Fitting

Recommended fitting details between the bearing and shaft or housing are shown in Table 1.

Table 1. Units : mm

Bearings	For Shafts			For Housings		
	Shaft Dia.	Ordinary Clearance f6~g6	Tight Clearance h6	Hole Dia.	Clearance Fit H7	Locking Fit J7
L-series	5		0	10	+0.018	+0.010
	6		−0.009	12	0	−0.008
	8	−0.010		15		
	10	−0.019	0	19	+0.021	+0.012
	12		−0.011	21	0	−0.009
	16			28		
	20			32		
	25	−0.010	0	40	+0.025	+0.014
	30A	−0.021	−0.013	45	0	−0.011
	30B			47		
	35			52		
	40	−0.012	0	60	+0.030	+0.018
	50A	−0.025	−0.016	76	0	−0.012
	50B			80		
	60		0	90	+0.035	+0.022
	80	−0.015	−0.019	120	0	−0.013
	100	−0.031	0 −0.022	150	+0.040 0	+0.026 −0.014
LE-series		h6	k6		H7	J7

Note 1: It is recommended that for normal fitting conditions, standard clearance fit dimensions for shafts and housings be used. The proper clearance between a bearing and a shaft is 10μm under normal conditions.

Note 2: In the case of pre-load application where unwanted clearance is to be avoided, the bearing assembly's status should be checked in order to prevent excessive preload from exerting adverse effects on the bearings' operating performance and life.
Following bearing assembly into the housing and after shaft insertion, one of three different states, see Table 2, must be verified by revolving the shaft manually. If the condition found is the same as in C_3, (excessive pre-loading) either review the fit tolerance or contact us for advice.

Table 2.

Classification	Required Check-up Item	Recommended Clearance
C_1	Shaft manually revolves easily in the rotating direction.	0~+10μm
C_2	Shaft manually revolves but with some force in the rotating direction.	0~−10μm
C_3	Shaft is unable to rotate manually in the rotational direction. (NG)	More than −10 μm

Installation

Typical installation examples are shown in Fig. 2 ~ Fig. 6.

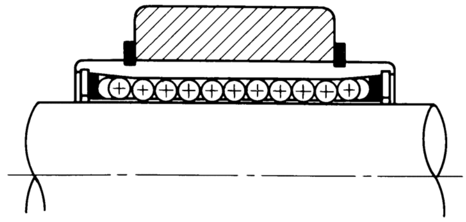


Fig. 2. The method features stop rings fixed into bearing grooves for installation.

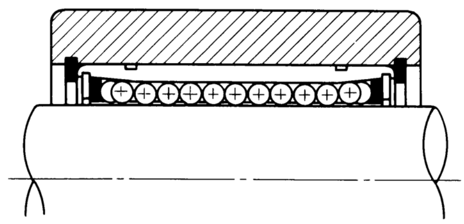


Fig. 3. The bearing installation method shows stop rings fixed into the inner grooves of a housing.

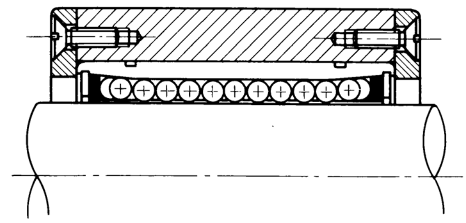


Fig. 4. The method uses fastening plates on both ends of a housing.

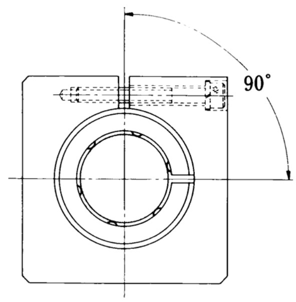


Fig. 5. The ADJ-type fixing method makes adjusting the clearance possible.

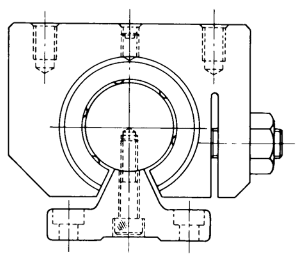


Fig. 6. The OP-type fixing method allows adjusting the clearance.

Notes for Installation

1) In press fitting a bearing into a housing, use a special setter for smooth drive, as shown in Fig. 7, instead of hitting the snap rings directly on both ends of the bearing.

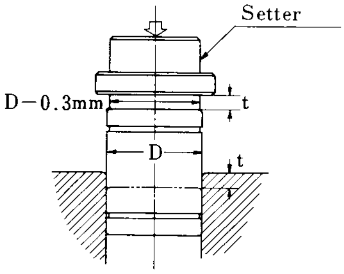


Fig. 7.

2) Do not use a single bolt for installation of a bearing. Using a single bolt may cause partial deformation of the outer sleeve and shorten bearing life significantly.
3) Insert the shaft carefully following alignment of each center to prevent its end from striking against a retainer or a snap ring.
4) Carefully assure, at the various manufacturing stages, concentricity of the housing holes which accommodate more than two bearings on the same shaft, in order not to markedly lower operational performance of the bearings.
5) If moment loads are expected to be applied to a bearing, use two or more bearings per shaft, installed with the proper spacing between each other.
6) To improve product life and operational performance uniform distribution of grouping of balls, corresponding to the direction of a load applied, is recommended in installing a bearing into a housing, as shown in Fig. 8.

	Number of Rows of Balls		
	Four Rows	Five Rows	Six Rows
Cases with one row of balls located right under applied load	F_1 P F_1=P	F_1 P_0 P_0 P F_1=1.106P	F_1 P_0 P_0 P F_1=1.354P
Cases with uniformly distributed rows of balls against load applied	F_2 P P F_2=1.414P	F_2 P P F_2=1.618P	F_2 P P F_2=1.732P
F_2/F_1	1.414	1.463	1.280

Fig. 8. Effective layout of rows of balls responding to the direction of applied loads

Felt Sealing

If lowering of frictional resistance is required along with a sealing function, felt seals are recommended. For further enhancement of dusttight and oil-leakage preventive functions, a double sealing method, as illustrated in Fig. 9, is recommended.

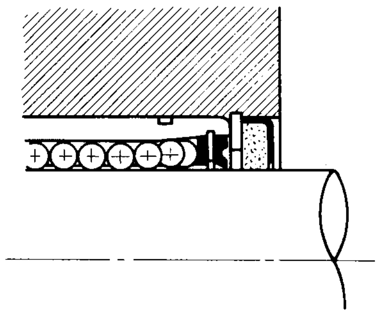


Fig. 9. Double Sealed Method

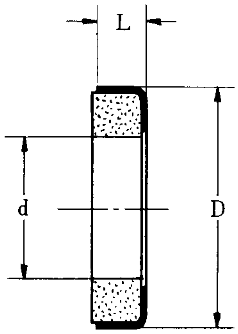


Table 3. Felt Seal Specification Chart

Type	Major Dimension(mm) d	D	L	Appropriate Bearings
FS− 6	6	12	2	L− 6
FS− 8	8	15	2	L− 8
FS−10	10	19	3	L−10
FS−12	12	21	3	L−12
FS−13	13	23	3	L−13
FS−16	16	28	4	L−16
FS−20	20	32	4	L−20
FS−25	25	40	5	L−25A・B
FS−30A	30	45	5	L−30A
FS−30B	30	47	5	L−30B
FS−35	35	52	5	L−35
FS−40	40	60	5	L−40
FS−50A	50	76	7	L−50A
FS−50B	50	80	7	L−50B
FS−60	60	90	7	L−60

Basic Load Rating and Rated Life

Rated Life:

The term is defined as the travel distance in fifty kilometers which 90% of a group of balls, of the same size and the same type, can cover under the same condition, without any signs of flaking caused by rolling contact fatigue.

Basic Dynamic Load Rating:

The above term is represented by the load, acting on a row of balls which are situated in the line of action, and show no change in direction and magnitude during their rated life of 50 km.

Basic Static Load Rating:

This term indicates a load which causes a permanent deformation amounting to ten thousandths of the rolling element's diameter at the contact surface of the ball under maximum stress, without any changes in the direction and magnitude of the acting load.

Formula for Rated Life Calculation

The rated life is calculated by the following equation, which includes such factors as loads acting on bearings, shaft hardness, operating temperature, impacts, vibrations, moment loads and arrangement of aligned balls.

$$L = \left(\frac{f_H \cdot f_t \cdot f_B \cdot C}{f_s \cdot k \cdot P} \right)^3 \cdot 50\ (km) \quad \cdots (1)$$

L	: Rated life	km
C	: Basic dynamic load rating	kgf
P	: Radial load	kgf
f_H	: Shaft hardness factor	Fig. 10
f_t	: Temperature factor	Fig. 11
f_B	: Layout factor of rows of balls	Fig. 12
f_s	: Impact and vibration factor	Table 4
k	: Moment load factor	Fig. 14 & 15

In case both the stroke and stroking frequency are expected to be constant, the rated life (L) in kilometers, obtained in the previous equation, can be converted into rated life in hours (L_h) by the following formula.

$$L_h = \frac{L \cdot 10^6}{2 \cdot l_s \cdot n \cdot 60}\ (hr) \quad \cdots (2)$$

L_h	: Rated life in hours	hr
l_s	: Stroke	mm
n	: Cycles per minute	cpm

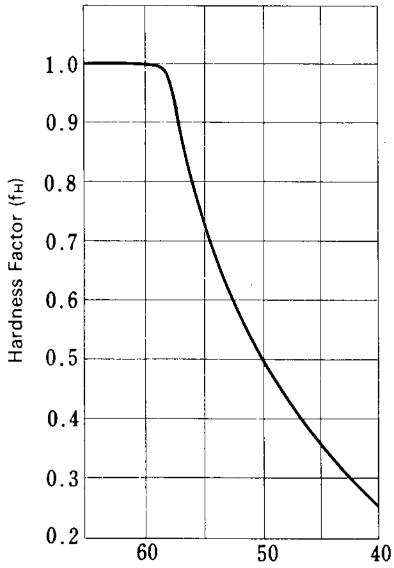


Fig. 10. Hardness Factor (f_H)

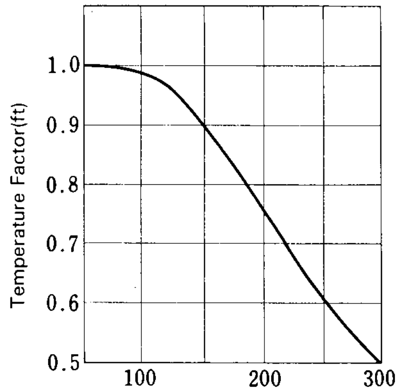


Fig. 11. Temperature Factor (f_t)

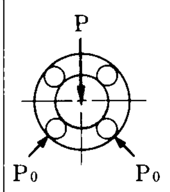
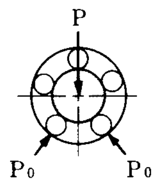
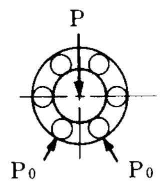
	Number of Rows of Balls		
	Four Rows	Five Rows	Six Rows
Illustrated correlation between rows of balls and applied loads			
f_B	1.414	1.463	1.280

Fig. 12. Layout Ball Row Factors

Table 4. Impact and Vibration Factors

Operating Conditions	f_s
Neither impacts nor vibrations exist with reciprocating speed, V, of 300 mm/sec or less	1 ~1.5
Slight impacts or vibrations exist with reciprocating speed, V, of 1000 mm/sec or less	1.5~2.0
Heavy impacts or vibrations exist with reciprocating speed, V, of 1000 mm/sec or more	2.0~4.0

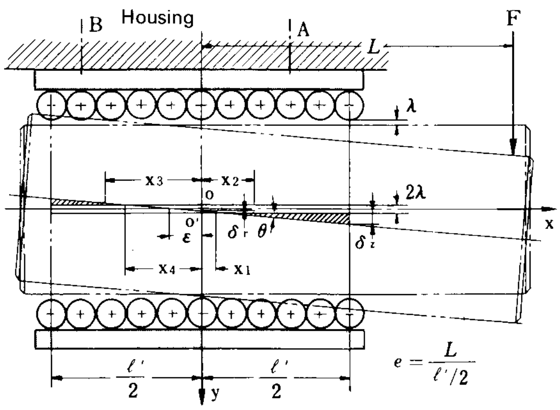
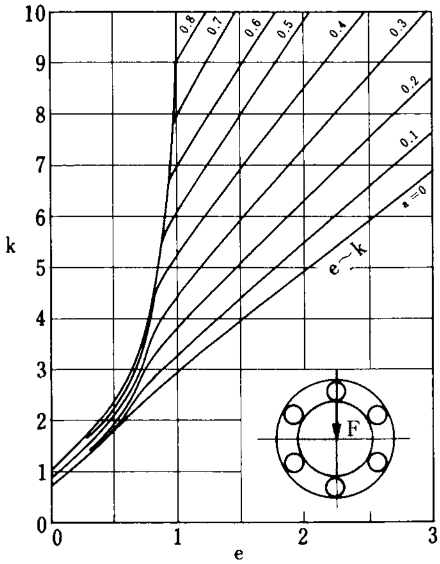
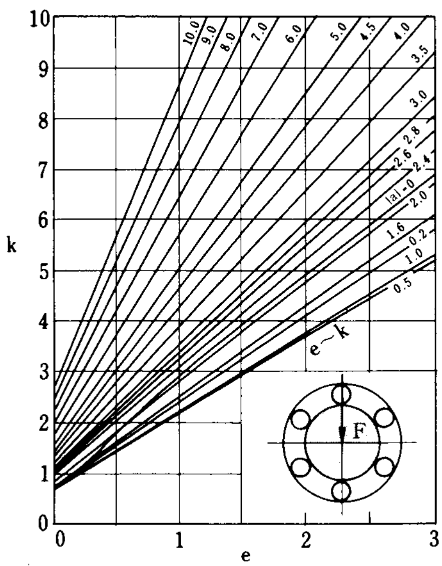


Fig. 13. Loaded Condition with Moment Applied



A case with positive bearing clearance in six rows of balls.

Fig. 14. Moment Load Factor, k



A case in which negative bearing clearance, or pre-loading, exists in six rows of balls.

Fig. 15. Moment Load Factor, k

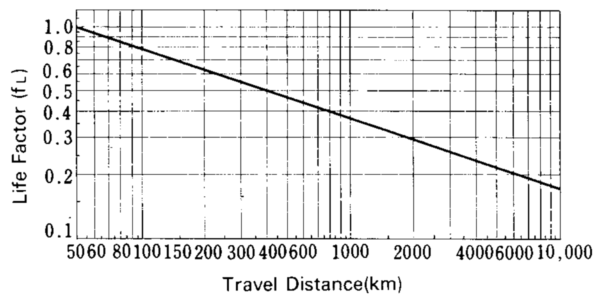
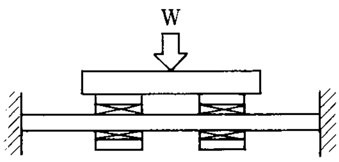


Fig. 16. Life Factor $f_L = \frac{f_s \cdot k \cdot P}{f_t \cdot f_H \cdot f_B \cdot C}$

Sample Calculation



Example 1.

Suppose two L-25 linear motion ball bearings are installed on a shaft, with 50 kgf of a load W working under room temperature without any moment loads, no possible impacts and running velocity V being 300 mm/sec or less, along with the use of an OZAK standard shaft. The rated life of the bearing can be obtained as follows;

The conditions described above give the following values. C=102kgf, P=W/2=25kgf, f_H=1.0, f_t=1.0, f_s=1.0 and k=1.0

The arrangements of ball rows in a bearing assembly into a housing will determine either of the next two cases.

1) A line of balls located right under the acting load, the resulting value, f_B=1.0, gives the bearing rated life, L.

$$L = \left(\frac{1.0 \times 1.0 \times 1.0 \times 102}{1.0 \times 1.0 \times 25}\right)^3 \times 50\text{km} = 3396\text{km}$$

2) For rows of balls distributed uniformly, with a subsequent value of f_B=1.463, the rated life of the bearing is determined as

$$L = \left(\frac{1.0 \times 1.0 \times 1.463 \times 102}{1.0 \times 1.0 \times 25}\right)^3 \times 50\text{km} = 10634\text{km}$$

Example 2.

Given that the operating time of a linear motion bearing is set at 5000 hours, the stroke is 100 mm with 100 cycles per minute, the radial load on each bearing is 10 kgf with no impacts, and it will be operated under room temperature with slight vibrations. Also assuming that the rows of balls are arranged right under the acting load in its direction, along with the use of an OZAK standard shaft. Proper bearing types can be given as follows.

The rated life in kilometers will be obtained in the next calculation.

$$\frac{100\,(\text{mm}) \times 2 \times 100\,(\text{cpm}) \times 60\,(\text{min}) \times 5000\,(\text{hr})}{10^6\,(\text{mm})} = 6000(\text{km})$$

Together with f_L=0.2 from Fig. 16, and other resulting values – P=10kgf, f_s=1.5, k=1.0, f_H=1.0, f_t=1.0, f_B=1.0 – give the basic dynamic load rating, C.

$$C = \frac{f_s \cdot k \cdot P}{f_L \cdot f_H \cdot f_t \cdot f_B} = \frac{1.5 \times 1.0 \times 10(\text{kgf})}{0.2 \times 1.0 \times 1.0 \times 1.0} = 75(\text{kgf})$$

Thus, referring to Table 6, the required linear ball bearing, L25A or L25B, can be determined.

Life Test Results

Fig. 17 shows a crank-driven type, rated life test device for linear motion ball bearings.

The bearings were mounted on the device, then made to break down under 120 kgf of a bearing load with a drip feed lubrication of machine oil. Each group of sixteen bearings presented a test result as shown in Table 5.

In the life test, a total of eighty bearings, or five groups of sixteen bearings, were made to break down. Each group in the table shows differences in travel distance between the first broken bearing and the last one. The average values of five tests, and their subsequent plotting on a Weibull chart, are presented in Fig. 18. The figure indicates the presence of a minimum life. $\hat{\ell}$, for linear motion ball bearings. Furthermore, the distribution of bearing's life, taking the minimum life into account, is found to be nearly equal to a Weibull slope, e=10/9.

Thus, the average life of OZAK linear motion ball bearings with the break down probability of F=50% proves to be about 430 km, representing extremely high dependability. Also, the reliability of OZAK linear motion ball bearings stands at 0.4, which means our products in use are guaranteed 100% reliable until they reach 0.4 times the amount of rated life obtained in the equation (1).

$$L = a_1 \cdot a_2 \cdot a_3 \left(\frac{f_H \cdot f_t \cdot f_B \cdot C}{f_s \cdot k \cdot P} \right)^3 \cdot 50\text{km} \quad \cdots(3)$$

a_1 : Coefficient of reliability ; OZAK linear motion ball bearings give a_1 =0.4 for a reliability of 100%.

a_2 : Coefficient of material ; varying from 1.0 to 2.0

a_3 : Coefficient of lubrication ; ranging between 1.0 and 2.0, depending on lubrication conditions

In order to further increase the life of the bearing, OZAK has conducted many experiments. The methods established in our R & D department are currently under patent application.

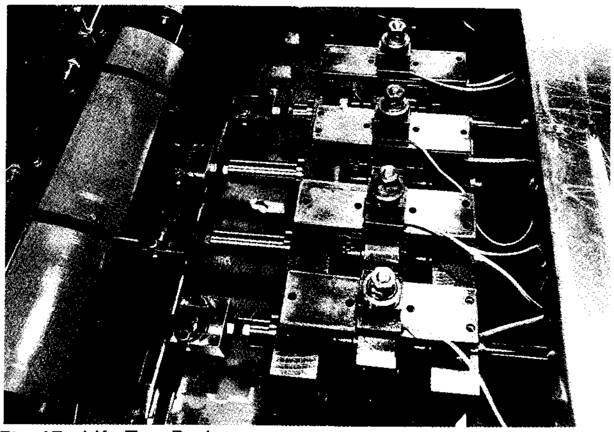


Fig. 17. Life Test Device

Table 5. Order of Break-downs and Travel Distance

Break-down Order	Travel Distance L (km) 1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial	Average Value $\bar{L}$ (km)
1	140	59	81	81	118	96
2	192	81	221	147	125	153
3	199	88	258	177	140	172
4	221	96	258	192	170	187
5	251	103	302	228	214	220
6	258	147	346	236	265	250
7	273	236	560	376	273	344
8	273	346	634	427	324	401
9	383	383	693	450	354	453
10	479	398	722	472	464	507
11	509	405	825	486	531	551
12	509	486	840	590	619	609
13	509	943	884	870	663	774
14	509	Values, 10^3km or more, are subject to truncation. ↓	899	899	Values, 10^3km or more, are subject to truncation. ↓	861
15	862		Values, 10^3km or more, are ↓ subject to truncation.	Values, 10^3km or more, are ↓ subject to truncation.		
16	1010					

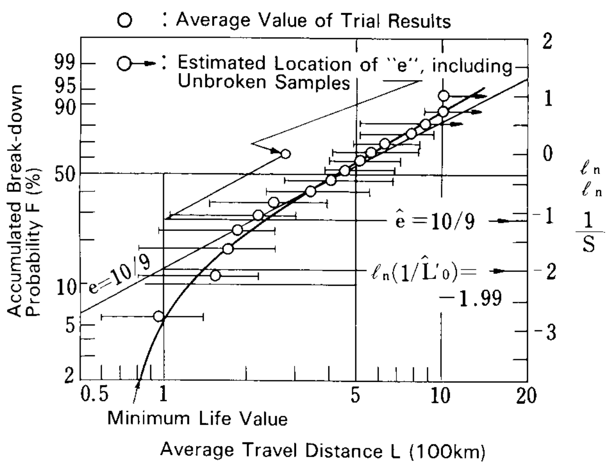


Fig. 18. Correlation between Average Travel Distance and Accumulated Break-down Probability

Friction

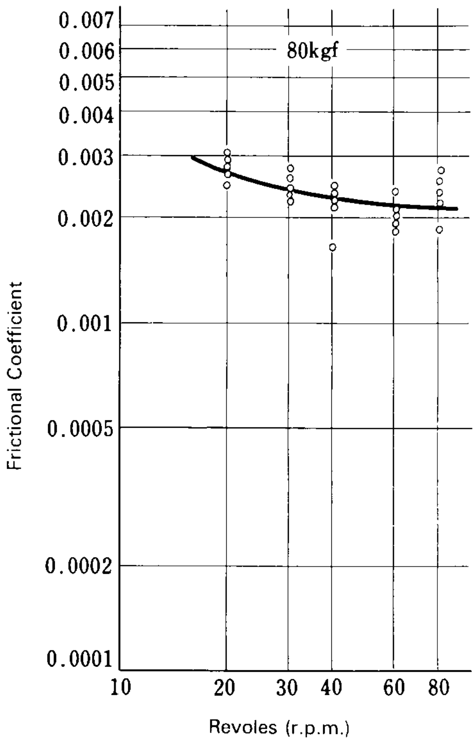


Fig. 19. Correlation between Revoles and Frictional Coefficient;

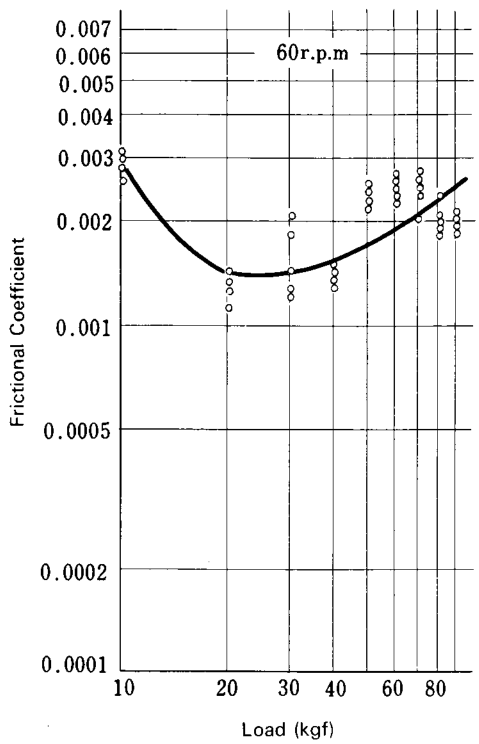


Fig. 20. Correlation between Load and Frictional Coefficient;

OZAK linear motion ball bearings must bear only an extraordinarily small starting friction, generally less friction than sliding bushing types.

The detrimental effects of friction on a machine's power consumption and temperature increase during operation. Friction, especially in precision guide systems, is one of the most crucial factors directly affecting positioning performance.

The friction of linear motion ball bearings is the aggregate value of the following various frictions, whose ratio in the total friction figure differ, depending on the types of bearings and working conditions.

(1) Rolling friction between balls and a shaft or an outer sleeve
(2) Sliding friction accompanied by rolling motion
(3) Sliding friction between balls and a retainer
(4) Viscous resistance of lubricant
(5) Friction originating from sealing

The frictional resistance of linear motion ball bearings, or F, is commonly described as a sum of two terms – F_0 which is independent of loads acting, and F_1 which varies in response to load conditions.

$F = F_0 + F_1$

F_0 gets larger in line with the increase in running speed, however due to the fact that the lubricant's viscosity increases, the actual value of F_0 shows little fluctuation caused by the running speed under normal conditions. An example is shown in Fig. 19.

Meanwhile, F_1 increases almost proportionally to the working load. Because of the sum $F_0 + F_1$, which constitutes the frictional resistance, the coefficient of friction of linear motion ball bearings gets somewhat bigger in the lightly loaded area. The coefficient bears a nearly constant value or a trend to gradually increase when the load surpasses a certain level, as exemplified in Fig. 20.

The frictional coefficient of our linear motion ball bearings varies from 0.001 to 0.003, or several tenths of that of sliding bushings.