Load Ratings and Fatigue Life

ANSI/ABMA Standard 11-1990
ISO Standard 76-1987

NTN Catalog A1500, which displays NTN•Bower Cylindrical and Tapered Roller Bearings, includes Dynamic Load Ratings based on the common U.S. Industry Method of 90 million revolutions (3000 hours @ 500 rpm). The purpose of this brochure is to supplement Catalog A1500 with Dynamic and Static Load Ratings based on ANSI/ABMA Standard 11-1990 which is in close conformity with ISO Standard 76-1987. The ANSI/ABMA Dynamic Load Rating is based on 1 million revolutions (500 hour @ 33-1/3 rpm).

Load Rating & Life

Bearing Life

Even in bearings operating under normal conditions, the surfaces of the raceway and rolling elements are constantly subjected to stresses which cause flaking of these surfaces to occur. This flaking is due to material fatigue, and will eventually cause the bearings to fail. The effective life of a bearing is usually defined in terms of the total number of revolutions a bearing can undergo before flaking of either the raceway surface or the rolling element surfaces occurs.

Other causes of bearing failure are attributed to problems such as seizing, abrasions, cracking, chipping, rust, etc. However, the “causes” of bearing failure are usually themselves caused by improper installation, insufficient or improper lubrication, faulty sealing or inaccurate bearing selection. Since these “causes” of bearing failure can be avoided by taking the proper precautions, and are not simply caused by material fatigue, they are considered separately from the flaking aspect.

Basic Rated Life & Basic Dynamic Load Rating

Basic rated bearing life is based on a 90% statistical model which is expressed as the total number of revolutions 90% of the bearings in an identical group, subjected to identical operating conditions, will attain or surpass before flaking due to material fatigue occurs. For bearings operating at fixed constant speeds, the basic rated life (90% reliability) is expressed in the total number of hours of operation.

The basic dynamic load rating is an expression of the load capacity of a bearing based on a constant load which the bearing can sustain for one million revolutions (the basic life rating). The basic dynamic load ratings given in the bearing table of this catalog are for bearings constructed of NTN standard bearing materials, using standard manufacturing techniques. Please consult NTN for basic load ratings of bearings constructed of special materials or using special manufacturing techniques.

The relationship between the basic rated life, the basic dynamic load rating and the bearing load is given in the formula

$$L_{10} = \left(\frac{C_r}{P_r}\right)^{10/3}$$

where,

L_{10}: Basic rated life in 106 revolutions
C_r: Basic dynamic radial rated load (Newtons)
P_r: Equivalent radial load (Newtons)

The basic rated life can also be expressed in terms of hours of operation, and is calculated by modifying the equation above as follows:

$$L_{10h} = \frac{10^6}{60 \times n}\left(\frac{C_r}{P_r}\right)^{10/3}$$

where,

L_{10h}: Basic rated life in hours
n: Rotational speed; revolutions per minute (rpm)

Adjusted Life Rating Factor

The basic bearing life rating (90% reliability factor) can be calculated through the formulas mentioned above. However, in some applications a bearing life factor of over 90% reliability may be required. To meet this requirement, bearing life can be lengthened by the use of special bearing materials or special construction techniques. In addition, the elastohydrodynamic lubrication theory shows that bearing operating conditions (lubrication, temperature, speed, etc.) exert an effect on bearing life as well. All these factors are taken into consideration when calculating bearing life, and using the life adjustment factor as prescribed in ISO 281, the adjusted bearing life can be arrived at:

$$L_{na} = a_1 \times a_2 \times a_3 \frac{10^6}{60 \times n}\left(\frac{C_r}{P_r}\right)^{10/3}$$

where,

Lna: Adjusted life rating in hours; adjusted for reliability, material and operating conditions

a1: Reliability adjustment factor

a2: Material/construction adjustment factor; for NTN Bearings which utilize case carburized steel, a2 = 1.4

a3: Operating condition adjustment factor

Life adjustment factor for reliability, a1. The values for the reliability factor a1 (for a reliability factor higher than 90%) can be found in Table 2.

TABLE 2

Reliability Level %	L_n	Life Adjustment Factor a_1
90	L_{10}	1.00
95	L_5	0.62
96	L_4	0.53
97	L_3	0.44
98	L_2	0.33
99	L_1	0.21

Life adjustment factor for material/construction, a2.

The values for the basic dynamic load ratings given in the bearing dimension tables are for bearings constructed from NTN's continued efforts at improving the quality and life of its bearings. For NTN cylindrical and tapered roller bearings which utilize case carburized steel, a2 = 1.4.

Life adjustment factor for operating conditions, a3.

The operating conditions life adjustment factor, a3, is used to account for such conditions as lubrication, operating temperature, and other operation factors which have an effect on bearing life. Generally speaking, when lubrication conditions are satisfactory, the a3 factor has a value of one. When lubricating conditions are exceptionally favorable and all other operating conditions are normal, a3 can have a value greater than one.

When lubricating conditions are particularly unfavorable and the oil film formation of the contact surfaces of the raceway and rolling elements is insufficient, the value of a3 becomes less than one. This insufficient oil film formation can be caused by the lubricating oil viscosity being too low for the operating temperature (below 20mm2/second for roller bearings); or by exceptionally low rotational speed (n rpm • dp mm less than 10,000). For bearings used under special operating conditions, please consult NTN.

Basic Static Load Rating

When stationary roller bearings are subjected to static loads of moderate magnitude, they suffer from partial permanent deformation of the contact surfaces at the contact point between the rolling elements and the raceway. The amount of deformity increases as the load increases, and if this increase in load exceeds certain limits, the subsequent smooth operation of the bearings is impaired.

It has been found that a permanent deformity of 0.0001 times the diameter of the rolling element, occurring at the most heavily stressed contact point between the raceway and rolling elements, can be tolerated without any impairment in running efficiency.

The basic static load rating refers to a fixed static load limit at which a specified amount of permanent deformation occurs. The maximum applied load values for contact stress occurring at the rolling element and raceway contact points for roller bearings is 4,000 MPa.

Allowable Misalignment

Optimized design for roller and raceway contact, not only prevents the occurrence of roller edge loading at the contact surface, but also tolerates some misalignment between the inner and outer rings for mounting error. The allowable misalignment for cylindrical roller bearings is approximately 0.001 radian (0°, 3.5') for series 200 and 300 bearings and 0.0005 radian (0°, 1.5') for series 2200 and 2300 bearings.

Combined Loading Equations

Bearings are frequently required to support a combination of radial and thrust loads. In order to calculate the bearing life under such conditions, it is necessary to calculate an Equivalent Radial Load. The theoretical bearing life under combined radial and thrust loading conditions will be the same as that which would be expected under a pure radial load equal to the Equivalent Radial Load.

Cylindrical roller bearings with opposed solid ribs on the inner and outer rings will support light to moderate thrust loads. The maximum thrust load that a cylindrical roller bearing will support is defined in the NTN • Bower Catalog A1500. Field experience and laboratory tests have proven that as long as the applied thrust load is less than the applied radial load and less than the limiting thrust rating, the fatigue life of the bearing will not be adversely affected. Therefore, the fatigue life of a cylindrical roller bearing under such combined loading conditions will be equivalent to the life under the applied radial load. The Equivalent Radial Load concept is not applicable to cylindrical roller bearings.

Tapered roller bearings, due to their basic design, generate a thrust reaction when subjected to a radial load. The magnitude of this thrust reaction is a function of the load, the included cup angle, and the size of the load zone within the bearing. For convenience in load and life calculations, a "Y" factor has been assigned to each tapered bearing series. This factor is defined as:

$$Y = 0.4\cot\alpha$$

$$\text{Where } \alpha = 1/2 \text{ included cup angle}$$

When the load on bearing (A) is pure radial (R_A) and the load zone within the bearing is 180° or less, the approximate thrust reaction (TR_A) is:

$$TR_A = \frac{R_A}{2 \times Y_A}$$

These thrust reactions are a critical part of the Equivalent Radial Load equations for tapered roller bearings.

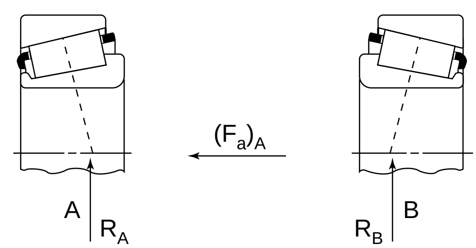
The general AFBMA equation for the equivalent radial load is:

$$P = XF_r + YF_a$$

where P = Equivalent radial load
F_r = Applied radial load
F_a = Applied thrust load
X = Radial load factor
Y = Thrust load factor

In the calculation of the equivalent radial load for a tapered bearing, the algebraic sum of all external thrust loads and the thrust reactions of the bearings must be considered. All factors are automatically included in the Equivalent Radial Load formulas shown in Table I. Note, when the calculated Equivalent Radial Load is less than the applied radial load, the radial load alone is used to estimate the bearing life.

TABLE I
EQUIVALENT RADIAL LOAD FORMULAS
SINGLE ROW MOUNTING



Thrust Condition	Equivalent Radial Load
$\frac{R_A}{2 \times Y_A} < \frac{R_B}{2 \times Y_B} + (F_a)_A$	$P_a = 0.40R_A + Y_A\left(\frac{R_B}{2 \times Y_B} + (F_a)_A\right)$ $P_B = R_B$
$\frac{R_A}{2 \times Y_A} > \frac{R_B}{2 \times Y_B} + (F_a)_A$	$P_A = R_A$ $P_B = 0.40R_B + Y_B\left(\frac{R_A}{2 \times Y_A} + (F_a)_A\right)$