3. Rated Load and Bearing Life

3-1 Bearing Life

Required properties for bearings are;

- Large load capacity and rigidity
- Small friction loss
- Smooth rotation, etc.

And, these properties should last for a specified period.

Even if bearings are used under the normal conditions, it is inevitable for flaking to happen to them after some period, due to deterioration of grease, repeatedly applied stress to raceway or rolling element, and/or general wear and tear, which in return increase the noise/vibration level and lower their accuracy.

Progress of flaking eventually ends the bearing' s life. The life of bearing can be measured either by total number of rotations or by a life period, and depending on measuring criteria, they are called as noise life, tear life, grease life, or rolling fatigue life. However, the rolling fatigue life is most commonly used when mentioning the life of bearing, and a lot of times, it is just called as the bearing life.

Also, bearings could stick to the raceway after burning or become cracked or rusted, but these incidences are regarded as the failures, and should be distinguished from the expected life span of bearings.

3-2 Basic Rating Life and Dynamic Load Rating

Lives of bearings of a kind vary widely, even if they have been operating under the same condition, as shown in the Table 3-1 below. This is because the fatigue level for each bearing is different. Therefore, it is meaningless to choose the average life of bearings as the life of a certain bearing, so, the statistically-obtained rating lives are used instead.

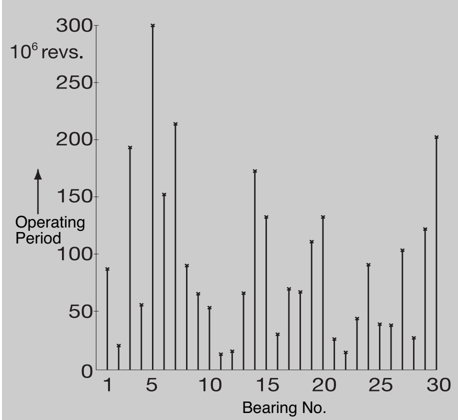

Table 3-1 Distribution of Bearing Fatigue Lives
(Test Result for 30 of Deep Groove Bearing No. 6309)

Basic rating life is the total number of rotations or total rotation time, that could be achieved by 90% of bearings of a kind, which have been rotated under the same condition.

Basic dynamic load rating, representing the bearing' s dynamic load carrying capacity, is the load with constant direction and magnitude, which allows one million rotations of rated fatigue life when outer ring is fixed and inner ring is rotating. Radial bearing takes only the pure radial loads, and thrust bearing takes only the pure axial loads.

Basic rating lives of KBC bearings have been determined in accordance with ISO 281/I and KS B 2019, and Cr of radial bearing and Ca of thrust bearing are shown in the dimension tables.

The correlations among bearing' s basic rating life, basic dynamic load rating, and dynamic equivalent load are shown in the Equation 3-1. Also, when basic rating life is represented as a rotating period, their relations are shown in the Equation 3-2.

$$L_{10} = L = \left(\frac{C}{P}\right)^{p} \quad \text{(Equation 3-1)}$$

$$L_{h10} = L_h = \frac{(C/P)^{p}}{60 \cdot n} = \frac{L_{10}}{60 \cdot n} \quad \text{(Equation 3-2)}$$

Whereas,

L_{10}, L : Basic rating life [10^6 Rotations]

L_{h10}, L_h : Basic rating life [Time]

C : Basic dynamic load rating [N], {kgf}

P : Dynamic equivalent load [N], {kgf}

(Refer to Pg. 34)

p : Life exponent

Ball bearing p=3

Roller bearing p=10/3

n : Rotating speed [rpm]

Above equation can be changed to;

$$L_h = \frac{L \cdot 500 \cdot 33^1/_3 \cdot 60}{n \cdot 60}$$

$$\frac{L_h}{500} = \left(\frac{C}{P}\right)^{P} \cdot \left(\frac{33^1/_3}{n}\right)$$

or, $$\sqrt[P]{\frac{L_h}{500}} = \sqrt[P]{\frac{33^1/_3}{n}} \cdot \frac{C}{P}$$

From above equation, both dynamic load factor and speed factor can be calculated.

Dynamic load factor f_L is defined as follows.

$$f_L = \sqrt[P]{\frac{L_h}{500}} \quad \text{(Equation 3-3)}$$

Here, when f_L=1, the life can be calculated to be 500 hours.

Speed factor f_n is obtained as follows.

$$f_n = \sqrt[P]{\frac{33^1/_3}{n}} \quad \text{(Equation 3-4)}$$

Hear the speed is $33^1/3\ \text{min}^{-1}$ when 1 is for ball bearings the values of L_h and f_L rotational speed n and f_n are shown in tables 3-1 and 3-2 where as for roller bearings the values are shown table 3-3 and 3-4.

Bearing life equation can be simplified as below vsing dymanic load factor and speed factor.

$$f_L = \frac{C}{P} \cdot f_n \quad \text{(Equation 3-5)}$$

Table 3-1 Basic Rating Life and Dynamic Load Factor f_L(for Ball Bearings)

$$f_L = \sqrt[3]{\frac{L_h}{500}}$$

L_h h	f_L	L_h h	f_L	L_h h	f_L	L_h h	f_L	L_h h	f_L
100	0.585	420	0.944	1700	1.5	6500	2.35	28000	3.83
110	0.604	440	0.958	1800	1.53	7000	2.41	30000	3.91
120	0.621	460	0.973	1900	1.56	7500	2.47	32000	4
130	0.638	480	0.986	2000	1.59	8000	2.52	34000	4.08
140	0.654	500	1	2200	1.64	8500	2.57	36000	4.16
150	0.669	550	1.03	2400	1.69	9000	2.62	38000	4.24
160	0.684	600	1.06	2600	1.73	9500	2.67	40000	4.31
170	0.698	650	1.09	2800	1.78	10000	2.71	42000	4.38
180	0.711	700	1.12	3000	1.82	11000	2.8	44000	4.45
190	0.724	750	1.14	3200	1.86	12000	2.88	46000	4.51
200	0.737	800	1.17	3400	1.89	13000	2.96	48000	4.58
220	0.761	850	1.19	3600	1.93	14000	3.04	50000	4.64
240	0.783	900	1.22	3800	1.97	15000	3.11	55000	4.79
260	0.804	950	1.24	4000	2	16000	3.17	60000	4.93
280	0.824	1000	1.26	4200	2.03	17000	3.24	65000	5.07
300	0.843	1100	1.3	4400	2.06	18000	3.3	70000	5.19
320	0.862	1200	1.34	4600	2.1	19000	3.36	75000	5.31
340	0.879	1300	1.38	4800	2.13	20000	3.42	80000	5.43
360	0.896	1400	1.41	5000	2.15	22000	3.53	85000	5.54
380	0.913	1500	1.44	5500	2.22	24000	3.63	90000	5.65
400	0.928	1600	1.47	6000	2.29	26000	3.73	100000	5.85

Table 3-2 Rotating Speed and Speed Factor f_n(for Ball Bearings)

$$f_n = \sqrt[3]{\frac{33\frac{1}{3}}{n}}$$

n min^{-1}	f_n	n min^{-1}	f_n	n min^{-1}	f_n	n min^{-1}	f_n	n min^{-1}	f_n
10	1.49	55	0.846	340	0.461	1800	0.265	9500	0.152
11	1.45	60	0.822	360	0.452	1900	0.26	10000	0.149
12	1.41	65	0.8	380	0.444	2000	0.255	11000	0.145
13	1.37	70	0.781	400	0.437	2200	0.247	12000	0.141
14	1.34	75	0.763	420	0.43	2400	0.24	13000	0.137
15	1.3	80	0.747	440	0.423	2600	0.234	14000	0.134
16	1.28	85	0.732	460	0.417	2800	0.228	15000	0.131
17	1.25	90	0.718	480	0.411	3000	0.223	16000	0.128
18	1.23	95	0.705	500	0.405	3200	0.218	17000	0.125
19	1.21	100	0.693	550	0.393	3400	0.214	18000	0.123
20	1.19	110	0.672	600	0.382	3600	0.21	19000	0.121
22	1.15	120	0.652	650	0.372	3800	0.206	20000	0.119
24	1.12	130	0.635	700	0.362	4000	0.203	22000	0.115
26	1.09	140	0.62	750	0.354	4200	0.199	24000	0.112
28	1.06	150	0.606	800	0.347	4400	0.196	26000	0.109
30	1.04	160	0.593	850	0.34	4600	0.194	28000	0.106
32	1.01	170	0.581	900	0.333	4800	0.191	30000	0.104
34	0.993	180	0.57	950	0.327	5000	0.188	32000	0.101
36	0.975	190	0.56	1000	0.322	5500	0.182	34000	0.0993
38	0.957	200	0.55	1100	0.312	6000	0.177	36000	0.0975
40	0.941	220	0.533	1200	0.303	6500	0.172	38000	0.0957
42	0.926	240	0.518	1300	0.295	7000	0.168	40000	0.0941
44	0.912	260	0.504	1400	0.288	7500	0.164	42000	0.0926
46	0.898	280	0.492	1500	0.281	8000	0.161	44000	0.0912
48	0.886	300	0.481	1600	0.275	8500	0.158	46000	0.0898
50	0.874	320	0.471	1700	0.27	9000	0.155	50000	0.0874

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Table 3-3 Basic Rating Life and Dynamic Load Factor f_L (for Roller Bearings)

$$f_L = \sqrt[10/3]{\frac{L_h}{500}}$$

L_h h	f_L	L_h h	f_L	L_h h	f_L	L_h h	f_L	L_h h	f_L
100	0.617	420	0.949	1700	1.44	6500	2.16	28000	3.35
110	0.635	440	0.962	1800	1.47	7000	2.21	30000	3.42
120	0.652	460	0.975	1900	1.49	7500	2.25	32000	3.48
130	0.668	480	0.988	2000	1.52	8000	2.3	34000	3.55
140	0.683	500	1	2200	1.56	8500	2.34	36000	3.61
150	0.697	550	1.03	2400	1.6	9000	2.38	38000	3.67
160	0.71	600	1.06	2600	1.64	9500	2.42	40000	3.72
170	0.724	650	1.08	2800	1.68	10000	2.46	42000	3.78
180	0.736	700	1.11	3000	1.71	11000	2.53	44000	3.83
190	0.748	750	1.13	3200	1.75	12000	2.59	46000	3.88
200	0.76	800	1.15	3400	1.78	13000	2.66	48000	3.93
220	0.782	850	1.17	3600	1.81	14000	2.72	50000	3.98
240	0.802	900	1.19	3800	1.84	15000	2.77	55000	4.1
260	0.822	950	1.21	4000	1.87	16000	2.83	60000	4.2
280	0.84	1000	1.23	4200	1.89	17000	2.88	65000	4.31
300	0.858	1100	1.27	4400	1.92	18000	2.93	70000	4.4
320	0.875	1200	1.3	4600	1.95	19000	2.98	80000	4.58
340	0.891	1300	1.33	4800	1.97	20000	3.02	90000	4.75
360	0.906	1400	1.36	5000	2	22000	3.11	100000	4.9
380	0.921	1500	1.39	5500	2.05	24000	3.19	150000	5.54
400	0.935	1600	1.42	6000	2.11	26000	3.27	200000	6.03

Table 3-4 Rotating Speed and Speed Factor f_n (for Roller Bearings)

$$f_n = \sqrt[10/3]{\frac{33\frac{1}{3}}{n}}$$

n min^{-1}	f_n	n min^{-1}	f_n	n min^{-1}	f_n	n min^{-1}	f_n	n min^{-1}	f_n
10	1.44	55	0.861	340	0.498	1800	0.302	9500	0.183
11	1.39	60	0.838	360	0.49	1900	0.297	10000	0.181
12	1.36	65	0.818	380	0.482	2000	0.293	11000	0.176
13	1.33	70	0.8	400	0.475	2200	0.285	12000	0.171
14	1.3	75	0.784	420	0.468	2400	0.277	13000	0.167
15	1.27	80	0.769	440	0.461	2600	0.270	14000	0.163
16	1.25	85	0.755	460	0.455	2800	0.265	15000	0.16
17	1.22	90	0.742	480	0.449	3000	0.259	16000	0.157
18	1.2	95	0.73	500	0.444	3200	0.254	17000	0.154
19	1.18	100	0.719	550	0.431	3400	0.25	18000	0.151
20	1.17	110	0.699	600	0.42	3600	0.245	19000	0.149
22	1.13	120	0.681	650	0.41	3800	0.242	20000	0.147
24	1.1	130	0.665	700	0.401	4000	0.238	22000	0.143
26	1.08	140	0.65	750	0.393	4200	0.234	24000	0.139
28	1.05	150	0.637	800	0.385	4400	0.231	26000	0.136
30	1.03	160	0.625	850	0.378	4600	0.228	28000	0.133
32	1.01	170	0.613	900	0.372	4800	0.225	30000	0.13
34	0.994	180	0.603	950	0.366	5000	0.222	32000	0.127
36	0.977	190	0.593	1000	0.36	5500	0.216	34000	0.125
38	0.961	200	0.584	1100	0.35	6000	0.211	36000	0.123
40	0.947	220	0.568	1200	0.341	6500	0.206	38000	0.121
42	0.933	240	0.553	1300	0.333	7000	0.201	40000	0.119
44	0.92	260	0.54	1400	0.326	7500	0.197	42000	0.117
46	0.908	280	0.528	1500	0.319	8000	0.193	44000	0.116
48	0.896	300	0.517	1600	0.313	8500	0.19	46000	0.114
50	0.885	320	0.507	1700	0.307	9000	0.186	50000	0.111

3-3 Adjusted Rating Life

The basic rating life of a bearing, the generally chosen method of stating a bearing life, can be obtained by using the Equations 3-1 and 3-2, but when the reliability of other than 90%(100-n%)(Where, n is the failure percentage) of bearing of a kind is required, they can be calculated by using the reliability factor a_1 from the following equation.

$$L_n = a_1 \cdot L_{10} \quad \text{(Equation 3-6)}$$

Also, basic rating life is calculated, assuming that usual bearing materials are used, and that normal conditions(good mounting, lubrication, and vibro-isolation without extreme load or operating temperature) are provided, but, if an adjusting rating life, L_{10a} for the bearing made of special material or under special conditions, is needed, following equation using the life adjustment factors of both material factor, a_2 and operating condition factor a_3 can be applied.

$$L_{10a} = a_2 \cdot a_3 \cdot L_{10} \quad \text{(Equation 3-7)}$$

The adjusted rating life, L_{na} for the bearing requiring all the adjustments mentioned above, can be obtained using the following equation.

$$L_{na} = a_1 \cdot a_2 \cdot a_3 \cdot L_{10} \quad \text{(Equation 3-8)}$$

However, if bearing dimensions are selected by using the adjusted rating lives, or L_{na} larger than L_{10}, the variables other than life, such as permissible deformation and hardness of shaft or hosing, etc., have to be taken into consideration.

Table 3-5 Reliability Factor

Reliability(%)	Ln	a_1
90	L_{10}	1
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

3-3-1 Reliability Factor a_1

When an adjusted rating life of reliability of 100-n% needs to be obtained, the values of reliability factor, a_1 shown in the following Table 3-5, have to be used.

3-3-2 Material Factor a_2

Reliability factor, a_2, is used to adjust the bearing life, which lengthens due to better bearing materials, and for usual KBC bearings of standard materials and production, a_2 is 1.

For the bearings of special materials and production, a_2 is larger than 1, but, for the bearings treated for better stability of dimensions, a_2 can be smaller than 1, because their hardness could have been lowered. For detailed informations, please contact us.

3-3-3 Operating Condition Factor a_3

The operating condition factor, a_3 is used to adjust the bearing life influenced by operating conditions of bearings, specially, fatigue life by lubricating condition.

Where there is no inclining of inner and outer ring, and where rolling element is sufficiently separated from raceway by lubricant, a_3 is generally regarded to be 1.

However, a_3 is smaller than 1 in following cases.

- When kinetic viscosity is too low.
  For ball bearings, below $13mm^2/s(1mm^2/s=1cSt)$
  For roller bearings, below $20mm^2/s$
- When rotating speed is too slow.
  When rotating speed(rpm) times pitch circle diameter(mm) of rolling element is smaller than 10,000.
- When operating temperature of bearing is too high. (Refer to Table 3-6)
- When any foreign material or moisture is mixed with lubricant.
- When load distribution inside the bearing is abnormal.

However, for the bearing of specially improved material or production with $a_2 > 1$, $a_2 \cdot a_3 < 1$ if lubricating condition is poor.

Table 3-6 Operating Condition Factor Based on Operating Temperatures

Operating Temperature	a_3
150℃	1
200℃	0.73
250℃	0.42
300℃	0.22

3-4 Operating Machine and Required Life

When selecting a bearing, it is not economical to choose a bearing of fatigue life unnecessarily longer than required, because it usually means a bigger bearing. In other words, a bearing life should not be a sole factor in selecting a bearing, but all of strength, rigidity, and dimension of shaft to which bearing is to be mounted have also to be considered.

Table 3-7 shows the dynamic load factors f_L and typical machines of application for each of various application methods, safety factors, operating intervals and cycles.

Table 3-7 Dynamic Load Factor f_L and Typical Machines of Application

Operating Condition	Values of f_L and Typical Applications				
	Below 2	2...3	3...4	4...6	6
Occasional short operation	Vacuum Washer Motored Tools	Farming machines Office machines			
Occasional short operation but requires high reliability	Medical instrument	Construction equipment Air-conditioner for homes Hot-water circulation pump	Elevator Crane		
Fairly long operation although not continuously	Small motor Passenger cars Bus Truck	Machine tools Crusher Vibration screen	Rotary press Compressor		
More than 8 hours of continuous operation per day		Escalator	Axle box for passenger coaches Air conditioner Large motor Knitting machine	Axle box for locomotive cars Traction motor Press machine	Paper making machine
Continuous operation requiring high reliability				Spinning machine	Power generating equipment Pumping equipment Mine draining equipment

3-5 Basic Static Load Rating

When an excessive load or sudden impact load is applied to a bearing, permanent plastic deformation, namely indentation, to the contact area between raceway and rolling element might occur. The larger the applied load is, the bigger the indentation, and the greater it hinders with smooth rotation of bearing.

Basic static load rating, C_O, is the load that theoretically generates the contact stress as follows on the center of contact area between rolling element and raceway, where the most load is applied.

- Self-aligning ball bearing 4600 N/mm²
- All ball bearings 4200 N/mm²
  (Except self-aligning ball bearings)
- All roller bearings 4000 N/mm²

When this basic static load rating, C_O, is applied to a bearing, the sum of permanent plastic deformation of rolling element and raceway at the contact point, where the most load is applied, gets to be approximately 1/10,000 of diameter of rolling element.

The values of basic static load rating, C_O , are represented as C_{Or} for radial bearings, and C_{Oa} for thrust bearings, but in the dimension tables, they are simply shown as C_O

3-6 Permissible Static Equivalent Load

A static load factor, f_S, is calculated to check whether a bearing with appropriate load rating has been selected.

$$f_s = \frac{C_0}{P_0} \qquad \text{(Equation 3-9)}$$

Whereas,
f_S : Static load factor
C_O : Static load rating [N], {kgf}
P_O : Static equivalent load [N], {kgf}
(Refer to Page 34.)

Static load factor, f_S, is the safety factor against the permanent plastic deformation of contact area of rolling element. The value of f_S has to be large enough to insure the smooth and especially quiet operation, however, if it is not required to be too quiet, then small value of f_S should be sufficient. Generally, the values shown in the following Table 3-8 are recommended.

Table 3-8 Static Load Factor f_s

Operating Conditions of Bearings	Lower Limit of f_s Ball Bearing	Roller Bearing
Specially quiet operation	2	3
Existence of vibration/impact	1.5	2
Normal operation	1	1.5
Not too quiet operation	0.5	1

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