Life and Load Ratings – Radial Ball Bearings

Bearing Life

When bearings rotate, the inner and outer rings and rolling elements are constantly loaded. This produces material fatigue and eventually bearing failure. The total number of revolutions before a failure occurs is called the basic rating life

Life of individual bearings varies considerably, even if they are of the same size, same material, same heat treatment and are under the same operating conditions.

Statistically, the total number of revolutions reached or exceeded by 90% of a sufficiently large group of apparently identical bearings before the first evidence of material fatigue occurs is called the **basic rating life.**

Load Ratings

Manufacturers of ball bearings typically publish **Load Ratings** for each bearing they produce. The methods used to calculate ratings can vary from manufacturer to manufacturer. However, both ABMA and ISO have published standards related to load ratings.

- **ABMA Std. 9 –** Load Ratings and Fatigue Life for Ball Bearings
- **ABMA Std. 12.1 and 12.2 –** Instrument Ball Bearings
- **ISO 76 –** Static Load Ratings
- **SO 281 –** Dynamic Load Ratings and Rating Life

With regard to load ratings, one thing to remember is - static load ratings (Cor) and dynamic load ratings (Cr) are formulated on completely different premises and have no direct relationship to one another.

Dynamic load ratings are determined by bearing geometry
number and size of balls, bearing pitch diameter, and ring and ball material. This load rating is used in conjunction with the actual applied radial load to calculate bearing fatigue life.

The static load rating relates to limiting loads applied to non-rotating bearings. The static load rating depends on the maximum contact stress between the balls and either of the two raceways. It is affected by material, number and size of balls, raceway curvatures, raceway depths, and contact angles. It is also based on using clean, high quality bearing steel with typical hardness levels of 58-64 HRC for rings and 60-65 HRC for balls.

Based on the above, for a given bearing, a change in the pitch circle can impact the dynamic load rating, and a change in the ball diameter or ball quantity can impact both load ratings. Changing all of these variables at the same time (depending on what the actual changes are) can result in the dynamic capacity moving in one direction and the static capacity moving in the opposite direction (when compared to the original configuration).

Basic Dynamic Load Rating Cr

The basic dynamic load rating of a bearing with rotating inner ring and stationary outer ring is that load of constant magnitude and size which a sufficiently large group of apparently identical bearings can endure for a basic rating life of one million revolutions.

Life Formula

The equation for the basic rating life for dynamically loaded ball bearings is as follows

$$L_{10} = (Cr/P)^3 \text{ X } 10^6 \qquad \text{(Revolution)}$$

$$L_{10}h = 16667 / n \cdot (Cr/P)^3 \qquad \text{(hours)}$$

Where:

L_{10} = Basic rating life
Cr = Basic dynamic load rating (N)
n= R.P.M (revolution per minute)
$L_{10}h$ = Basic rating life in operating hours
P = Equivalent load (N)

Examples of rating life L_{10} h values

OPERATING CONDITIONS	BASIC RATING LIFE $L_{10}h$
Infrequent operation	500
Short or intermittent operation. Failure has little effect on function	4000 ~ 8000
Intermittent operation. Failure has significant effect on function	8000 ~ 12000
8 hours of non-continuous operation	12000 ~ 20000
8 hours of continuous operation	20000 ~ 30000
24 hours continuous operation	40000 ~ 60000
24 hours of guaranteed trouble free operation	100000 ~ 200000

Adjusted Life Formula

The above life formula is for general use. In cases where a reliability of over 90% is required and where influences apart from load and speed or operating frequency should be taken into account for the rating life, ISO 281, 1990 gives an extended life formula:

$$Lna = a_1 \text{ x } a_2 \text{ x } a_3 \text{ x } (Cr/P)^3 \text{ x } 10^6 \text{ (Revolution)}$$

Where:

Lna = Adjusted rating life in millions with a reliability of (100-n)% (n= the reliability rate)
Cr = Basic dynamic load rating (N)
P= Equivalent dynamic load rating (N)
a_1=Factor for a reliability other than 90%
a_2=Factor for non-conventional materials
a_3=Factor for non-conventional operating conditions, in particular lubrication

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Reliability Factor a_1

When a reliability of over 90% is required, the corresponding factor should be selected from the following table

Reliability	90	91	92	93	94	95	96	97	98	99	99.6	99.9
a_1	1	0.92	0.84	0.77	0.64	0.62	0.53	0.44	0.33	0.21	0.1	0.037

Material Factor a_2

Improvement in manufacturing techniques for raw material and for heat treatment of components has led to an extended fatigue life for bearings. AST's standard bearing materials are a superior quality of vacuum degassed steel leading to an extended life for bearings. The basic load ratings have been established by taking this longer life into consideration. This gives an increase in the operating life in hours of a factor of 2.2 and a factor of 1.3 for the load carrying capacity. The material factor a_2=1.

Operating Conditions Factor a_3

This is an adjustment factor to meet non-conventional operating conditions for lubrication, temperature and load, Under good lubrication conditions with a permanent oil film between rolling elements and rings, the factor a_3=1. In unfavorable conditions ($dm \cdot n \leq 10000$) a factor $a_3 < 1$ must be selected.

dm (mean bearing diameter) = (D+d)/2
n= the operating speed

At temperatures above 120ºC, greater dimensional changes occur and the material hardness deteriorates which affects the bearing life.
The operating factor f_t for temperature can be taken from the following table

BEARING TEMPERATURE ºC	120	150	175	200	225	250	275	300
TEMPERATURE FACTOR f_t	1	0.9	0.85	0.75	0.65	0.6	0.52	0.45

Basic Static Load Rating Cor

The Basic Static Load Rating applies to bearings where rotating motion does not occur or occurs only infrequently. The Basic Load Ratings and calculation methods are based on methods described in ISO 281 and in ISO Recommendations NR.76, taking into account the current level of bearing technology.
Excessive static load causes brinelling at the contact point between the rolling element and raceway. As a standard of permissible static load, the basic load rating Cor for radial bearings is specified as follows:

- Maximum contact pressure at the contact point between rolling element and bearing ring to be 4200 MPa and total permanent deformation of the bearing of approximately 1/10,000th of the rolling element's diameter.
- Basic static load rating for stainless steel is 80% of that for standard bearing steel

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Equivalent Dynamic Bearing Load "P"

Load conditions on bearings are usually a combination of radial and axial loads, In order to establish the equivalent radial load with definite force and direction we use the following formula:

$$P=XFr+YFa \text{ (N)}$$

Where:

Fr= Radial load (N)
Fa=Axial load (N)
X=Radial load factor
Y=Axial load factor
D=Ball diameter (mm)

Radial load factor and axial load factor

$Fa/(ZD^2)$	e	Fa/Fr ≤ e		Fa/Fr > e	
		X	Y	X	Y
0.172	0.19	1	0	0.56	2.3
0.345	0.22	1	0	0.56	1.99
0.689	0.26	1	0	0.56	1.71
1.03	0.28	1	0	0.56	1.55
1.38	0.3	1	0	0.56	1.45
2.07	0.34	1	0	0.56	1.31
3.45	0.38	1	0	0.56	1.15
5.17	0.42	1	0	0.56	1.04
6.89	0.44	1	0	0.56	1

- This table applies to radial ball bearings with a bore diameter up to 10mm, and thin type ball bearings with a bore diameter up to 50 mm, consult with AST's Engineering team for calculations for other types of bearings.