cdots\cdots (5.3)$$

Different factors are adopted according to the transmission system in use. These will be dealt with in the following paragraphs.

Belt transmission

When power is transmitted by belt, the effective transmission force working on the belt pulley is calculated by formula (5.2). The term "effective transmission force of the belt" refers to the difference in tension between the tensioned side and the loose side of the belt. Therefore, to obtain the load actually acting on the shaft through the medium of the belt pulley, it is necessary to multiply the effective transmission force by a factor which takes into account the type of belt and the initial tension. This is known as the "belt factor".

Table 5.1 Load factors f_w

Load conditions	f_w	Examples
Little or no shock	1 to 1.2	Machines tools, electric machines, etc.
Some degree of shock; machines with reciprocating parts	1.2 to 1.5	Vehicles, driving mechanism, metal-working machinery, steel-making machines, paper-making machinery, rubber mixing machines, hydraulic equipment, hoists, transportation machinery, power-transmission equipment, woodworking machines, printing machines, etc.
violent shocks	1.5 to 3	Agriculture machines, vibrator screens, ball and tube mills, etc.

In the case of power transmission by belts, gearwheels, etc., load factors adopted are somewhat different from the above.

Factors used for power transmission by belts, gearwheels and chains, respectively, are given the following sections.

Table 5.2 Belt factors f_w

Bell type	f_b
V-belt	1.5 to 2.0
Timing belt	1.1 to 1.3
Flat belt (with tension pulley)	2.5 to 3.0
Flat belt	3.0 to 4.0

Note: In cases where the distance between shafts is short, the revolution speed is low, or where operating conditions are severe, the higher f_b values should be adopted.

Gear transmission

In the case of gear transmissions, the theoretical gear load can be calculated from the transmission force and the type of gear. With spur gears, only a radial load is involved; whereas, with helical gears and bevel gears, an additional axial load is present.

The simplest case is that of spur gears. In this instance, the tangential force K_t is obtained from the formula (5.2) and the radial force K_s can be obtained from the following formula:

$$K_s = K_t \bullet \tan\alpha \cdots\cdots\cdots\cdots (5.4)$$

where,

α is the pressure angle of the gear.

Accordingly, the theoretical composite force, K_r, working on the gear is obtained from the following formula:

$$K_r = \sqrt{K_t^2 + K_s^2} = K_t \bullet \sec\alpha \cdots\cdots\cdots (5.5)$$

Therefore, to obtain the radial load actually working on the shaft, the theoretical composite force, as above, is multiplied by a factor in which the accuracy and the degree of precision of the gear is taken into account. This is called the "gear factor" and is represented by the symbol f_z. In Table 5.3 is below, f_z values for spur wheels are given.

The gear factor is essentially almost the same as the previously described load factor, f_w. In some cases, however, vibrations and shocks are produced also by the machine of which the gear is a part. Here it is necessary to calculate the actual load working on the gear by further multiplying the gear load, as obtained above, by the load factor shown in Table 5.1, according to the degree of shock.

Table 5.3 Gear factors f_z

Gear	f_z
Precision gears (tolerance 0.02 mm 0.0008 inch max., for both pitch and shape)	1.05 to 1.1
Gears finished by ordinary machining work (tolerance 0.02 to 0.1 mm, 0.0008 to 0.0039 inch for both pitch and shape	1.1 to 1.3

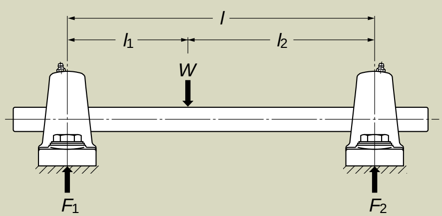
Chain transmission

When power is transmitted by chain, the effective transmission force working on the sprocket wheel is calculated by formula (5.2). To obtain the load actually working, the effective transmission force must be multiplied by the "chain factor", 1.2 to 1.5.

5.1.2 Distribution of the radial load

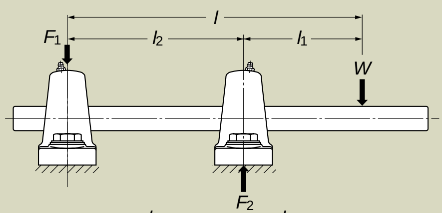
The load acting on the shaft is distributed to the bearings which support the shaft.

In Fig. 5.1, the load is applied to the shaft between two bearings; in Fig. 5.2 the load is applied to the shaft outside the two bearings. In practice, however, most cases are combinations of Fig. 5.1 and 5.2, and the load is usually a composite load, that is to say, a combination of radial and axial loads. Therefore they are calculated by the methods described in the following sections.



$$F_1 = \frac{l_2}{l} \bullet W \qquad F_2 = \frac{l_1}{l} \bullet W$$

Fig. 5.1



$$F_1 = \frac{l_1}{l_2} \bullet W \qquad F_2 = \frac{l}{l_2} \bullet W$$

Fig. 5.2

5.2 Equivalent dynamic radial load

For ball bearings used in the NTN unit, the basic rated dynamic loads C_r mentioned in the table of dimensions are applicable only when the load is purely radial. In practice, however, bearings are usually subjected to a composite load. As the table of dimensions is not directly applicable here, it is necessary to convert the values of the radial and axial lads into a single radial load value that would have an effect on the life of bearing equivalent to that of the actual load applied. This is known as the "equivalent dynamic radial load", and from this the life of the ball bearings for the unit is the calculated. The equivalent dynamic radial load is calculated by the following formula:

$$P_r = \mathrm{X} \bullet F_r + \mathrm{Y} \bullet F_a \cdots\cdots\cdots (5.6)$$

where,

P_r : Equivalent dynamic radial load N, lbf
F_r : Radial load, N, lbf
F_a : Axial load N, lbf
X : Radial factor
Y : Axial factor

Values of X and Y are shown in Table 5.4 below.

With ball bearings for the unit, when only radial load is involved, or when $F_a/F_r \leq e$ (e is value which is determined by the size of an individual bearing and the load acting thereon), the values of X and Y will be 1 and 0 respectively, resulting in the following equation:

$$P_r = F_r \cdots\cdots\cdots (5.7)$$

Table 5.4 Values of X and Y applying when $\frac{F_a}{F_r} > e$

$\frac{F_a}{C_{or}}$	e	$\frac{F_a}{F_r} > e$	
		X	Y
0.010	0.18		2.46
0.020	0.20		2.14
0.040	0.24		1.83
0.070	0.27		1.61
0.10	0.29	0.56	1.48
0.15	0.32		1.35
0.20	0.35		1.25
0.30	0.38		1.13
0.40	0.41		1.05
0.50	0.44		1.00

Note: C_{or} is the basic rated static load. (See table of dimensions.) When the value of $\frac{F_a}{C_{or}}$ or $\frac{F_a}{F_r}$ is not in conformity with those given in Table 5.4 above, find the value by interpolation.

5.3 Equivalent static radial load

In the case of a bearing which is stationary, rotates at a low speed of about 10 rpm, or makes slight oscillating movements, it is necessary to take into account the equivalent static radial load, which is the counterpart of the equivalent dynamic radial load of a rotating bearing. In this case, the following formula is used.

$$P_{or} = X_o \bullet F_r + Y_o \bullet F_a \cdots\cdots\cdots (5.8)$$

where,

P_{or} : Equivalent static radial load N, lbf
F_r : Radial load N, lbf
F_a : Axial load N, lbf
X_o : Static radial factor
Y_o : Static axial factor

With the ball bearings for the NTN unit, the values of X_o and Y_o are X_o=0.6; Y_o=0.5.

However when only radial load is involved, or when $F_a/F_r \leq e$, the following values in used:

X_o=1 Y_o=0

Accordingly, the following equation holds.

$$P_{or} = F_r \cdots\cdots\cdots (5.9)$$