A-Ⅱ-2.3 Calculating Friction Force by Preload

- Dynamic friction force per one ball slide of the linear guide can be calculated from preload vlue.
- The followings is a simple calculation to obtain the criterion of dynamic friction force.

  For slight preload ZZ of interchangeable type with preload , use preload volume of slight preload Z1 of preloaded assembly.

$$F = iP$$

F: Dynamic friction force(N)
P: Preload (N)
i: Contact coefficient

Use the following contact coefficient values (i).
LH/LS, LW Series : 0.004
LA Series : 0.012
LY, LE, LU Series : 0.026

- The starting friction force when the ball slide begins to move depends on lubrication condition. Roughly estimate it at 1.5 to 2 times of the dynamic friction obtained by the above method.

Calculation example

In case of LH35AN - Z3

i = 0.004
P = 2350 (N) (from Table Ⅱ-2•1)
$F = iP$
= 0.004 x 2350 = 9.4 (N)

Therefore, the criteria of the dynamic friction force of LH35AN - Z3 is 9.4 N.

For seal friction, refer to "**A-Ⅱ-5 Dust Proof of Linear Guide**."

A-Ⅱ-3 Rating Life

A-Ⅱ-3.1 Rating Life and Basic Load Rating

(1) Life

Although used in appropriate conditions, the linear guide deteriorates after a certain period of operation, and eventually becomes unusable. In broad definition, the period until the linear guide becomes unusable is called "life." There are "fatigue life " caused by flaking, and "life of accuracy deterioration" which is caused by wear.

(2) Rating fatigue life

When the linear guide runs under load, the balls and the rolling contact surface of the grooves are exposed to repetitive load. This brings about fatigue to the material, and generates flaking. Flaking is scale-like damage to the surface of the ball groove.

Total running distance until first appearance of flaking is called "fatigue life." This is "life" in the narrow sense. Fatigue life varies significantly even in linear guides produced in the same lot, and even when they are operated under the same conditions. This is attributable to the inherent variation of the fatigue of the material itself.

"Rating fatigue life" is the total running distance which allows 90% of the group of linear guides of the same reference number to run without causing flaking when they are independently run under the same conditions. Rating fatigue life is sometimes indicated by total operating hours when the linear guides run at a certain speed.

(3) Basic dynamic load rating

- Basic dynamic load rating, which indicates load carrying capacity of the linear guide, is a load whose direction and volume do not change, and which furnishes 50 km of rating fatigue life.
- In case of linear guide, it is a constant load applied to downward direction to the center of the ball slide.
- Value of basic dynamic load rating C is shown in "**Selection Guide to Linear Guides A-Ⅰ-5 Model Number and Dimension Table**."

(4) Calculation of rating fatigue life

In general, rating fatigue life "L" can be calculated from basic dynamic load rating "C" and the load "F" to ball slide using the following formula.

For balls as rolling element $$L=50 \times \left[\frac{C}{F}\right]^{3}$$

For rollers as rolling element $$L=50 \times \left[\frac{C}{F}\right]^{\frac{10}{3}}$$

L: Rating fatigue life (km)
C: Basic dynamic load rating (N)
F: Load to a ball slide (N)
(dynamic equivalent load)

(5) Dynamic equivalent load

- Load applied to the linear guide (ball slide load) comes from various directions up/down and right/left directions and/or as moment load. Sometimes more than one type of load is applied simultaneously. Sometimes volume and direction of the load may change.

Varying load cannot be used as it is to calculate life of linear guide. Therefore, it is necessary to use a hypothetical load to ball slide with a constant volume which would generate a value equivalent to an actual fatigue life. This is called "dynamic equivalent load." For actual calculation, refer to "**A-Ⅱ-3.2 (4) How to calculate dynamic equivalent load**."

(6) Basic static load rating

- When an excessive load or a momentary large impact is applied to the linear guide, local permanent deformation takes place to the balls and to the rolling contact surface. After exceeding a certain level, the deformation hampers smooth linear guide operation.
- Basic static load rating is a static load when: [Permanent deformation of the balls] + [permanent deformation of the rolling contact surfaces] becomes 0.0001 times of the ball diameter.
- In case of linear guide, it is a load which is applied downward direction to the center of the ball slide.
- Values of basic static load rating C0 are shown in "**Selection Guide to Linear Guide A-Ⅰ-5 Model Number and Dimension Table**."

(7) Basic static moment load rating

- Generally, NSK linear guide uses a set of two rails and four ball slides for the guide way of one axis. Under some operating condition, static moment load should be taken into account.

"M0," which is the limit of static moment load in such use is shown in "**Selection Guide to Linear Guide A-Ⅰ-5 Model Number and Dimension Table**."

A-Ⅱ-3.2 How to Calculate Life

(1) Flow chart to calculate life

Setting operating conditions Refer to Section (2) .... Page A130

↓ Set operating conditions such as volume of load to the linear guide, installation method, set up of axes, number of ball slide, etc.

Calculating load which applies to each bearing Refer to Section (3) .... Page A130

↓ Calculate up/down, right/left direction loads and moment load of the linear guide.

Calculating dynamic equivalent load Refer to Section (4) .... Page A134

↓ Calculate dynamic equivalent load based on the load from each direction which are applied to each linear guide.

Calculating mean effective load Refer to Section (5) .... Page A136

↓ Calculate mean effective load based on the dynamic equivalent load which changes by the stroke position.

Determining load factor Refer to Section (6) .... Page A137

↓ Determine load factor to satisfy operating conditions.

Calculating rating life Refer to Section (7) .... Page A139

↓ Calculate running distance from the life formula.

Checking static load Refer to Section (8) .... Page A139

↓ Confirm that static load is within permissible range.

Completion

(2) Setting operating condition of linear guide

- First, set operating conditions to determine whether the temporarily selected model satisfies the required life.
- Major operating conditions are as follows. Set all values to calculate applied loads to each ball slide (Refer to Table Ⅱ-3•1).

Axis set up	: Horizontal, vertical
Rail combination	: Single rail, multiple rail
Applying loads	: F_x, F_y and F_z (N)
Ball slide span	: l (mm)
Rail span	: L (mm)
Point of load action point	: X, Y, Z (mm)
Center of driving mechanism	: X_b, Y_b, Z_b (mm)
Operating speed	: V (mm/sec)
Time in acceleration	: t (sec)
Operating frequency (duty cycle)	

(3) Calculating load to a ball slide

- Table Ⅱ-3•1 shows a formula to calculate loads that are going to be applied to each assembled ball slide into a machine.
  The Table shows six typical patterns of linear guide installing structure.
- In the Tables, directions indicated by arrows denote "plus" for the applied loads (F_x, F_y, F_z) and the loads which is applied to the ball slide. (F_r, F_s, M_r, M_p, M_y).
- Codes in the Tables are as follows:

  F_r : Vertical loads to the ball slide (N)
  F_s : Lateral loads to the ball slide (N)
  M_r : Rolling moment to the ball slide (N • mm)
  M_p : Pitching moment the ball slide (N • mm)
  M_y : Yawing moment the ball slide (N • mm)
  Suffixes (1, 2, ...) to the above F_r ~ M_y : Ball slide number
  F_{xi} : Load applied in X direction (i = 1~n; n is the number of loads applied in X direction) (N)
  F_{yj} : Load applied in Y direction (j = 1~n; n is the number of loads applied in Y direction) (N)
  F_{zk} : Load applied in Z direction (k = 1~n; n is the number of loads applied in Z direction) (N)
  Coordinates (X_{xi}, Y_{xi}, Z_{xi}): Point where load F_{xi} (mm) is applied.
  Coordinates (X_{yj}, Y_{yj}, Z_{yj}): Point where load F_{yj} (mm) is applied.
  Coordinates (X_{zk}, Y_{zk}, Z_{zk}): Point where load F_{zk} (mm) is applied.
  l: Ball slide span (mm)
  L: Rail span (mm)
  Coordinates (X_b, Y_b, Z_b): Center of driving mechanism

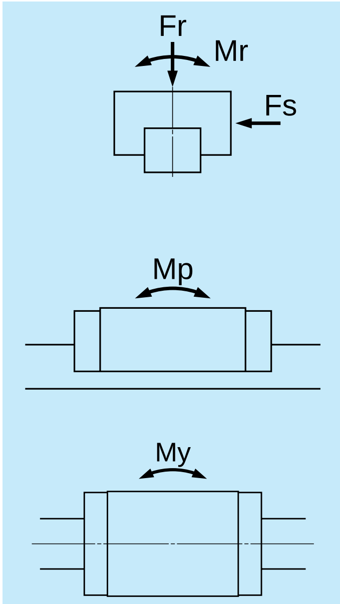
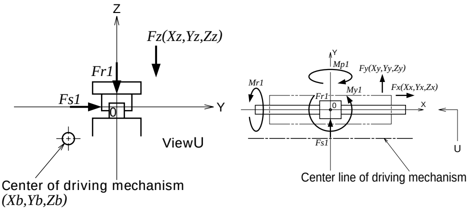
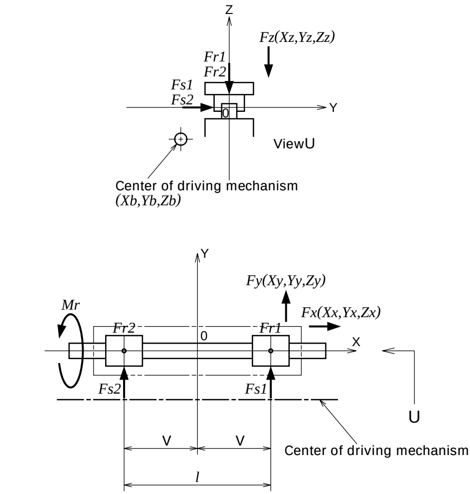
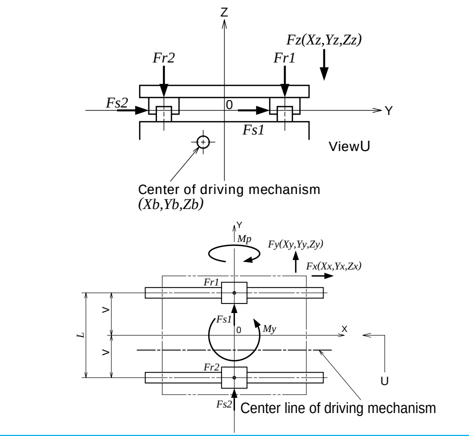
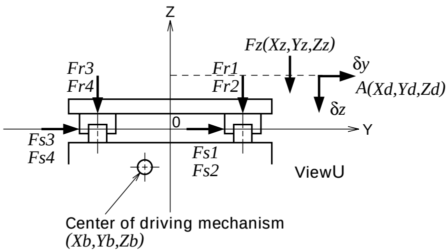


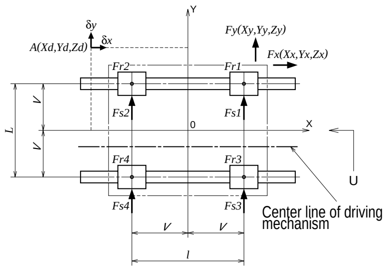
Fig. Ⅱ-3•2

Table Ⅱ-3•1 Loads applied to the ball slides

<table>
<tr><th>Pattern</th><th>Arrangement of ball slides</th><th>Load to ball slide and displacement of Point A</th></tr>
<tr><td>1</td><td>
</td><td>$Fr_1=\sum_{k=1}^{n}Fz_k$, $Fs_1=\sum_{j=1}^{n}Fy_j$
$Mr_1=\sum_{j=1}^{n}(Fyj\cdot Zyj)+\sum_{k=1}^{n}(Fzk\cdot Yzk)$
$Mp_1=\sum_{i=1}^{n}\{Fxi\cdot(Zxi-Zb)\}+\sum_{k=1}^{n}(Fzk\cdot Xzk)$
$My_1=-\sum_{i=1}^{n}\{Fxi\cdot(Yxi-Yb)\}+\sum_{j=1}^{n}(Fyj\cdot Xyj)$</td></tr>
<tr><td>2</td><td>
</td><td>$Fr_1=\frac{\sum_{k=1}^{n}Fz_k}{2}+\frac{M2}{l}$, $Fr_2=\frac{\sum_{k=1}^{n}Fz_k}{2}-\frac{M2}{l}$
$Fs_1=\frac{\sum_{j=1}^{n}Fy_j}{2}+\frac{M3}{l}$, $Fs_2=\frac{\sum_{j=1}^{n}Fy_j}{2}-\frac{M3}{l}$
$Mr_1=\frac{M1}{2}$, $Mr_2=\frac{M1}{2}$
$M1=\sum_{j=1}^{n}(Fy_j\cdot Zy_j)+\sum_{k=1}^{n}(Fz_k\cdot Yz_k)$
$M2=\sum_{i=1}^{n}\{Fx_i\cdot(Zx_i-Zb)\}+\sum_{k=1}^{n}(Fz_k\cdot Xz_k)$
$M3=-\sum_{i=1}^{n}\{Fx_i\cdot(Yx_i-Yb)\}+\sum_{j=1}^{n}(Fy_j\cdot Xy_j)$</td></tr>
<tr><td>3</td><td>
</td><td>$Fr_1=\frac{\sum_{k=1}^{n}Fz_k}{2}+\frac{M1}{L}$, $Fr_2=\frac{\sum_{k=1}^{n}Fz_k}{2}-\frac{M1}{L}$
$Fs_1=Fs_2=\frac{\sum_{j=1}^{n}Fy_j}{2}$
$Mp_1=Mp_2=\frac{M2}{2}$, $My_1=My_2=\frac{M3}{2}$
$M1=\sum_{j=1}^{n}(Fy_j\cdot Zy_j)+\sum_{k=1}^{n}(Fz_k\cdot Yz_k)$
$M2=\sum_{i=1}^{n}\{Fx_i\cdot(Zx_i-Zb)\}+\sum_{k=1}^{n}(Fz_k\cdot Xz_k)$
$M3=-\sum_{i=1}^{n}\{Fx_i\cdot(Yx_i-Yb)\}+\sum_{j=1}^{n}(Fy_j\cdot Xy_j)$</td></tr>
</table>

<table>
<tr><th>Pattern</th><th>Arrangement of ball slides</th><th>Load to ball slide and displacement of Point A</th></tr>
<tr><td>4</td><td>





</td><td>

$$Fr_1=\frac{\sum_{k=1}^{n}Fz_k}{4}+\frac{M1}{2L}+\frac{M2}{2l}\ ,\quad Fr_2=\frac{\sum_{k=1}^{n}Fz_k}{4}+\frac{M1}{2L}-\frac{M2}{2l}$$

$$Fr_3=\frac{\sum_{k=1}^{n}Fz_k}{4}-\frac{M1}{2L}+\frac{M2}{2l}\ ,\quad Fr_4=\frac{\sum_{k=1}^{n}Fz_k}{4}-\frac{M1}{2L}-\frac{M2}{2l}$$

$$Fs_1=Fs_3=\frac{\sum_{j=1}^{n}Fy_j}{4}+\frac{M3}{2l}\ ,\quad Fs_2=Fs_4=\frac{\sum_{j=1}^{n}Fy_j}{4}-\frac{M3}{2l}$$

$$M1=\sum_{j=1}^{n}(Fy_j\cdot Zy_j)+\sum_{k=1}^{n}(Fz_k\cdot Yz_k)$$

$$M2=\sum_{i=1}^{n}\{Fx_i(Zx_i-Zb)\}+\sum_{k=1}^{n}(Fz_k\cdot Xz_k)$$

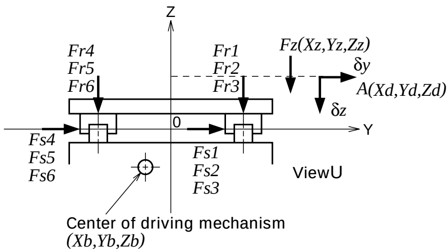
$$M3=-\sum_{i=1}^{n}\{Fx_i(Yx_i-Yb)\}+\sum_{j=1}^{n}(Fy_j\cdot Xy_j)$$

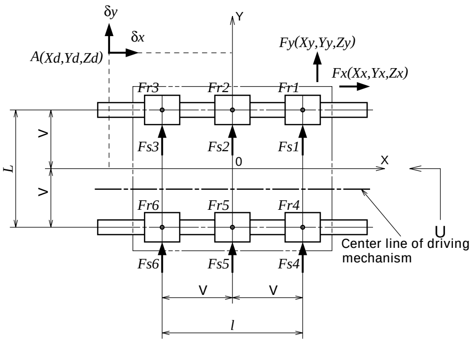
$$\delta x=Y_d\cdot\frac{Fs_2-Fs_1}{l\cdot Ks}+Z_d\cdot\frac{Fr_1-Fr_2}{l\cdot Kr}$$

$$\delta y=\frac{\sum_{j=1}^{n}Fy_j}{4\cdot Ks}+X_d\cdot\frac{Fs_1-Fs_2}{l\cdot Ks}+Z_d\cdot\frac{Fr_1-Fr_3}{L\cdot Kr}$$

$$\delta z=\frac{\sum_{k=1}^{n}Fz_k}{4\cdot Kr}+X_d\cdot\frac{Fr_1-Fr_2}{l\cdot Kr}+Y_d\cdot\frac{Fr_1-Fr_3}{L\cdot Kr}$$

</td></tr>
<tr><td>5</td><td>





</td><td>

$$Fr_1=\frac{\sum_{k=1}^{n}Fz_k}{6}+\frac{M1}{3L}+\frac{M2}{2l}\ ,\quad Fr_2=\frac{\sum_{k=1}^{n}Fz_k}{6}+\frac{M1}{3L}$$

$$Fr_3=\frac{\sum_{k=1}^{n}Fz_k}{6}+\frac{M1}{3L}-\frac{M2}{2l}\ ,\quad Fr_4=\frac{\sum_{k=1}^{n}Fz_k}{6}-\frac{M1}{3L}+\frac{M2}{2l}$$

$$Fr_5=\frac{\sum_{k=1}^{n}Fz_k}{6}-\frac{M1}{3L}\ ,\quad Fr_6=\frac{\sum_{k=1}^{n}Fz_k}{6}-\frac{M1}{3L}-\frac{M2}{2l}$$

$$Fs_1=Fs_4=\frac{\sum_{j=1}^{n}Fy_j}{6}+\frac{M3}{2l}\ ,\quad Fs_2=Fs_5=\frac{\sum_{j=1}^{n}Fy_j}{6}$$

$$Fs_3=Fs_6=\frac{\sum_{j=1}^{n}Fy_j}{6}-\frac{M3}{2l}$$

$$M1=\sum_{j=1}^{n}(Fy_j\cdot Zy_j)+\sum_{k=1}^{n}(Fz_k\cdot Yz_k)$$

$$M2=\sum_{i=1}^{n}\{Fx_i\cdot(Zx_i-Zb)\}+\sum_{k=1}^{n}(Fz_k\cdot Xz_k)$$

$$M3=-\sum_{i=1}^{n}\{Fx_i\cdot(Yx_i-Yb)\}+\sum_{j=1}^{n}(Fy_j\cdot Xy_j)$$

$$\delta x=Y_d\cdot\frac{Fs_3-Fs_1}{l\cdot Ks}+Z_d\cdot\frac{Fr_1-Fr_3}{l\cdot Kr}$$

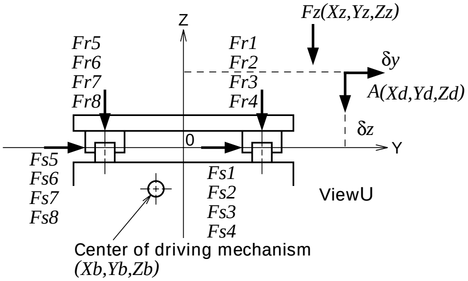
$$\delta y=\frac{\sum_{j=1}^{n}Fy_j}{6\cdot Ks}+X_d\cdot\frac{Fs_1-Fs_3}{l\cdot Ks}+Z_d\cdot\frac{Fr_1-Fr_4}{L\cdot Kr}$$

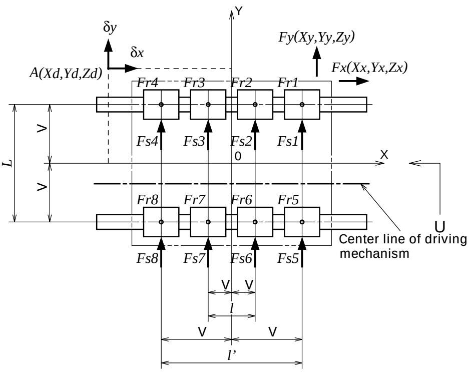
$$\delta z=\frac{\sum_{k=1}^{n}Fz_k}{6\cdot Kr}+X_d\cdot\frac{Fr_1-Fr_3}{l\cdot Kr}+Y_d\cdot\frac{Fr_1-Fr_4}{L\cdot Kr}$$

</td></tr>
</table>

Pattern	Arrangement of ball slides	Load to ball slide and displacement of Point A

6





$$Fr_1 = \frac{\sum_{k=1}^{n} Fz_k}{8} + \frac{M1}{4L} + \frac{M2 \cdot l'}{2 \cdot (l^2 + l'^2)}$$

$$Fr_2 = \frac{\sum_{k=1}^{n} Fz_k}{8} + \frac{M1}{4L} + \frac{M2 \cdot l}{2 \cdot (l^2 + l'^2)}$$

$$Fr_3 = \frac{\sum_{k=1}^{n} Fz_k}{8} + \frac{M1}{4L} - \frac{M2 \cdot l}{2 \cdot (l^2 + l'^2)}$$

$$Fr_4 = \frac{\sum_{k=1}^{n} Fz_k}{8} + \frac{M1}{4L} - \frac{M2 \cdot l'}{2 \cdot (l^2 + l'^2)}$$

$$Fr_5 = \frac{\sum_{k=1}^{n} Fz_k}{8} - \frac{M1}{4L} + \frac{M2 \cdot l'}{2 \cdot (l^2 + l'^2)}$$

$$Fr_6 = \frac{\sum_{k=1}^{n} Fz_k}{8} - \frac{M1}{4L} + \frac{M2 \cdot l}{2 \cdot (l^2 + l'^2)}$$

$$Fr_7 = \frac{\sum_{k=1}^{n} Fz_k}{8} - \frac{M1}{4L} - \frac{M2 \cdot l}{2 \cdot (l^2 + l'^2)}$$

$$Fr_8 = \frac{\sum_{k=1}^{n} Fz_k}{8} - \frac{M1}{4L} - \frac{M2 \cdot l'}{2 \cdot (l^2 + l'^2)}$$

$$Fs_1 = Fs_5 = \frac{\sum_{j=1}^{n} Fyj}{8} + \frac{M3 \cdot l'}{2 \cdot (l^2 + l'^2)}$$

$$Fs_2 = Fs_6 = \frac{\sum_{j=1}^{n} Fy_j}{8} + \frac{M3 \cdot l}{2 \cdot (l^2 + l'^2)}$$

$$Fs_3 = Fs_7 = \frac{\sum_{j=1}^{n} Fy_j}{8} - \frac{M3 \cdot l}{2 \cdot (l^2 + l'^2)}$$

$$Fs_4 = Fs_8 = \frac{\sum_{j=1}^{n} Fy_j}{8} - \frac{M3 \cdot l'}{2 \cdot (l^2 + l'^2)}$$

$$M1 = \sum_{j=1}^{n} (Fy_j \cdot Zy_j) + \sum_{k=1}^{n} (Fz_k \cdot Yz_k)$$

$$M2 = \sum_{i=1}^{n} \{Fx_i \cdot (Zx_i - Zb)\} + \sum_{k=1}^{n} (Fz_k \cdot Xz_k)$$

$$M3 = -\sum_{i=1}^{n} \{Fx_i \cdot (Yx_i - Yb)\} + \sum_{j=1}^{n} (Fy_j \cdot Xy_j)$$

$$\delta x = Y_d \cdot \frac{Fs_4 - Fs_1}{l_2 \cdot Ks} + Z_d \cdot \frac{Fr_1 - Fr_4}{l_2 \cdot Kr}$$

$$\delta y = \frac{\sum_{j=1}^{n} Fy_j}{8 \cdot Ks} + X_d \cdot \frac{Fs_1 - Fs_4}{l_2 \cdot Ks} + Z_d \cdot \frac{Fr_1 - Fr_5}{L \cdot Kr}$$

$$\delta z = \frac{\sum_{k=1}^{n} Fz_k}{8 \cdot Kr} + X_d \cdot \frac{Fr_1 - Fr_4}{l_2 \cdot Kr} + Y_d \cdot \frac{Fr_1 - Fr_5}{L \cdot Kr}$$

(4) Calculation of dynamic equivalent load

• For calculation of dynamic equivalent load, use the load in Table Ⅱ-3•2 which matches the intended use of the linear guide.

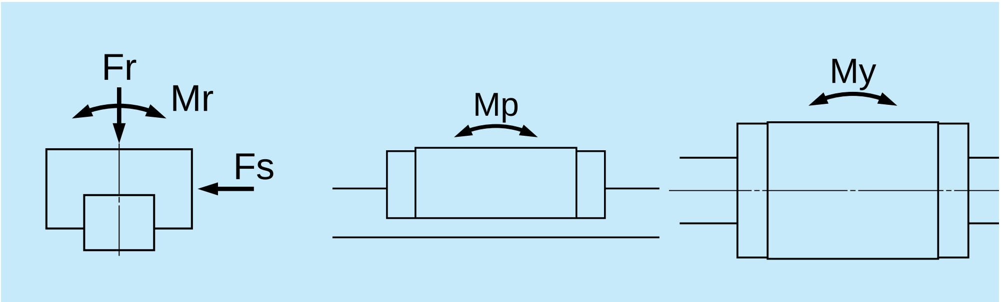
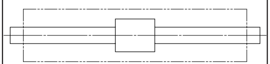
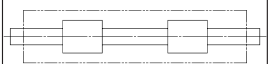
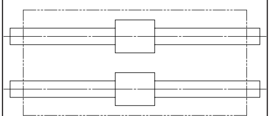
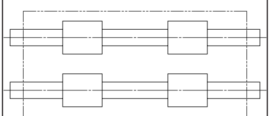


Fig. Ⅱ-3•3

Table Ⅱ-3•2 Loads in the arrangement of linear guides

<table>
<tr><th rowspan="3">Pattern</th><th rowspan="3">Arrangement of linear guide</th><th colspan="5">Loads necessary to calculate dynamic equivalent load</th><th rowspan="3">Dynamic equivalent load</th></tr>
<tr><th colspan="2">Load</th><th colspan="3">Moment load</th></tr>
<tr><th>Up/down (vertical)</th><th>Right/left (lateral)</th><th>Rolling</th><th>Pitching</th><th>Yawing</th></tr>
<tr><td>1</td><td></td><td>F_r</td><td>F_s</td><td>M_r</td><td>M_p</td><td>M_y</td><td rowspan="4">$F_r = F_r$
$F_{se} = F_s \cdot \tan\alpha$
$F_{re} = \varepsilon_r \cdot M_r$
$F_{pe} = \varepsilon_p \cdot M_p$
$F_{ye} = \varepsilon_y \cdot M_y$

α :Contact angle
LH, LS, LW Series
α=50°
LA, LY, LU, LE Series
α=45°</td></tr>
<tr><td>2</td><td></td><td>F_r</td><td>F_s</td><td>M_r</td><td></td><td></td></tr>
<tr><td>3</td><td></td><td>F_r</td><td>F_s</td><td></td><td>M_p</td><td>M_y</td></tr>
<tr><td>4</td><td></td><td>F_r</td><td>F_s</td><td></td><td></td><td></td></tr>
</table>

- Use dynamic equivalent coefficient ε in the table below for easy conversion of moment load to dynamic equivalent load.
- Coefficient of each moment direction is as follows.
  ε_r : Rolling direction
  ε_p : Pitching direction
  ε_y : Yawing direction

Table Ⅱ-3•3 Dynamic equivalent coefficients

Unit:1/m

Model number	ε_r	ε_p	ε_y	Model number	ε_r	ε_p	ε_y	Model number	ε_r	ε_p	ε_y
LH20	142	81	97					LW17	66	125	149
LH20L	142	57	68					LW21	59	108	129
LH25	123	68	81	LA30	105	63	63	LW27	53	76	91
LH25L	123	51	61	LA30L	105	43	43	LW35	32	51	61
LH30A	98	70	83	LA35	84	54	54	LW50	25	38	46
LH30EF	98	58	69	LA35L	84	37	37				
LH30L	98	44	52	LA45	60	41	41	LE05	196	248	248
LH35	78	51	61	LA45L	60	31	31	LE05S	196	323	323
LH35L	78	36	43	LA55	51	33	33	LE07	141	188	188
LH45	60	38	45	LA55L	51	26	26	LE07S	141	349	349
LH45L	60	30	36	LA65	43	29	29	LE07L	141	122	122
LH55	51	31	37	LA65L	43	20	20	LE09	123	149	149
LH55L	51	25	30					LE09S	123	277	277
LH65	43	27	32					LE09L	123	102	102
LH65L	43	20	24					LE12	90	125	125
LH85L	33	17	20	LY15	133	111	111	LE12S	90	233	233
				LY20	100	89	89	LE12L	90	86	86
				LY20L	100	65	65	LE15	50	102	102
				LY25	90	75	75	LE15S	50	174	174
				LY25L	90	51	51	LE15L	50	68	68
LS15	177	116	138	LY30	74	63	63				
LS15S	177	174	208	LY30L	74	48	48	LU05	385	359	359
LS20	127	94	112	LY35	61	54	54	LU07	286	305	305
LS20S	127	136	162	LY35L	61	41	41	LU09	217	242	242
LS25	111	70	83	LY45	46	41	41	LU09L	217	138	138
LS25S	111	108	129	LY45L	46	30	30	LU09R	217	203	203
LS30	94	63	75	LY55	39	35	35	LU12	167	204	204
LS30S	94	102	121	LY55L	39	26	26	LU12L	167	116	116
LS35	76	54	64	LY65	33	31	31	LU15	133	174	174
LS35S	76	87	104	LY65L	33	21	21	LU15L	133	94	94

Definitions of codes appearing at the end of the model number in Table Ⅱ-3•3:

L	: Super-high load type	LH45L
S	: Medium load type	LS25S
No code	: High load type	LY45_
A	: Ball slide shape is square	LH30A (only LH30)
EF	: Ball slide shape is flanged type	LH30EF (only LH30)
R	: Miniature Series with ball retainer	LU09R

• Formula is determined by the relationship of loads in terms of volume. Full dynamic equivalent load can be easily obtained by using each coefficient.

After obtaining the dynamic equivalent load of the necessary load directions from Table Ⅱ-3•3, use the formulas below to calculate full dynamic equivalent loads.

- When Fr is the largest load : $Fe=Fr+0.5Fse+0.5Fre+0.5Fpe+0.5Fye$
- When Fse is the largest load : $Fe=0.5Fr+Fse+0.5Fre+0.5Fpe+0.5Fye$
- When Fre is the largest load : $Fe=0.5Fr+0.5Fse+Fre+0.5Fpe+0.5Fye$
- When Fpe is the largest load : $Fe=0.5Fr+0.5Fse+0.5Fre+Fpe+0.5Fye$
- When Fye is the largest load : $Fe=0.5Fr+0.5Fse+0.5Fre+0.5Fpe+Fye$

For the values of each dynamic equivalent load in the formulas above, disregard load directions and take the absolute value.

(5) Calculation of mean effective load

When the load to the ball slide deviates, obtain a mean effective load which becomes equal to the life of ball slide under variable load conditions. If the load does not vary, use the dynamic equivalent load as it is.

① When load and running distance vary by phase (Fig. Ⅱ-3•4)

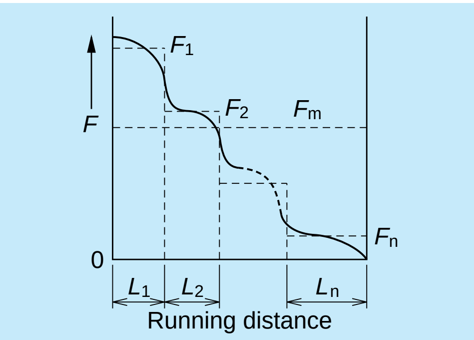


Fig. Ⅱ-3•4 Variable load by phase

Running distance while dynamic equivalent load F_1 is applied: L_1
Running distance while dynamic equivalent load F_2 is applied: L_2
Running distance while dynamic equivalent load F_3 is applied: L_3
• •
Running distancewhile dynamic equivalent load Fn is applied: Ln

From the above, mean effective load Fm can be obtained by the following formula.

$$Fm \quad \sqrt[3]{\frac{1}{L}\left(F_1^3 L_1 + F_2^3 L_2 + \ldots\ldots + F_n^3 L_n\right)}$$

Fm: Mean effective load of the deviating load (N)
L : Running distance (ΣLn)

② **When load changes almost lineally (Fig. Ⅱ-3•5)**

Approximate mean effective load Fm can be obtained by the following formula.

$$Fm \fallingdotseq \frac{1}{3}(F\min+2F\max)$$

Fmin : Minimum value of dynamic equivalent load (N)

Fmax : Maximum value of dynamic equivalent load (N)

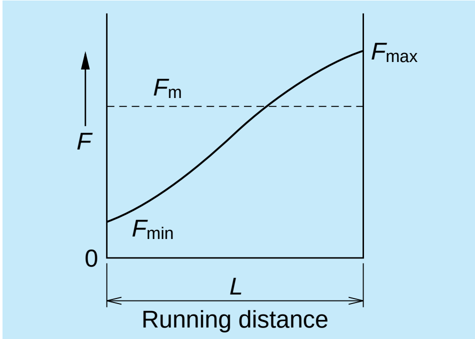


Fig. Ⅱ-3•5 Simple variable load

③ **When load changes similar to a sine curve (Fig. Ⅰ-3•6)**

At time of (a): Fm = 0.65 Fmax

At time of (b): Fm = 0.75 Fmax

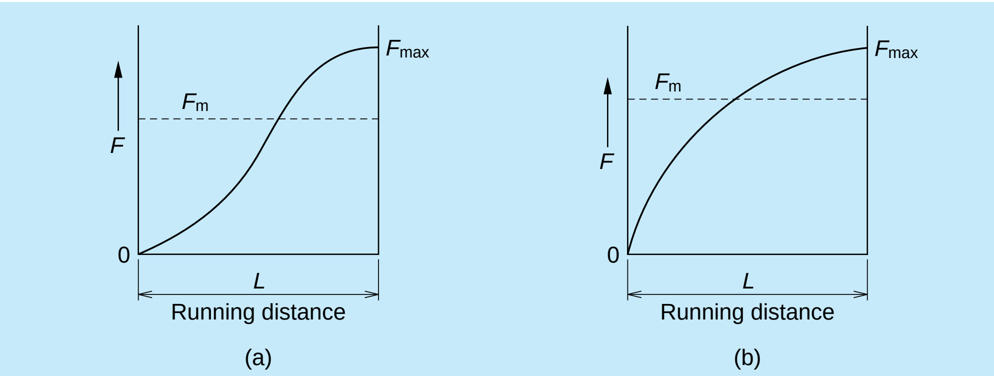


Fig. Ⅱ-3•6 Load that changes similar to a sine curve

(6) Various coefficients

① **Load factors**

- Although a load applied to the ball slide can be calculated, the actual load becomes larger than the calculated value due to the machine's vibration and impact.
- Therefore, calculation of load on the ball slide should take into consideration the load factors in Table II-3.4.

Table Ⅱ-3•4 Load factor *f*w

Impact/Vibration	Load factor
No external impact/ vibration	1.0〜1.5
There is impact/ vibration from outside.	1.5〜2.0
There is significant impact / vibration.	2.0〜3.0

② **Hardness coefficient**

- For linear guides, in order to function optimally, both the balls and the rolling contact surface must have a hardness of HRC58 to 62 to an appropriate depth.
- The hardness of NSK linear guide fully satisfies HRC58 to 62. Therefore, in most cases it is not necessary to consider hardness. If the linear guide is made of a special material by a customer's request, as the material hardness is lower than HRC58, use the following formula for adjustment.

$$C_H = f_H \cdot C$$

$$C_{OH} = f_H' \cdot C_o$$

C_H : Basic dynamic load rating adjusted by hardness coefficient

f_H : Hardness coefficient (Refer to Fig. Ⅱ-3.7)

C_{OH} : Basic static load rating adjusted by hardness coefficient

f_H' : Static hardness coefficient (Refer to Fig. Ⅱ-3.7)

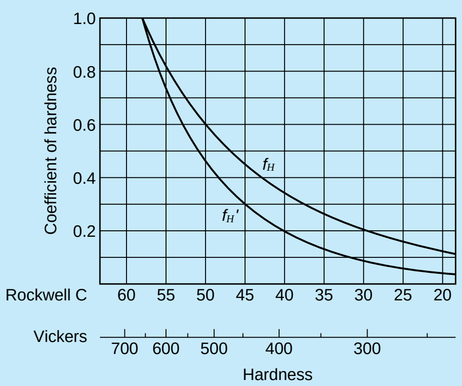


Fig. Ⅱ-3.7 Hardness coefficient

③ **Reliability coefficient**

- In general, a reliability of 90% is customary. In this case, reliability coefficient is 1. Therefore, the reliability coefficient does not have to be included in calculation.

(7) Calculation of rating life

Life calculating formula in the stroke movement with normal lubrication, the following relationships exist between ball slide mean effective load F_m (N), basic dynamic load rating to load application direction C (N), and rating fatigue life L (Km).

$$L = 50 \times \left(\frac{f_H \cdot C}{f_W \cdot F_m}\right)^n \text{(Km)}$$

Ball linear guide bearing which uses balls n= 3
Roller linear guide bearing which uses rollers n=10/3

f_H : Hardness coefficient
f_W : Load factor
F_m : Mean effective load

Use basic dynamic load rating C to calculate the life.

Note: Do not use basic static load rating C_0, basic static moment rating M_{R0}, M_{P0} or M_{Y0}.

Life as an entire guide way system

In those cases when several ball slides comprise a single guide way system (such as a single-axis table), the life of the ball slide to which the most strenuous condition is applied is considered to be the life of the entire system. For example, in Fig. Ⅱ-3•8, if "Ball slide A" is the ball slide which receives the largest mean effective load, or if "Ball slide A" is the one which has the shortest life, the life of the system is considered to be the life of "Ball slide A."

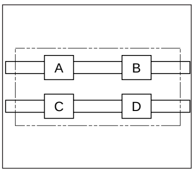


Fig. Ⅱ-3•8 Life of a system

(8) Examination of static load

① Examine from basic static load rating

- Examine static permissible load P_0, which is applied to the ball slide, from basic static load rating C_0 and static permissible load factor f_S.

$$P_0 = \frac{C_0}{f_S}$$

When static equivalent load P_0 is a combination of vertical loads F_r and lateral load F_s, calculate using formulas below.

For LH, LS, LW Series:

If compressed load and lateral load are combined

$$P_0 = F_r + 1.59F_s$$

If tensile load and lateral load are combined

$$P_0 = 1.34F_r + 1.59F_s$$

For LA, LY, LU, LE Series:

$$P_0 = F_r + F_s$$

- The table below shows guidelines of fs for general industrial use.

Table Ⅱ-3•5

Use conditions	f_S
Under normal operating conditions	1~2
Operating under vibration/impact	1.5~3

- Basic static load rating is not a destructive force to the balls, rails, or ball slide. The balls can withstand a load more than seven times larger than the basic static load rating . It is sufficient as a safety factor to the destruction load designed for general machines.
- However, when the linear guide is mounted upside down, the strength of the bolt which secures rail and ball slide affects the strength of the entire system. Strength of the bolt and its material should be considered.

② Examining from static moment load rating

- Also examine static permissible load M_0 from basic static moment load M_{P0} and static permissible load factor f_S.

$$M_0 = \frac{M_{P0}}{f_S}$$

If more than one moment load in any direction is combined, please consult NSK.

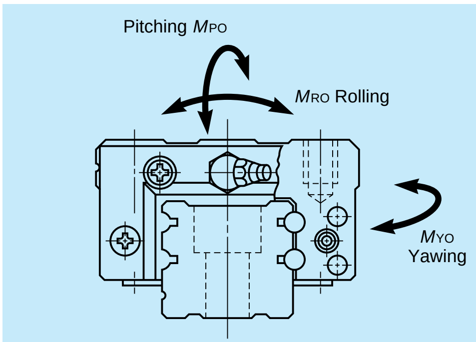


Fig. Ⅱ-3•9 Moment load directions

(9) Precautions for the design in examining the life

The following points must be heeded in examining the life.

In case of oscillating stroke

- If the balls do not rotate all the way, but only halfway, and if this minute stroke is repeated, lubricant disappears from the contact surface of balls and grooves. This generates "fretting," a premature wear. Fretting cannot be entirely prevented, but it can be mitigated.
- A grease which prevents fretting is recommended for oscillating stroke operations. Using a standard grease, life can be markedly prolonged by adding a normal stroke travel (about the ball slide length) once every several thousand cycles.

When applying pitching or yawing moment

- Load applied to the ball rows inside the ball slide is inconsistent if pitching or yawing moment load is applied. Loads are heavy on the balls on each end of the row.
- In such case, a heavy load lubricant grease or oil are recommended. Another countermeasure is using one size larger model of linear guide to reduce the load per ball.
- Moment load is insignificant for 2-rail, 4--ball slides combination which is commonly used.

When an extraordinary large load is applied during stroke

- If an extraordinary large load is applied at certain position of the stroke, calculate not only the life based on the mean effective load, but also the life based on the load in this range.

When calculated life is extraordinarily short
(Less than 3000 km in calculated life, or the load exceeds 10% of the basic dynamic load rating.)

- In such case, the contact pressure to the balls and the rolling contact surface is extraordinarily high.
- Operated under such state continually, the life is significantly affected by the loss of lubrication and the presence of dust, and the actual life becomes shorter than calculated.
- It is necessary to reconsider arrangement, the number of ball slide, and the type of model in order to reduce the load to the ball slide.