NB LINEAR SYSTEMS

The NB linear systems is a linear motion mechanism which utilizes the rolling motion of ball and/or roller elements. NB offers a wide range of linear motion products of high precision quality that contribute to the size and weight reduction of machinery and equipment.

ADVANTAGES

Low Friction and Excellent Response

The dynamic friction of the ball or roller elements is substantially lower than that of full-face surface sliding friction. Since the difference between dynamic and static frictional resistance is small, motion response is excellent in terms of positioning accuracy and in high speed applications with acceleration and deceleration.

High Precision and Smooth Movement

The NB linear systems is designed for the rolling elements to achieve extremely smooth motion. The raceway surface is finished by precision grinding for high precision movement with optimal clearance.

High Load Capacity and Long Travel Life

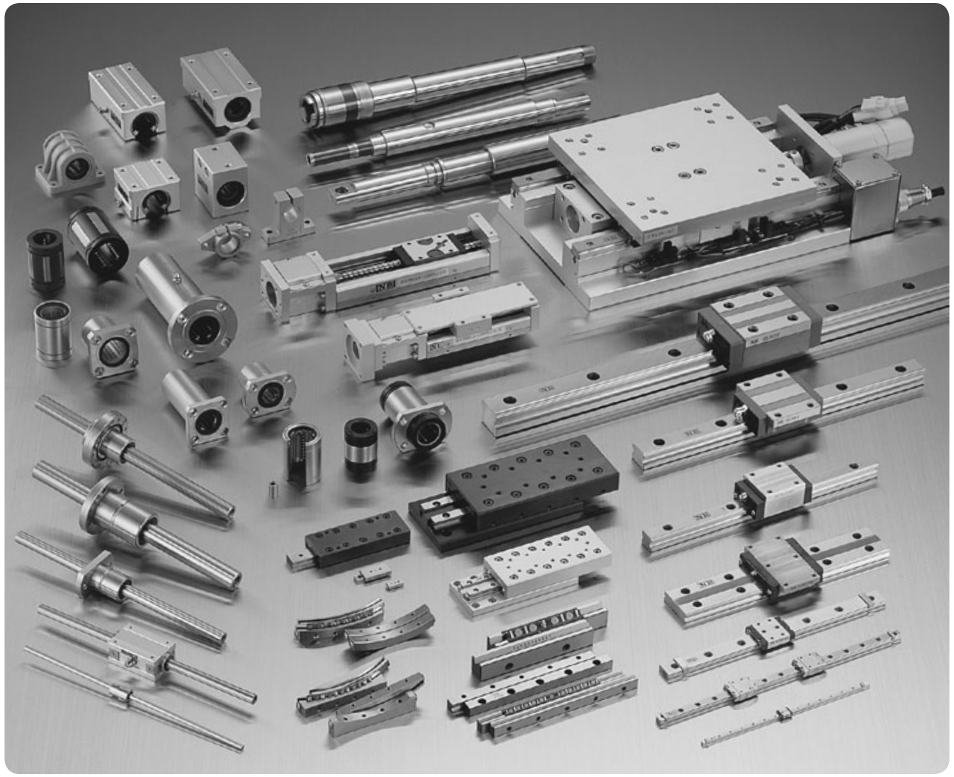
Despite the compactness of the NB linear systems, the system uses relatively large rolling elements on a long raceway resulting in a high load capacity and a long travel life.

Ease of Installation

The NB linear systems shortens machining and assembly time compared with that of a full-face surface sliding bearing.

Variety of Types

A wide variety of types and sizes of the NB linear systems are available to best serve the purpose for every application and requirement.



PROCESS FOR SELECTING NB LINEAR SYSTEMS

Check the application conditions		Identify machine type to be used, application conditions, environmental conditions, and desired accuracy.
Decide system type		Slide Guide Ball Spline Slide Bush Slide Way
Pre-select the size and number of linear systems		Pre-select the size and number based on balance of machinery and other equipment as well as past experience.
Calculate load		Calculate load on each system. Calculate average variable load. (refer to page Eng-6-8)
Determine static load	NG / OK	Determine basic static load rating and allowable static moment by applying static safety factor. (refer to page Eng-3)
Compute rated life	NG / OK	Compute rated life and compare to required life. (refer to page Eng-4)
Determine preload and accuracy	NG / OK	Decide preload and accuracy based on the operating conditions. (refer to each product description for preload and accuracy)
Select lubrication and dust prevention method	OK	Select lubrication and dust prevention method. (seals, bellows, covers)
Confirm the space needed in the equipment	NG / OK	Confirm space and installation dimensions in consideration of the machine size and ease of maintenance.
Selection completed		

(NG: return to "Decide system type")

ALLOWABLE LOAD

Load and Moment

A load is applied to the linear systems as Figure 1-1 shows. Sometimes moment loads are applied to, for example, slide guides. Load and moment are defined as follows.

Basic Static Load Rating (compliant with ISO14728-2*1) and Allowable Static Moment

When excess load or impact load is applied to the linear systems while it is stationary or moving slowly, a permanent deformation occurs on the rolling elements and the race way.

If this deformation exceeds a certain limit, it causes vibration and noise during operation resulting in a non-smooth motion and a shorter life time. To prevent this permanent deformation and deterioration in motion accuracy, the basic static load rating (Co) is given as the allowable load for the linear systems. This basic static load rating is defined as the static load that results in the maximum allowable stress at the center of the contact surface between the rolling elements and the race way. The sum of the permanent deformation of the rolling element and that of the race way is 0.0001 time the diameter of the rolling element. In the linear systems, a moment load may be present in addition to the static load. The allowable static moments are defined by M_P, M_Y, and M_R as illustrated in Figure 1-1.

*1: This does not apply to some products.

Allowable Load and Static Safety Factor

The basic static load rating and allowable static moment define the maximum static load in each direction, however, these maximum static loads are not necessarily applicable depending on the operating conditions, the mounting accuracy, and the required motion accuracy. Therefore, an allowable load with a safety factor must be obtained. The minimum static safety factor is listed in Table 1-1.

Allowable Load

$$P_{max.} \leqq C_o / f_s \quad \cdots\cdots (1)$$

Allowable Moment

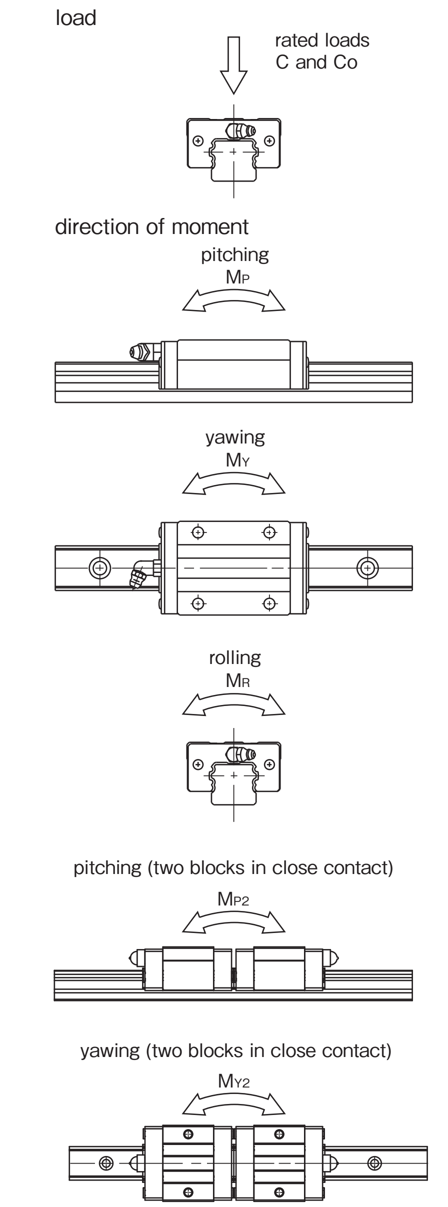
$$M_{max.} \leqq (M_P, M_Y, M_R, M_{P2}, M_{Y2}) / f_s \quad \cdots\cdots (2)$$

f_s: static safety factor　C_o: basic static load rating (N)
$P_{max.}$: allowable load (N)
$M_P, M_R, M_Y, M_{P2}, M_{Y2}$: allowable static moment (N・m)
$M_{max.}$: allowable moment (N・m)

Table 1-1 Minimum Static Safety Factor (fs)

operating conditions	static safety factor
normal	1～2
smooth motion required	2～4
vibration/impact loading	3～5

Figure 1-1 Load and Moment



LIFE

Life of a Linear Systems

When a linear systems reciprocates under loading, a continuous stress acts on it, ultimately causing flaking of its race way surface due to material fatigue. The distance a linear system travels before this flaking occurs is defined as the life of the linear system. A linear systems can also become inoperable due to sintering, cracking, pitting, or rusting, however, these causes are differentiated from flaking because they are related to installation accuracy, operating environment, and relubrication method.

Rated Life

Even when a group of linear systems from the same production lot operated under identical conditions, the life time can differ due to differences in the material fatigue failure characteristics. This fact prevents from determining the exact life time of a single linear systems for use. Therefore, the rated life is defined statistically as the distance of 90% of the linear systems travel before causing flaking.

Basic Dynamic Load Rating (compliant with ISO14728-1*2) and Basic Dynamic Torque Rating

The life of a linear systems is expressed in terms of the distance traveled. Therefore, the life of a linear systems is calculated reversely by using the allowable load that achieves a certain travel distance. This allowable load is called the basic dynamic load rating. The basic dynamic load rating is defined as a constant load in weight and direction that can achieve a travel distance of 50×10^3m on the linear systems. NB assumes the load is applied from the top as a normal radial load, because basic dynamic load ratings change depending on the applied load direction. The basic dynamic load ratings in the dimensional tables are based on this assumption. Ball splines can carry torque loading, so the basic dynamic torque rating is defined for the Ball Spline.

*2: This does not apply to some products.

Rated Life Estimation

The rated life estimation depends on the type of the rolling element. Equations (3) and (4) are used for the ball element and for the roller element, respectively. Equation (5) is used when torque loading is present.

balls are used as the rolling element

$$L = \left(\frac{C}{P}\right)^3 \cdot 50 \quad \cdots\cdots (3)$$

rollers are used as the rolling element

$$L = \left(\frac{C}{P}\right)^{10/3} \cdot 50 \quad \cdots\cdots (4)$$

torque loading is present

$$L = \left(\frac{C_T}{T}\right)^3 \cdot 50 \quad \cdots\cdots (5)$$

L: rated life (km)　C: basic dynamic load rating (N)
P: applied load (N)　C_T: basic dynamic torque rating (N・m)
T: applied torque(N・m)

In the actual application, numerous variable factors are present such as in guide rail/shaft accuracy, in mounting conditions, in operating conditions, vibration and shock, etc. Therefore, calculating the actual applied load accurately is extremely difficult. In general, the calculation is simplified by using coefficients representing these factors: hardness coefficient (f_H), temperature coefficient (f_T), contact coefficient (f_C), and applied load coefficient (f_W). Taking these coefficients into account, Equations (3) to (5) become Equations (6) to (8).

balls are used as the rolling element

$$L = \left(\frac{f_H \cdot f_T \cdot f_C}{f_W} \cdot \frac{C}{P}\right)^3 \cdot 50 \quad \cdots\cdots (6)$$

rollers are used as the rolling element

$$L = \left(\frac{f_H \cdot f_T \cdot f_C}{f_W} \cdot \frac{C}{P}\right)^{10/3} \cdot 50 \quad \cdots\cdots (7)$$

torque loading is present

$$L = \left(\frac{f_H \cdot f_T \cdot f_C}{f_W} \cdot \frac{C_T}{T}\right)^3 \cdot 50 \quad \cdots\cdots (8)$$

L: rated life (km)　f_H: hardness coefficient
f_T: temperature coefficient　f_C: contact coefficient
f_W: applied load coefficient　P: applied load (N)
C: basic dynamic load rating (N)
C_T: basic dynamic torque rating (N・m)
T: applied torque (N・m)

When the travel distance per unit time is constant, the rated life can be expressed in terms of time (hour). Equation (9) shows the relationship between stroke length, number of cycles per minute, and the life time.

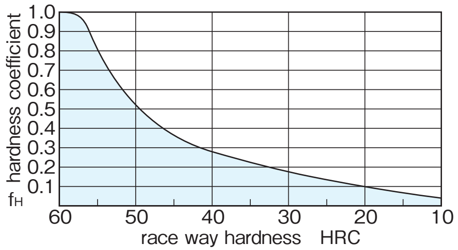
$$L_h = \frac{L\cdot 10^3}{2\cdot \ell_s \cdot n_1 \cdot 60} \quad \cdots\cdots (9)$$

L_h: life time (hr) ℓ_s: stroke length (m)
n_1: number of cycles per minute (cpm)

・Hardness Coefficient (f_H)

In the linear systems, the guide rail or shaft works as race way of the rolling elements. Therefore, the hardness of the rail or shaft is an important factor in determining the rated load. The rated load decreases as the hardness decrease below 58HRC. NB products hold appropriate hardness by advanced heat treatment technology. In case of using the rail or shaft of insufficient hardness, please take the hardness coefficient (Figure 1-2) into the life calculation equation.

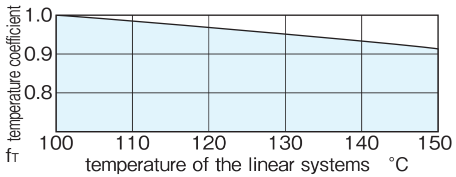
Figure 1-2 Hardness Coefficient



・Temperature Coefficient (f_T)

In order to give low wear characteristics NB products are hardened by heat treatment. If the temperature of the linear systems exceeds 100℃, the hardness is decreased by tempering effect, so as the rated load decreases. Figure 1-3 shows the temperature coefficient as hardness changes with temperature.

Figure 1-3 Temperature Coefficient



・Contact Coefficient (f_C)

When more than one bearing is used in close contact, the contact coefficient should be taken into consideration due to the variation of products and the accuracy of the mounting surface. Table 1-2 shows the contact coefficient for life calculation.

Table 1-2 Contact Coefficient

number of linear bearings in close contact on rail/shaft	contact coefficient f_C
1	1.00
2	0.81
3	0.72
4	0.66
5	0.61

・Applied Load Coefficient (f_W)

The actual applied load on a liner system can be greater than the calculated load due to impact, vibration, or inertia. Hence, an appropriate applied load coefficient(table 1-3) must be incorporated into a life calculation.

There are separate applied load coefficient tables for TOPBALL products on page D-4.

Table 1-3 Applied Load Coefficient

operating conditions		applied load coefficient
loading	velocity	f_W
no shock and vibration	0.25 m/s less	1.0〜1.5
low shock and vibration	1 m/s less	1.5〜2.0
high shock and vibration	1 m/s more	2.0〜3.5

Calculation of Applied Load (1)

Tables 1-4 and 1-5 show the formulas of applied load calculation for typical applications.

W: applied load (N) P_1 - P_4: load applied to linear systems (N) X,Y: linear systems span (mm)
x, y, ℓ: distance to applied load or to working center of gravity (mm) g: gravitational acceleration (9.8 x 10^3mm/s^2)
V: velocity (mm/s) t_1: acceleration time (sec) t_3: deceleration time (sec)

Table 1-4 Applied Load Calculation (1)

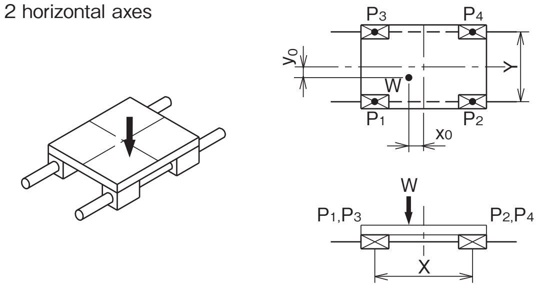
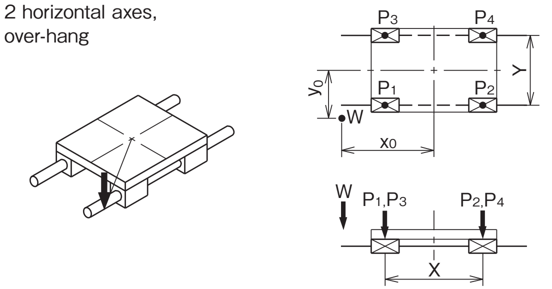
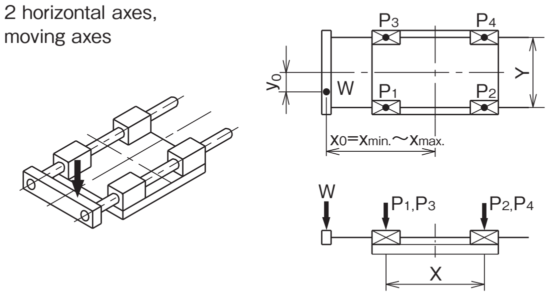
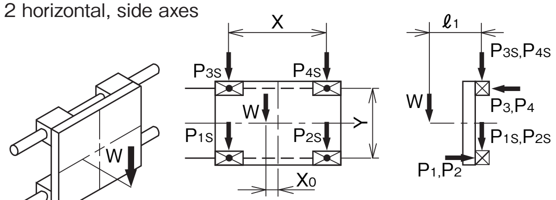
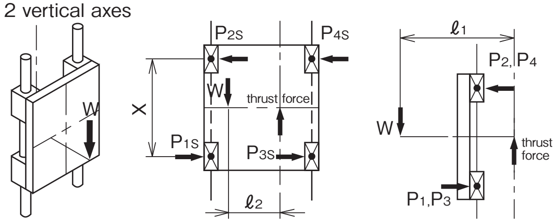
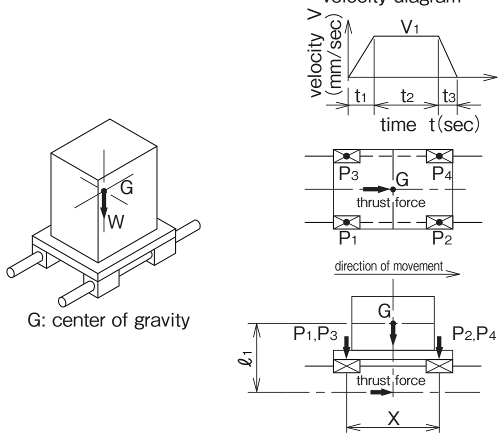
	condition	applied load calculation formula
under static conditions or constant velocity motion	2 horizontal axes 	$P_1=\frac{1}{4}W+\frac{x_0}{2X}W+\frac{y_0}{2Y}W$ $P_2=\frac{1}{4}W-\frac{x_0}{2X}W+\frac{y_0}{2Y}W$ $P_3=\frac{1}{4}W+\frac{x_0}{2X}W-\frac{y_0}{2Y}W$ $P_4=\frac{1}{4}W-\frac{x_0}{2X}W-\frac{y_0}{2Y}W$ Note : If the calculation results in a negative value, the loading direction is in the opposite direction.
	2 horizontal axes, over-hang 	
	2 horizontal axes, moving axes 	

Table 1-5 Applied Load Calculation (2)

	condition	applied load calculation formula
under static conditions or constant velocity motion	2 horizontal, side axes 	$P_1=P_2=P_3=P_4=\frac{\ell_1}{2Y}W$ $P_{1S}=P_{3S}=\frac{1}{4}W+\frac{X_0}{2X}W$ $P_{2S}=P_{4S}=\frac{1}{4}W-\frac{X_0}{2X}W$
	2 vertical axes 	$P_1=P_2=P_3=P_4=\frac{\ell_1}{2X}W$ $P_{1S}=P_{2S}=P_{3S}=P_{4S}=\frac{\ell_2}{2X}W$
under constant acceleration conditions	2 horizontal axes 	under acceleration $P_1=P_3=\frac{1}{4}W\left(1+\frac{2V_1\ell_1}{gt_1X}\right)$ $P_2=P_4=\frac{1}{4}W\left(1-\frac{2V_1\ell_1}{gt_1X}\right)$ under deceleration $P_1=P_3=\frac{1}{4}W\left(1-\frac{2V_1\ell_1}{gt_3X}\right)$ $P_2=P_4=\frac{1}{4}W\left(1+\frac{2V_1\ell_1}{gt_3X}\right)$ under constant velocity $P_1=P_2=P_3=P_4=\frac{1}{4}W$ ※g: acceleration of gravity (9.8×10^3mm/sec^2)

・Equivalent Coefficient

The linear systems are generally used with two axes, each axis with a couple of bearings installed. However, due to a space limitation, there must be an application in which one axis with one or two bearings in close contact installed. In such a case, multiply the applied moment by the equivalent moment coefficient shown in Tables 1-7~1-25 for applied load calculation. The following is a formula for calculating the equivalent moment load when a moment is applied to the linear systems.

$$P=E\cdot M$$

P: equivalent moment load per bearing (N)
E: equivalent moment coefficient
M: applied moment (N・mm)

Calculation of Applied Load (2)

Table 1-6 shows the formulas for determining the applied load when moment is applied to the linear systems.

W: applied load (N) P: load applied to the linear system (N) ℓ: distance to applied load or to working center of gravity (mm)

Table 1-6 Applied Load Calculation (3)

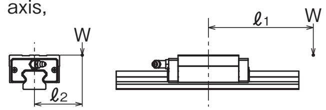
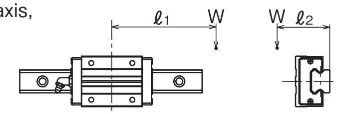
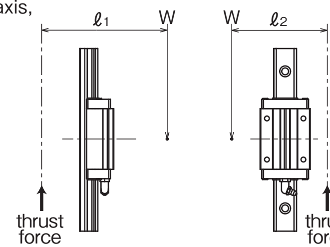
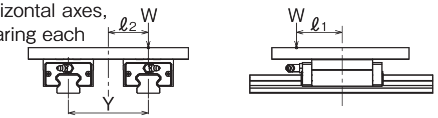
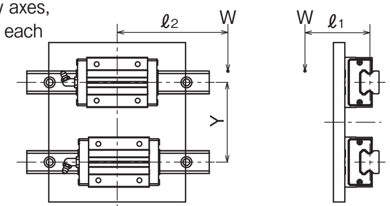
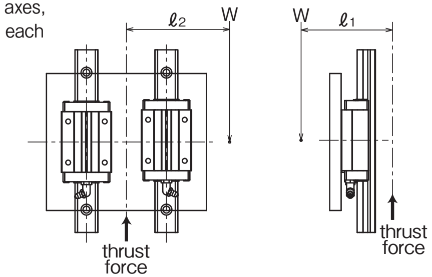
	condition	applied load calculation formula
1 axis application	1 horizontal axis, 1 bearing 	$P=W+E_{P1}W\ell_1+E_RW\ell_2$ E_{P1}: M_P equivalent coefficient with 1 bearing used E_R: M_R equivalent coefficient
	1 sideway axis, 1 bearing 	$P=W+E_{Y1}W\ell_1+E_RW\ell_2$ E_{Y1}: M_Y equivalent coefficient with 1 bearing used E_R: M_R equivalent coefficient
	1 vertical axis, 1 bearing 	$P=E_{P1}W\ell_1+E_{Y1}W\ell_2$ E_{P1}: M_P equivalent coefficient with 1 bearing used E_{Y1}: M_Y equivalent coefficient with 1 bearing used
2 axes application	2 horizontal axes, 1 bearing each 	$P=W/2+W\ell_2/Y+E_{P1}W\ell_1/2$ E_{P1}: M_P equivalent coefficient with 1 bearing used Y: span between the two axes centers
	2 sideway axes, 1 bearing each 	$P=W/2+E_{Y1}W\ell_2/2+W\ell_1/Y$ E_{Y1}: My equivalent coefficient with 1 bearing used Y: span between the two axes centers
	2 vertical axes, 1 bearing each 	$P=E_{P1}W\ell_1/2+E_{Y1}W\ell_2/2$ E_{P1}: M_P equivalent coefficient with 1 bearing used E_{Y1}: M_Y equivalent coefficient with 1 bearing used

Table 1-7 Slide Guide SEB type unit : 1/mm

part number	equivalent coefficient				
	E_{P1}	E_{P2}	E_{Y1}	E_{Y2}	E_R
SEBS 5B	6.64×10^{-1}	9.61×10^{-2}	7.91×10^{-1}	1.15×10^{-1}	3.85×10^{-1}
SEBS 5BY(D)	5.17×10^{-1}	8.38×10^{-2}	6.16×10^{-1}	9.99×10^{-2}	3.85×10^{-1}
SEBS 7BS	6.70×10^{-1}	7.76×10^{-2}	7.98×10^{-1}	9.25×10^{-2}	2.74×10^{-1}
SEBS 7B	4.62×10^{-1}	6.65×10^{-2}	5.50×10^{-1}	7.93×10^{-2}	2.74×10^{-1}
SEBS 7BY	2.84×10^{-1}	5.00×10^{-2}	3.38×10^{-1}	5.96×10^{-2}	2.74×10^{-1}
SEBS 9BS	5.83×10^{-1}	6.96×10^{-2}	6.95×10^{-1}	8.30×10^{-2}	2.15×10^{-1}
SEBS 9B	3.26×10^{-1}	5.26×10^{-2}	3.88×10^{-1}	6.27×10^{-2}	2.15×10^{-1}
SEBS 9BY	2.26×10^{-1}	4.14×10^{-2}	2.69×10^{-1}	4.94×10^{-2}	2.15×10^{-1}
SEBS12BS	5.27×10^{-1}	5.90×10^{-2}	6.28×10^{-1}	7.03×10^{-2}	1.60×10^{-1}
SEBS12B	3.08×10^{-1}	4.71×10^{-2}	3.67×10^{-1}	5.61×10^{-2}	1.60×10^{-1}
SEBS12BY	2.02×10^{-1}	3.64×10^{-2}	2.41×10^{-1}	4.33×10^{-2}	1.60×10^{-1}
SEBS15BS	3.95×10^{-1}	5.01×10^{-2}	4.71×10^{-1}	5.97×10^{-2}	1.30×10^{-1}
SEBS15B	2.31×10^{-1}	3.85×10^{-2}	2.75×10^{-1}	4.58×10^{-2}	1.29×10^{-1}
SEBS15BY	1.52×10^{-1}	2.90×10^{-2}	1.81×10^{-1}	3.45×10^{-2}	1.29×10^{-1}
SEBS20B	1.41×10^{-1}	2.47×10^{-2}	1.68×10^{-1}	2.94×10^{-2}	9.76×10^{-2}
SEBS20BY	1.01×10^{-1}	1.95×10^{-2}	1.20×10^{-1}	2.32×10^{-2}	9.76×10^{-2}
SEBS 5WB	4.51×10^{-1}	7.70×10^{-2}	5.37×10^{-1}	9.17×10^{-2}	1.96×10^{-1}
SEBS 5WBY	3.25×10^{-1}	6.15×10^{-2}	3.88×10^{-1}	7.33×10^{-2}	1.96×10^{-1}
SEBS 7WBS	5.83×10^{-1}	6.96×10^{-2}	6.95×10^{-1}	8.30×10^{-2}	1.40×10^{-1}
SEBS 7WB	3.26×10^{-1}	5.26×10^{-2}	3.88×10^{-1}	6.27×10^{-2}	1.40×10^{-1}
SEBS 7WBY	2.26×10^{-1}	4.14×10^{-2}	2.69×10^{-1}	4.94×10^{-2}	1.40×10^{-1}
SEBS 9WBS	4.63×10^{-1}	6.05×10^{-2}	5.52×10^{-1}	7.21×10^{-2}	1.09×10^{-1}
SEBS 9WB	2.41×10^{-1}	4.23×10^{-2}	2.87×10^{-1}	5.04×10^{-2}	1.08×10^{-1}
SEBS 9WBY	1.71×10^{-1}	3.31×10^{-2}	2.03×10^{-1}	3.94×10^{-2}	1.08×10^{-1}
SEBS12WBS	3.89×10^{-1}	5.28×10^{-2}	4.64×10^{-1}	6.29×10^{-2}	8.17×10^{-2}
SEBS12WB	2.17×10^{-1}	3.81×10^{-2}	2.59×10^{-1}	4.55×10^{-2}	8.16×10^{-2}
SEBS12WBY	1.51×10^{-1}	2.94×10^{-2}	1.79×10^{-1}	3.50×10^{-2}	8.16×10^{-2}
SEBS15WBS	2.58×10^{-1}	4.06×10^{-2}	3.07×10^{-1}	4.83×10^{-2}	4.71×10^{-2}
SEBS15WB	1.63×10^{-1}	3.03×10^{-2}	1.94×10^{-1}	3.61×10^{-2}	4.71×10^{-2}
SEBS15WBY	1.13×10^{-1}	2.29×10^{-2}	1.35×10^{-1}	2.73×10^{-2}	4.71×10^{-2}

E_{P1}: M_P equivalent coefficient with 1 block used E_{P2}: M_P equivalent coefficient with 2 blocks used in close contact
E_{Y1}: M_Y equivalent coefficient with 1 block used E_{Y2}: M_Y equivalent coefficient with 2 blocks used in close contact
E_R: M_R equivalent coefficient

Table 1-8 Slide Guide SEB and SER type unit : 1/mm

part number	equivalent coefficient				
	E_{P1}	E_{P2}	E_{Y1}	E_{Y2}	E_R
SEBS 2A	7.06×10^{-1}	1.37×10^{-1}	5.92×10^{-1}	1.15×10^{-1}	9.09×10^{-1}
SEBS 3A	9.16×10^{-1}	1.49×10^{-1}	7.69×10^{-1}	1.25×10^{-1}	6.25×10^{-1}
SEBS 3AY	6.02×10^{-1}	1.13×10^{-1}	5.05×10^{-1}	9.48×10^{-2}	6.25×10^{-1}
SEBS 5A	6.11×10^{-1}	1.01×10^{-1}	5.13×10^{-1}	8.46×10^{-2}	3.85×10^{-1}
SEBS 5AY	4.65×10^{-1}	8.45×10^{-2}	3.90×10^{-1}	7.09×10^{-2}	3.85×10^{-1}
SEBS 7A	4.62×10^{-1}	7.48×10^{-2}	3.87×10^{-1}	6.27×10^{-2}	2.74×10^{-1}
SEBS 7AY	2.84×10^{-1}	5.49×10^{-2}	2.38×10^{-1}	4.61×10^{-2}	2.74×10^{-1}
SEBS 9A	3.32×10^{-1}	5.89×10^{-2}	2.78×10^{-1}	4.94×10^{-2}	2.20×10^{-1}
SEBS 9AY	2.25×10^{-1}	4.46×10^{-2}	1.89×10^{-1}	3.74×10^{-2}	2.20×10^{-1}
SEB(S)12A	3.08×10^{-1}	5.62×10^{-2}	2.58×10^{-1}	4.72×10^{-2}	1.60×10^{-1}
SEB(S)12AY	2.02×10^{-1}	4.11×10^{-2}	1.70×10^{-1}	3.45×10^{-2}	1.60×10^{-1}
SEB(S)15A	2.31×10^{-1}	4.30×10^{-2}	1.94×10^{-1}	3.61×10^{-2}	1.29×10^{-1}
SEB(S)15AY	1.52×10^{-1}	3.12×10^{-2}	1.27×10^{-1}	2.62×10^{-2}	1.29×10^{-1}
SEB(S)20A	1.53×10^{-1}	3.03×10^{-2}	1.28×10^{-1}	2.54×10^{-2}	9.76×10^{-2}
SEB(S)20AY	1.01×10^{-1}	2.16×10^{-2}	8.44×10^{-2}	1.81×10^{-2}	9.76×10^{-2}
SEBS 3WA	6.74×10^{-1}	1.14×10^{-1}	5.42×10^{-1}	9.58×10^{-2}	3.23×10^{-1}
SEBS 3WAY	4.48×10^{-1}	8.78×10^{-2}	3.76×10^{-1}	7.37×10^{-2}	3.23×10^{-1}
SEBS 7WA(D)	3.26×10^{-1}	5.56×10^{-2}	2.73×10^{-1}	4.67×10^{-2}	1.40×10^{-1}
SEBS 7WAY	2.26×10^{-1}	4.32×10^{-2}	1.90×10^{-1}	3.63×10^{-2}	1.40×10^{-1}
SEB(S)9WA(D)	2.41×10^{-1}	4.72×10^{-2}	2.02×10^{-1}	3.96×10^{-2}	1.08×10^{-1}
SEB(S)9WAY	1.71×10^{-1}	3.58×10^{-2}	1.43×10^{-1}	3.00×10^{-2}	1.08×10^{-1}
SEB(S)12WA	2.02×10^{-1}	4.13×10^{-2}	1.70×10^{-1}	3.46×10^{-2}	8.16×10^{-2}
SEB(S)12WAY	1.43×10^{-1}	3.10×10^{-2}	1.20×10^{-1}	2.60×10^{-2}	8.16×10^{-2}
SEB(S)15WA	1.63×10^{-1}	3.29×10^{-2}	1.37×10^{-1}	2.76×10^{-2}	4.71×10^{-2}
SEB(S)15WAY	1.13×10^{-1}	2.43×10^{-2}	9.48×10^{-2}	2.04×10^{-2}	4.71×10^{-2}
SER(S)9A	2.49×10^{-1}	4.15×10^{-2}	2.15×10^{-1}	3.58×10^{-2}	1.50×10^{-1}
SER(S)12A	2.50×10^{-1}	4.16×10^{-2}	2.23×10^{-1}	3.71×10^{-2}	1.33×10^{-1}
SER(S)15A	1.99×10^{-1}	3.32×10^{-2}	1.79×10^{-1}	2.98×10^{-2}	1.05×10^{-1}
SER(S)20A	1.66×10^{-1}	2.77×10^{-2}	1.47×10^{-1}	2.45×10^{-2}	6.49×10^{-2}
SER(S)9WA	1.52×10^{-1}	2.53×10^{-2}	1.36×10^{-1}	2.26×10^{-2}	7.17×10^{-2}
SER(S)12WA	1.42×10^{-1}	2.36×10^{-2}	1.28×10^{-1}	2.13×10^{-2}	5.86×10^{-2}
SER(S)15WA	1.60×10^{-1}	2.66×10^{-2}	1.45×10^{-1}	2.41×10^{-2}	4.15×10^{-2}

E_{P1}: M_P equivalent coefficient with 1 block used E_{P2}: M_P equivalent coefficient with 2 blocks used in close contact
E_{Y1}: M_Y equivalent coefficient with 1 block used E_{Y2}: M_Y equivalent coefficient with 2 blocks used in close contact
E_R: M_R equivalent coefficient

Table 1-9 Slide Guide SGL, SGW type unit : 1/mm

part number	equivalent coefficient				
	E_{P1}	E_{P2}	E_{Y1}	E_{Y2}	E_{R}
SGL15F (E)	2.57×10^{-1}	3.75×10^{-2}	2.57×10^{-1}	3.75×10^{-2}	1.28×10^{-1}
SGL20F (E)	2.06×10^{-1}	3.31×10^{-2}	2.06×10^{-1}	3.31×10^{-2}	9.31×10^{-2}
SGL25F (E)	1.72×10^{-1}	2.81×10^{-2}	1.72×10^{-1}	2.81×10^{-2}	8.31×10^{-2}
SGL30F (E)	1.47×10^{-1}	2.28×10^{-2}	1.47×10^{-1}	2.28×10^{-2}	6.88×10^{-2}
SGL35F (E)	1.29×10^{-1}	2.02×10^{-2}	1.29×10^{-1}	2.02×10^{-2}	5.45×10^{-2}
SGL15TF (TE)	1.63×10^{-1}	2.87×10^{-2}	1.63×10^{-1}	2.87×10^{-2}	1.29×10^{-1}
SGL20TF (TE)	1.41×10^{-1}	2.59×10^{-2}	1.41×10^{-1}	2.59×10^{-2}	9.28×10^{-2}
SGL25TF (TE)	1.09×10^{-1}	2.09×10^{-2}	1.09×10^{-1}	2.09×10^{-2}	8.31×10^{-2}
SGL30TF (TE)	9.32×10^{-2}	1.71×10^{-2}	9.32×10^{-2}	1.71×10^{-2}	6.87×10^{-2}
SGL35TF (TE)	8.14×10^{-2}	1.51×10^{-2}	8.14×10^{-2}	1.51×10^{-2}	5.49×10^{-2}
SGL15HTF (HTE,HTEX)	1.63×10^{-1}	2.87×10^{-2}	1.63×10^{-1}	2.87×10^{-2}	1.29×10^{-1}
SGL20HTF (HTE,HTEX)	1.22×10^{-1}	2.33×10^{-2}	1.22×10^{-1}	2.33×10^{-2}	9.29×10^{-2}
SGL25HTF (HTE,HTEX)	1.09×10^{-1}	2.09×10^{-2}	1.09×10^{-1}	2.09×10^{-2}	8.31×10^{-2}
SGL30HTF (HTE,HTEX)	9.32×10^{-2}	1.71×10^{-2}	9.32×10^{-2}	1.71×10^{-2}	6.87×10^{-2}
SGL35HTF (HTE,HTEX)	8.14×10^{-2}	1.51×10^{-2}	8.14×10^{-2}	1.51×10^{-2}	5.49×10^{-2}
SGL45HTF (HTE,HTEX)	6.52×10^{-2}	1.22×10^{-2}	6.52×10^{-2}	1.22×10^{-2}	4.37×10^{-2}
SGL15HYF (HYE)	1.08×10^{-1}	2.13×10^{-2}	1.08×10^{-1}	2.13×10^{-2}	1.28×10^{-1}
SGL20HYF (HYE)	8.61×10^{-2}	1.79×10^{-2}	8.61×10^{-2}	1.79×10^{-2}	9.31×10^{-2}
SGL25HYF (HYE)	7.54×10^{-2}	1.57×10^{-2}	7.54×10^{-2}	1.57×10^{-2}	8.32×10^{-2}
SGL30HYF (HYE)	6.47×10^{-2}	1.30×10^{-2}	6.47×10^{-2}	1.30×10^{-2}	6.90×10^{-2}
SGL35HYF (HYE)	5.65×10^{-2}	1.15×10^{-2}	5.65×10^{-2}	1.15×10^{-2}	5.46×10^{-2}
SGL45HYF (HYE)	5.00×10^{-2}	1.01×10^{-2}	5.00×10^{-2}	1.01×10^{-2}	4.35×10^{-2}
SGW17TF (TE)	2.00×10^{-1}	3.28×10^{-2}	2.00×10^{-1}	3.28×10^{-2}	5.35×10^{-2}
SGW21TF (TE)	1.67×10^{-1}	2.89×10^{-2}	1.67×10^{-1}	2.89×10^{-2}	4.78×10^{-2}
SGW27TF (TE)	1.26×10^{-1}	2.31×10^{-2}	1.26×10^{-1}	2.31×10^{-2}	4.33×10^{-2}
SGW35TF (TE)	8.39×10^{-2}	1.56×10^{-2}	8.39×10^{-2}	1.56×10^{-2}	2.62×10^{-2}

E_{P1}: M_P equivalent coefficient with 1 block used E_{P2}: M_P equivalent coefficient with 2 blocks used in close contact
E_{Y1}: M_Y equivalent coefficient with 1 block used E_{Y2}: M_Y equivalent coefficient with 2 blocks used in close contact
E_R: M_R equivalent coefficient

Table 1-10 Ball Spline・Rotary Ball Spline unit : 1/mm

part number			equivalent coefficient	
			E_1	E_2
SSP 4	—	—	6.19×10^{-1}	1.18×10^{-1}
SSP 6	**SPR 6**	**SPB 6 KP**	4.47×10^{-1}	5.70×10^{-2}
SSP 8	**SPR 8**	**SPB 8 KP**	3.88×10^{-1}	5.74×10^{-2}
SSP 10	**SPR 10**	**SPB 10 KP**	2.82×10^{-1}	4.37×10^{-2}
SSP 13A	**SPR 13**	**SPB 13 KP**	3.57×10^{-1}	4.49×10^{-2}
SSP 16A	**SPR 16**	**SPB 16 (KP)**	2.43×10^{-1}	3.75×10^{-2}
SSP 20A	**SPR 20A**	**SPB 20 (KP)**	1.48×10^{-1}	2.91×10^{-2}
SSP 25A	**SPR 25A**	**SPB 25 (KP)**	1.37×10^{-1}	2.27×10^{-2}
SSP 30A	**SPR 30A**	—	1.28×10^{-1}	1.58×10^{-2}
SSP 40A	**SPR 40A**	—	1.05×10^{-1}	1.28×10^{-2}
SSP 50A	**SPR 50A**	—	9.41×10^{-2}	1.59×10^{-2}
SSP 60A	**SPR 60A**	—	9.02×10^{-2}	1.45×10^{-2}
SSP 80A	—	—	5.43×10^{-2}	1.03×10^{-2}
SSP 80AL	—	—	3.76×10^{-2}	7.72×10^{-3}
SSP100A	—	—	4.78×10^{-2}	8.79×10^{-3}
SSP100AL	—	—	3.33×10^{-2}	6.74×10^{-3}
SSP 20	**SPR 20**	—	1.79×10^{-1}	2.26×10^{-2}
SSP 25	**SPR 25**	—	1.55×10^{-1}	1.94×10^{-2}
SSP 30	**SPR 30**	—	1.28×10^{-1}	1.58×10^{-2}
SSP 40	**SPR 40**	—	1.05×10^{-1}	1.28×10^{-2}
SSP 50	**SPR 50**	—	1.07×10^{-1}	1.69×10^{-2}
SSP 60	**SPR 60**	—	9.77×10^{-2}	1.44×10^{-2}
SPLFS 6			2.68×10^{-1}	6.67×10^{-2}
SPLFS 8			2.57×10^{-1}	6.48×10^{-2}
SPLFS 10			2.09×10^{-1}	5.25×10^{-2}
SPLFS 13			1.96×10^{-1}	4.90×10^{-2}
SPLFS 16			1.59×10^{-1}	3.97×10^{-2}

E_1: equivalent moment coefficient with 1 nut used
E_2: equivalent moment coefficient with 2 nuts used in close contact

unit : 1/mm

part number	equivalent coefficient			
	E_{P1}	E_{P2}	E_{Y1}	E_{Y2}
SSP 4AM	7.42×10^{-1}	1.30×10^{-1}	4.25×10^{-1}	7.50×10^{-2}
SSP 5AM	5.52×10^{-1}	8.70×10^{-2}	4.53×10^{-1}	7.10×10^{-2}
SSP 6AM	5.06×10^{-1}	7.80×10^{-2}	4.15×10^{-1}	6.40×10^{-2}
SSP 8AM	4.40×10^{-1}	6.50×10^{-2}	3.62×10^{-1}	5.40×10^{-2}
SSP10AM	3.66×10^{-1}	5.50×10^{-2}	3.01×10^{-1}	4.50×10^{-2}

E_{P1}: M_P equivalent coefficient with 1 nut used
E_{P2}: M_P equivalent coefficient with 2 nuts used in close contact
E_{Y1}: M_Y equivalent coefficient with 1 nut used
E_{Y2}: M_Y equivalent coefficient with 2 nuts used in close contact

Table 1-11 Slide Bush SM type unit : 1/mm

part number	equivalent coefficient	
	E_1	E_2
SM 3	1.24	2.13×10^{-1}
SM 4	1.21	1.78×10^{-1}
SM 5	8.96×10^{-1}	1.40×10^{-1}
SM 6	7.29×10^{-1}	1.09×10^{-1}
SM 8s	7.19×10^{-1}	1.20×10^{-1}
SM 8	5.46×10^{-1}	8.42×10^{-2}
SM 10	4.55×10^{-1}	7.02×10^{-2}
SM 12	4.32×10^{-1}	6.64×10^{-2}
SM 13	4.06×10^{-1}	6.21×10^{-2}
SM 16	3.59×10^{-1}	5.46×10^{-2}
SM 20	3.07×10^{-1}	4.70×10^{-2}
SM 25	2.17×10^{-1}	3.33×10^{-2}
SM 30	1.99×10^{-1}	3.07×10^{-2}
SM 35	1.71×10^{-1}	2.70×10^{-2}
SM 40	1.64×10^{-1}	2.51×10^{-2}
SM 50	1.20×10^{-1}	1.89×10^{-2}
SM 60	1.13×10^{-1}	1.75×10^{-2}
SM 80	8.18×10^{-2}	1.36×10^{-2}
SM100	6.66×10^{-2}	1.11×10^{-2}
SM120	5.63×10^{-2}	9.38×10^{-3}
SM150	4.62×10^{-2}	7.71×10^{-3}

E_1: equivalent coefficient with 1 bush used
E_2: equivalent coefficient with 2 bushes used in close contact

Table 1-12 Slide Bush SM-G-L type unit : 1/mm

part number	equivalent coefficient	
	E_1	E_2
SM 6G-LUU	4.14×10^{-1}	7.39×10^{-2}
SM 8G-LUU	3.17×10^{-1}	5.90×10^{-2}
SM10G-LUU	2.53×10^{-1}	4.78×10^{-2}
SM12G-LUU	2.28×10^{-1}	4.47×10^{-2}
SM13G-LUU	2.03×10^{-1}	4.03×10^{-2}
SM16G-LUU	1.78×10^{-1}	3.45×10^{-2}
SM20G-LUU	1.53×10^{-1}	3.06×10^{-2}
SM25G-LUU	1.09×10^{-1}	2.17×10^{-2}
SM30G-LUU	9.59×10^{-2}	1.97×10^{-2}

E_1: equivalent coefficient with 1 bush used
E_2: equivalent coefficient with 2 bushes used in close contact

Table 1-13 Slide Bush SM-W type unit : 1/mm

part number	equivalent coefficient E_1	E_2
SM 3W	4.12×10^{-1}	–
SM 4W	4.03×10^{-1}	–
SM 5W	2.99×10^{-1}	–
SM 6W	2.43×10^{-1}	–
SM 8W	1.82×10^{-1}	–
SM 10W	1.52×10^{-1}	–
SM 12W	1.44×10^{-1}	–
SM 13W	1.35×10^{-1}	–
SM 16W	1.19×10^{-1}	–
SM 20W	1.02×10^{-1}	–
SM 25W	7.24×10^{-2}	–
SM 30W	6.63×10^{-2}	–
SM 35W	5.70×10^{-2}	–
SM 40W	5.47×10^{-2}	–
SM 50W	4.01×10^{-2}	–
SM 60W	3.77×10^{-2}	–

E_1: equivalent coefficient with 1 bush used

Table 1-14 Slide Bush TRF type unit : 1/mm

part number	equivalent coefficient E_1	E_2
TRF 6	6.46×10^{-2}	–
TRF 8	4.90×10^{-2}	–
TRF10	4.07×10^{-2}	–
TRF12	3.92×10^{-2}	–
TRF13	3.66×10^{-2}	–
TRF16	3.20×10^{-2}	–
TRF20	2.80×10^{-2}	–
TRF25	2.00×10^{-2}	–
TRF30	1.85×10^{-2}	–
TRF35	1.68×10^{-2}	–
TRF40	1.45×10^{-2}	–
TRF50	1.16×10^{-2}	–
TRF60	1.11×10^{-2}	–

E_1: equivalent coefficient with 1 bush used

Table 1-15 Slide Bush KB type unit : 1/mm

part number	equivalent coefficient E_1	E_2
KB 3	1.28	2.13×10^{-1}
KB 4	1.05	1.75×10^{-1}
KB 5	5.40×10^{-1}	9.00×10^{-2}
KB 8	5.61×10^{-1}	8.00×10^{-2}
KB10	4.21×10^{-1}	7.02×10^{-2}
KB12	4.02×10^{-1}	6.20×10^{-2}
KB16	3.77×10^{-1}	5.73×10^{-2}
KB20	3.29×10^{-1}	4.49×10^{-2}
KB25	2.14×10^{-1}	3.37×10^{-2}
KB30	2.08×10^{-1}	2.96×10^{-2}
KB40	1.64×10^{-1}	2.51×10^{-2}
KB50	1.20×10^{-1}	1.89×10^{-2}
KB60	1.21×10^{-1}	1.55×10^{-2}
KB80	7.34×10^{-2}	1.22×10^{-2}
KB 8W	1.87×10^{-1}	–
KB12W	1.34×10^{-1}	–
KB16W	1.25×10^{-1}	–
KB20W	1.10×10^{-1}	–
KB25W	7.14×10^{-2}	–
KB30W	6.96×10^{-2}	–
KB40W	5.47×10^{-2}	–
KB50W	4.02×10^{-2}	–
KB60W	4.11×10^{-2}	–

E_1: equivalent coefficient with 1 bush used
E_2: equivalent coefficient with 2 bushes used in close contact

Table 1-16 TOPBALL TK type unit : 1/mm

part number	equivalent coefficient E_1	E_2
TK 8	4.91×10^{-1}	8.18×10^{-2}
TK10	4.17×10^{-1}	6.95×10^{-2}
TK12	3.70×10^{-1}	6.17×10^{-2}
TK16	3.30×10^{-1}	5.49×10^{-2}
TK20	2.55×10^{-1}	4.24×10^{-2}
TK25	1.90×10^{-1}	3.16×10^{-2}
TK30	1.66×10^{-1}	2.76×10^{-2}
TK40	1.42×10^{-1}	2.36×10^{-2}
TK50	1.11×10^{-1}	1.84×10^{-2}

E_1: equivalent coefficient with 1 bush used
E_2: equivalent coefficient with 2 bushes used in close contact

Table 1-17 TOPBALL TW type unit : 1/mm

part number	equivalent coefficient E_1	E_2
TW 3	8.70×10^{-1}	1.45×10^{-1}
TW 4	6.57×10^{-1}	1.09×10^{-1}
TW 6	5.17×10^{-1}	8.60×10^{-2}
TW 8	3.55×10^{-1}	5.90×10^{-2}
TW10	3.00×10^{-1}	5.00×10^{-2}
TW12	2.66×10^{-1}	4.40×10^{-2}
TW16	1.90×10^{-1}	3.10×10^{-2}
TW20	1.66×10^{-1}	2.70×10^{-2}
TW24	1.44×10^{-1}	2.40×10^{-2}
TW32	1.08×10^{-1}	1.80×10^{-2}

E_1: equivalent coefficient with 1 bush used
E_2: equivalent coefficient with 2 bushes used in close contact

Table 1-18 Slide Bush SW type unit : 1/mm

part number	equivalent coefficient E_1	E_2
SWS 2	8.90×10^{-1}	1.48×10^{-1}
SWS 3	8.01×10^{-1}	1.33×10^{-1}
SW 4	7.95×10^{-1}	1.05×10^{-1}
SW 6	6.98×10^{-1}	9.75×10^{-2}
SW 8	4.09×10^{-1}	6.23×10^{-2}
SW10	3.54×10^{-1}	5.33×10^{-2}
SW12	3.10×10^{-1}	4.76×10^{-2}
SW16	2.29×10^{-1}	3.40×10^{-2}
SW20	1.94×10^{-1}	3.01×10^{-2}
SW24	1.69×10^{-1}	2.59×10^{-2}
SW32	1.19×10^{-1}	1.87×10^{-2}
SW40	9.23×10^{-2}	1.54×10^{-2}
SW48	7.84×10^{-2}	1.31×10^{-2}
SW64	5.47×10^{-2}	9.11×10^{-3}
SW 4W	2.65×10^{-1}	–
SW 6W	2.33×10^{-1}	–
SW 8W	1.37×10^{-1}	–
SW10W	1.18×10^{-1}	–
SW12W	1.03×10^{-1}	–
SW16W	7.62×10^{-2}	–
SW20W	6.47×10^{-2}	–
SW24W	5.62×10^{-2}	–
SW32W	3.98×10^{-2}	–

E_1: equivalent coefficient with 1 bush used
E_2: equivalent coefficient with 2 bushes used in close contact

Table 1-19 Slide Bush GM type unit : 1/mm

part number	equivalent coefficient E_1	E_2
GM 6	6.43×10^{-1}	1.08×10^{-1}
GM 8	4.92×10^{-1}	8.20×10^{-2}
GM10	4.21×10^{-1}	7.01×10^{-2}
GM12	3.85×10^{-1}	6.42×10^{-2}
GM13	3.78×10^{-1}	6.29×10^{-2}
GM16	3.25×10^{-1}	5.42×10^{-2}
GM20	2.75×10^{-1}	4.58×10^{-2}
GM25	1.98×10^{-1}	3.30×10^{-2}
GM30	1.82×10^{-1}	3.03×10^{-2}
GM 6W	3.54×10^{-1}	6.53×10^{-2}
GM 8W	2.38×10^{-1}	4.96×10^{-2}
GM10W	2.20×10^{-1}	4.50×10^{-2}
GM12W	2.07×10^{-1}	3.81×10^{-2}
GM13W	1.94×10^{-1}	3.76×10^{-2}
GM16W	1.71×10^{-1}	3.44×10^{-2}
GM20W	1.37×10^{-1}	2.69×10^{-2}
GM25W	9.03×10^{-2}	1.94×10^{-2}
GM30W	9.55×10^{-2}	1.78×10^{-2}

E_1: equivalent coefficient with 1 bush used
E_2: equivalent coefficient with 2 bushes used in close contact

Table 1-20 Slide Rotary Bush unit : 1/mm

part number	equivalent coefficient E_1	E_2
SRE 6	6.83×10^{-1}	1.14×10^{-1}
SRE 8	4.98×10^{-1}	8.31×10^{-2}
SRE10	4.12×10^{-1}	6.86×10^{-2}
SRE12	4.19×10^{-1}	6.98×10^{-2}
SRE13	3.93×10^{-1}	6.54×10^{-2}
SRE16	3.40×10^{-1}	5.66×10^{-2}
SRE20	2.90×10^{-1}	4.84×10^{-2}
SRE25	1.98×10^{-1}	3.29×10^{-2}
SRE30	1.80×10^{-1}	3.01×10^{-2}
SRE40	1.52×10^{-1}	2.54×10^{-2}
RK12	4.32×10^{-1}	6.64×10^{-2}
RK16	3.59×10^{-1}	5.46×10^{-2}
RK20	3.07×10^{-1}	4.70×10^{-2}
RK25	2.17×10^{-1}	3.33×10^{-2}
RK30	1.99×10^{-1}	3.07×10^{-2}

E_1: equivalent coefficient with 1 bush used
E_2: equivalent coefficient with 2 bushes used in close contact

Table 1-21 Slide Table NVT type (1) unit : 1/mm

part number	equivalent coefficient		
	E_P	E_Y	E_R
NVT1025	2.28×10^{-1}	2.67×10^{-1}	1.48×10^{-1}
NVT1035	9.55×10^{-1}	3.99×10^{-1}	8.76×10^{-1}
NVT1045	2.79×10^{-1}	2.47×10^{-1}	3.31×10^{-1}
NVT1055	2.40×10^{-1}	2.03×10^{-1}	3.53×10^{-1}
NVT1065	1.70×10^{-1}	1.59×10^{-1}	2.77×10^{-1}
NVT1075	1.54×10^{-1}	1.39×10^{-1}	2.96×10^{-1}
NVT1085	1.24×10^{-1}	1.17×10^{-1}	2.58×10^{-1}
NVT2035	1.51×10^{-1}	1.74×10^{-1}	1.12×10^{-1}
NVT2050	1.62×10^{-1}	1.63×10^{-1}	1.45×10^{-1}
NVT2065	1.25×10^{-1}	1.29×10^{-1}	1.32×10^{-1}
NVT2080	1.15×10^{-1}	1.14×10^{-1}	1.54×10^{-1}
NVT2095	9.51×10^{-2}	9.56×10^{-2}	1.43×10^{-1}
NVT2110	8.81×10^{-2}	8.63×10^{-2}	1.57×10^{-1}
NVT2125	8.22×10^{-2}	7.88×10^{-2}	1.69×10^{-1}
NVT2140	7.13×10^{-2}	6.94×10^{-2}	1.59×10^{-1}
NVT2155	6.48×10^{-2}	6.26×10^{-2}	1.69×10^{-1}
NVT2170	6.10×10^{-2}	5.81×10^{-2}	1.76×10^{-1}
NVT2185	5.77×10^{-2}	5.42×10^{-2}	1.82×10^{-1}
NVT3055	3.41×10^{-1}	2.17×10^{-1}	1.97×10^{-1}
NVT3080	9.64×10^{-2}	1.02×10^{-1}	7.86×10^{-2}
NVT3105	8.55×10^{-2}	8.67×10^{-2}	8.90×10^{-2}
NVT3130	8.00×10^{-2}	7.57×10^{-2}	1.16×10^{-1}
NVT3155	5.56×10^{-2}	5.59×10^{-2}	8.78×10^{-2}
NVT3180	5.12×10^{-2}	5.08×10^{-2}	9.25×10^{-2}
NVT3205	4.76×10^{-2}	4.66×10^{-2}	9.65×10^{-2}
NVT3230	4.45×10^{-2}	4.31×10^{-2}	9.99×10^{-2}
NVT4085	1.01×10^{-1}	1.08×10^{-1}	5.63×10^{-2}
NVT4125	9.48×10^{-2}	8.81×10^{-2}	8.72×10^{-2}
NVT4165	6.01×10^{-2}	5.97×10^{-2}	6.56×10^{-2}
NVT4205	4.34×10^{-2}	4.39×10^{-2}	6.03×10^{-2}
NVT4245	4.06×10^{-2}	3.97×10^{-2}	7.11×10^{-2}
NVT4285	3.30×10^{-2}	3.28×10^{-2}	6.38×10^{-2}
NVT6110	1.74×10^{-1}	1.24×10^{-1}	1.10×10^{-1}
NVT6160	6.02×10^{-2}	6.08×10^{-2}	5.66×10^{-2}
NVT6210	4.82×10^{-2}	4.75×10^{-2}	6.63×10^{-2}
NVT6260	4.21×10^{-2}	4.06×10^{-2}	6.85×10^{-2}
NVT6310	2.95×10^{-2}	2.99×10^{-2}	5.28×10^{-2}
NVT6360	2.70×10^{-2}	2.70×10^{-2}	5.53×10^{-2}
NVT6410	2.53×10^{-2}	2.46×10^{-2}	6.37×10^{-2}

E_P: M_P equivalent coefficient E_Y: M_Y equivalent coefficient
E_R: M_R equivalent coefficient

Table 1-21 Slide Table NVT type (2) unit : 1/mm

part number	equivalent coefficient		
	E_P	E_Y	E_R
NVT9210	7.51×10^{-2}	6.05×10^{-2}	5.66×10^{-2}
NVT9310	3.26×10^{-2}	3.25×10^{-2}	4.00×10^{-2}
NVT9410	2.36×10^{-2}	2.34×10^{-2}	3.84×10^{-2}
NVT9510	1.82×10^{-2}	1.83×10^{-2}	3.34×10^{-2}

E_P: M_P equivalent coefficient E_Y: M_Y equivalent coefficient
E_R: M_R equivalent coefficient

Table 1-22 Slide Table NYT type unit : 1/mm

part number	equivalent coefficient		
	E_P	E_Y	E_R
NYT1025	2.28×10^{-1}	2.67×10^{-1}	2.67×10^{-1}
NYT1035	9.55×10^{-1}	3.99×10^{-1}	1.58
NYT1045	2.79×10^{-1}	2.47×10^{-1}	5.96×10^{-1}
NYT1055	2.40×10^{-1}	2.03×10^{-1}	6.36×10^{-1}
NYT1065	1.70×10^{-1}	1.59×10^{-1}	4.98×10^{-1}
NYT1075	1.54×10^{-1}	1.39×10^{-1}	5.31×10^{-1}
NYT1085	1.24×10^{-1}	1.17×10^{-1}	4.68×10^{-1}
NYT2035	1.50×10^{-1}	1.73×10^{-1}	1.53×10^{-1}
NYT2050	1.61×10^{-1}	1.63×10^{-1}	2.28×10^{-1}
NYT2065	1.24×10^{-1}	1.28×10^{-1}	1.96×10^{-1}
NYT2080	1.15×10^{-1}	1.14×10^{-1}	2.27×10^{-1}
NYT2095	9.50×10^{-2}	9.55×10^{-2}	2.07×10^{-1}
NYT2110	8.81×10^{-2}	8.64×10^{-2}	2.27×10^{-1}
NYT2125	8.15×10^{-2}	7.85×10^{-2}	2.41×10^{-1}
NYT3055	3.88×10^{-1}	2.17×10^{-1}	4.74×10^{-1}
NYT3080	9.68×10^{-2}	1.02×10^{-1}	1.39×10^{-1}
NYT3105	8.56×10^{-2}	8.66×10^{-2}	1.55×10^{-1}
NYT3130	8.07×10^{-2}	7.59×10^{-2}	2.00×10^{-1}
NYT3155	5.55×10^{-2}	5.58×10^{-2}	1.48×10^{-1}
NYT3180	5.11×10^{-2}	5.07×10^{-2}	1.55×10^{-1}
NYT3205	4.76×10^{-2}	4.66×10^{-2}	1.61×10^{-1}

E_P: M_P equivalent coefficient E_Y: M_Y equivalent coefficient
E_R: M_R equivalent coefficient

Table 1-23 Slide Table SVT type (1) unit : 1/mm

part number	equivalent coefficient		
	E_P	E_Y	E_R
SVT1025	2.67×10^{-1}	3.25×10^{-1}	1.48×10^{-1}
SVT1035	3.10×10^{-1}	2.73×10^{-1}	1.48×10^{-1}
SVT1045	1.71×10^{-1}	1.87×10^{-1}	1.48×10^{-1}
SVT1055	1.51×10^{-1}	1.63×10^{-1}	1.48×10^{-1}
SVT1065	1.35×10^{-1}	1.44×10^{-1}	1.48×10^{-1}
SVT1075	1.11×10^{-1}	1.17×10^{-1}	1.48×10^{-1}
SVT1085	1.02×10^{-1}	1.07×10^{-1}	1.48×10^{-1}
SVT2035	1.67×10^{-1}	2.03×10^{-1}	1.11×10^{-1}
SVT2050	1.45×10^{-1}	1.64×10^{-1}	1.11×10^{-1}
SVT2065	1.22×10^{-1}	1.37×10^{-1}	1.11×10^{-1}
SVT2080	1.28×10^{-1}	1.19×10^{-1}	1.11×10^{-1}
SVT2095	1.10×10^{-1}	1.03×10^{-1}	1.11×10^{-1}
SVT2110	7.61×10^{-2}	8.08×10^{-2}	1.11×10^{-1}
SVT2125	6.94×10^{-2}	7.33×10^{-2}	1.11×10^{-1}
SVT2140	7.01×10^{-2}	6.73×10^{-2}	1.11×10^{-1}
SVT2155	6.43×10^{-2}	6.19×10^{-2}	1.11×10^{-1}
SVT2170	5.12×10^{-2}	5.33×10^{-2}	1.11×10^{-1}
SVT2185	4.81×10^{-2}	4.99×10^{-2}	1.11×10^{-1}
SVT3055	2.00×10^{-1}	1.75×10^{-1}	7.14×10^{-2}
SVT3080	1.22×10^{-1}	1.12×10^{-1}	7.14×10^{-2}
SVT3105	7.53×10^{-2}	8.14×10^{-2}	7.14×10^{-2}
SVT3130	6.08×10^{-2}	6.47×10^{-2}	7.14×10^{-2}
SVT3155	6.17×10^{-2}	5.89×10^{-2}	7.14×10^{-2}
SVT3180	5.15×10^{-2}	4.96×10^{-2}	7.14×10^{-2}
SVT3205	4.75×10^{-2}	4.59×10^{-2}	7.14×10^{-2}
SVT3230	3.85×10^{-2}	3.99×10^{-2}	7.14×10^{-2}
SVT3255	3.87×10^{-2}	3.76×10^{-2}	7.14×10^{-2}
SVT3280	3.64×10^{-2}	3.54×10^{-2}	7.14×10^{-2}

E_P: M_P equivalent coefficient E_Y: M_Y equivalent coefficient
E_R: M_R equivalent coefficient

Table 1-23 Slide Table SVT type (2) unit : 1/mm

part number	equivalent coefficient		
	E_P	E_Y	E_R
SVT3305	3.09×10^{-2}	3.18×10^{-2}	7.14×10^{-2}
SVT4085	8.29×10^{-2}	9.38×10^{-2}	5.00×10^{-2}
SVT4125	6.11×10^{-2}	6.67×10^{-2}	5.00×10^{-2}
SVT4165	6.27×10^{-2}	5.88×10^{-2}	5.00×10^{-2}
SVT4205	4.89×10^{-2}	4.65×10^{-2}	5.00×10^{-2}
SVT4245	4.01×10^{-2}	3.85×10^{-2}	5.00×10^{-2}
SVT4285	3.39×10^{-2}	3.28×10^{-2}	5.00×10^{-2}
SVT4325	2.94×10^{-2}	2.86×10^{-2}	5.00×10^{-2}
SVT4365	2.60×10^{-2}	2.53×10^{-2}	5.00×10^{-2}
SVT4405	2.20×10^{-2}	2.27×10^{-2}	5.00×10^{-2}
SVT6110	6.83×10^{-2}	7.72×10^{-2}	4.44×10^{-2}
SVT6160	5.03×10^{-2}	5.49×10^{-2}	4.44×10^{-2}
SVT6210	3.97×10^{-2}	4.24×10^{-2}	4.44×10^{-2}
SVT6260	3.27×10^{-2}	3.45×10^{-2}	4.44×10^{-2}
SVT6310	2.78×10^{-2}	2.90×10^{-2}	4.44×10^{-2}
SVT6360	2.79×10^{-2}	2.70×10^{-2}	4.44×10^{-2}
SVT6410	2.42×10^{-2}	2.35×10^{-2}	4.44×10^{-2}
SVT6460	2.14×10^{-2}	2.08×10^{-2}	4.44×10^{-2}
SVT6510	1.92×10^{-2}	1.87×10^{-2}	4.44×10^{-2}
SVT9210	3.50×10^{-2}	3.90×10^{-2}	2.78×10^{-2}
SVT9310	3.14×10^{-2}	2.94×10^{-2}	2.78×10^{-2}
SVT9410	2.41×10^{-2}	2.57×10^{-2}	2.78×10^{-2}
SVT9510	1.98×10^{-2}	2.09×10^{-2}	2.78×10^{-2}
SVT9610	2.00×10^{-2}	1.92×10^{-2}	2.78×10^{-2}
SVT9710	1.70×10^{-2}	1.64×10^{-2}	2.78×10^{-2}
SVT9810	1.37×10^{-2}	1.42×10^{-2}	2.78×10^{-2}
SVT9910	1.22×10^{-2}	1.26×10^{-2}	2.78×10^{-2}
SVT91010	1.10×10^{-2}	1.13×10^{-2}	2.78×10^{-2}

E_P: M_P equivalent coefficient E_Y: M_Y equivalent coefficient
E_R: M_R equivalent coefficient

Table 1-24 Slide Table SYT type　unit : 1/mm

part number	equivalent coefficient		
	E_P	E_Y	E_R
SYT1025	2.67×10^{-1}	3.25×10^{-1}	2.67×10^{-1}
SYT1035	3.10×10^{-1}	2.73×10^{-1}	2.67×10^{-1}
SYT1045	1.71×10^{-1}	1.87×10^{-1}	2.67×10^{-1}
SYT1055	1.51×10^{-1}	1.63×10^{-1}	2.67×10^{-1}
SYT1065	1.35×10^{-1}	1.44×10^{-1}	2.67×10^{-1}
SYT1075	1.11×10^{-1}	1.17×10^{-1}	2.67×10^{-1}
SYT1085	1.02×10^{-1}	1.07×10^{-1}	2.67×10^{-1}
SYT2035	1.67×10^{-1}	2.03×10^{-1}	1.54×10^{-1}
SYT2050	1.45×10^{-1}	1.64×10^{-1}	1.54×10^{-1}
SYT2065	1.22×10^{-1}	1.37×10^{-1}	1.54×10^{-1}
SYT2080	1.28×10^{-1}	1.19×10^{-1}	1.54×10^{-1}
SYT2095	1.10×10^{-1}	1.03×10^{-1}	1.54×10^{-1}
SYT2110	7.61×10^{-2}	8.08×10^{-2}	1.54×10^{-1}
SYT2125	6.94×10^{-2}	7.33×10^{-2}	1.54×10^{-1}
SYT3055	2.00×10^{-1}	1.75×10^{-1}	1.15×10^{-1}
SYT3080	1.22×10^{-1}	1.12×10^{-1}	1.15×10^{-1}
SYT3105	7.53×10^{-2}	8.14×10^{-2}	1.15×10^{-1}
SYT3130	6.08×10^{-2}	6.47×10^{-2}	1.15×10^{-1}
SYT3155	6.17×10^{-2}	5.89×10^{-2}	1.15×10^{-1}
SYT3180	5.15×10^{-2}	4.96×10^{-2}	1.15×10^{-1}
SYT3205	4.75×10^{-2}	4.59×10^{-2}	1.15×10^{-1}

E_P: M_P equivalent coefficient　E_Y: M_Y equivalent coefficient
E_R: M_R equivalent coefficient

Table 1-25 Miniature Slide SYBS type　unit : 1/mm

part number	equivalent coefficient		
	E_P	E_Y	E_R
SYBS 6-13	8.35×10^{-1}	7.01×10^{-1}	8.51×10^{-1}
SYBS 6-21	5.45×10^{-1}	4.57×10^{-1}	8.51×10^{-1}
SYBS 8-11	8.82×10^{-1}	7.40×10^{-1}	5.88×10^{-1}
SYBS 8-21	4.81×10^{-1}	4.04×10^{-1}	5.88×10^{-1}
SYBS 8-31	3.57×10^{-1}	2.99×10^{-1}	5.88×10^{-1}
SYBS12-23	4.31×10^{-1}	3.62×10^{-1}	3.13×10^{-1}
SYBS12-31	3.57×10^{-1}	2.99×10^{-1}	3.13×10^{-1}
SYBS12-46	2.35×10^{-1}	1.97×10^{-1}	3.13×10^{-1}
SYBS17-23	4.25×10^{-1}	3.57×10^{-1}	2.67×10^{-1}
SYBS17-31	3.26×10^{-1}	2.74×10^{-1}	2.66×10^{-1}
SYBS17-46	2.23×10^{-1}	1.88×10^{-1}	2.66×10^{-1}

E_P: M_P equivalent coefficient　E_Y: M_Y equivalent coefficient
E_R: M_R equivalent coefficient

Average Applied Load

The load applied to a linear systems generally varies with the travel distance depending on how the system is operated. This includes the start/stop processes of the reciprocating motion and work on the system. The average applied load is used to compute the life corresponding to the actual application conditions.

①When the load varies in a step manner with the travel distance (Figure 1-7).

ℓ_1 is the travel distance under load P_1
ℓ_2 is the travel distance under load P_2
⋮
ℓ_n is the travel distance under load P_n

The average applied load Pm is obtained by the following equation.

$$P_m=\sqrt[3]{\frac{1}{\ell}\left(P_1^3\ell_1+P_2^3\ell_2\cdots+P_n^3\ell_n\right)}\quad\cdots(10)$$

P_m: average applied load (N)　ℓ: total travel distance (m)

②When the applied load varies linearly with the travel distance (Figure 1-8), the average applied load Pm is approximated by the following equation.

$$P_m\fallingdotseq\frac{1}{3}\left(P_{min}+2P_{max}\right)\cdots\cdots(11)$$

P_{min}: minimum applied load (N)
P_{max}: maximum applied load (N)

③When the applied load draws a sine-curve as shown by Figures 1-9 (a) and (b), the average applied load Pm is approximated by the following equations.

$$\text{Figure1-9 (a)}\quad P_m\fallingdotseq0.65P_{max}\quad\cdots\cdots(12)$$
$$\text{Figure1-9 (b)}\quad P_m\fallingdotseq0.75P_{max}\quad\cdots\cdots(13)$$

Figure 1-7 Applied Load Varies Stepwise

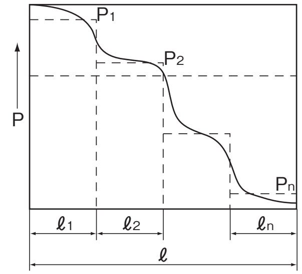


Figure 1-8 Applied Load Varies Linearly

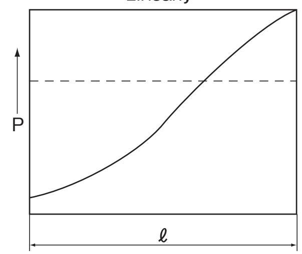
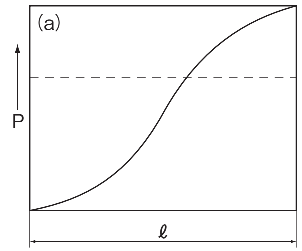
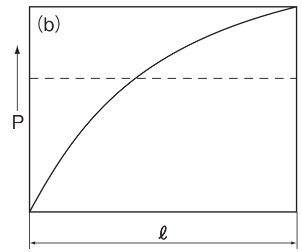


Figure 1-9 Applied Load Varies Sine-Curve





RATED LIFE CALCULATION EXAMPLE 1

2 Horizontal Axes, 2 Blocks each, Considering Acceleration/Deceleration

Operating Conditions

part number: SGL15F/E
basic dynamic load rating $C=7.29kN$
basic static load rating $C_0=9.45kN$
guide block span: $L_{unit}=100mm$
guide rail span: $L_{rail}=100mm$
drive: $Y_d=10mm$
$Z_d=-10mm$
mass: $m_1=30kg$ $X_1=15mm$
$Y_1=-20mm$
$Z_1=20mm$
$m_2=15kg$ $X_2=80mm$
$Y_2=50mm$
$Z_2=100mm$
velocity: $V_{max}=200mm/s$
time: $t_1=0.2s$
$t_2=3.3s$
$t_3=0.2s$
acceleration: $a_1=1.0m/s^2$
$a_3=1.0m/s^2$
stroke: $\ell s=700mm$
number of cycles per minute: $n_1=8cpm$

Figure 1-10

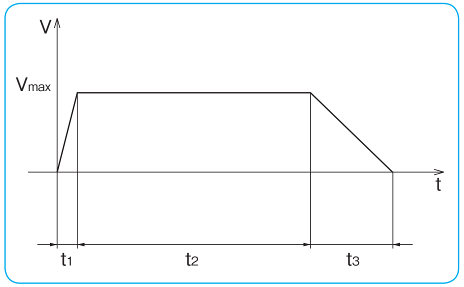
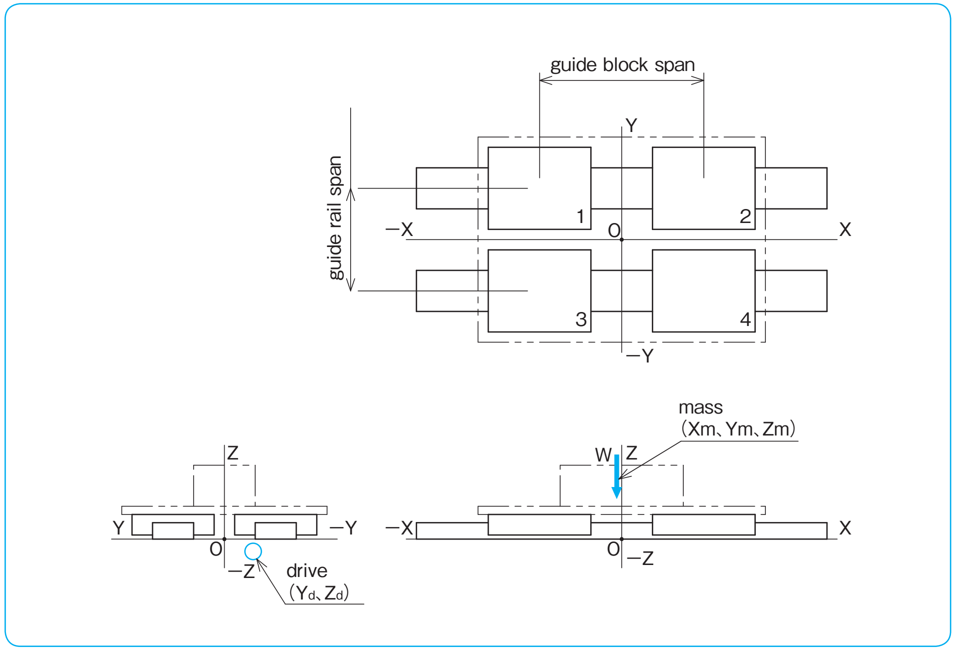


Figure 1-11



In case that some external force is applied to the system, please refer to "Slide Guide Travel Life Calculation Program" at NB website.

①Calculating Moment Applied to the Unit

〈acceleration〉

pitching $Ma_1=m\cdot g\cdot Xm-m\cdot a_1\cdot(Zm-Zd)$

$Ma_1=30\times9.8\times(15)-30\times1\times\{(20)-(-10)\}+15\times9.8\times(80)-15\times1\times\{(100)-(-10)\}=13620N\cdot mm$

yawing $Ma_2=-m\cdot a_1\cdot(Ym-Yd)$

$Ma_2=-30\times1\times\{(-20)-(10)\}-15\times1\times\{(50)-(10)\}=300N\cdot mm$

rolling $Ma_3=m\cdot g\cdot Ym$

$Ma_3=30\times9.8\times(-20)+15\times9.8\times(50)=1470N\cdot mm$

〈constant〉

pitching $M_1=m\cdot g\cdot Xm$

$M_1=30\times9.8\times(15)+15\times9.8\times(80)=16170N\cdot mm$

yawing $M_2=0$

rolling $M_3=m\cdot g\cdot Ym$

$M_3=30\times9.8\times(-20)+15\times9.8\times(50)=1470N\cdot mm$

〈deceleration〉

pitching $Md_1=m\cdot g\cdot Xm+m\cdot a_3\cdot(Zm-Zd)$

$Md_1=30\times9.8\times(15)+30\times1\times\{(20)-(-10)\}+15\times9.8\times(80)+15\times1\times\{(100)-(-10)\}=18720N\cdot mm$

yawing $Md_2=m\cdot a_3\cdot(Ym-Yd)$

$Md_2=30\times1\times\{(-20)-(10)\}+15\times1\times\{(50)-(10)\}=-300N\cdot mm$

rolling $Md_3=m\cdot g\cdot Ym$

$Md_3=30\times9.8\times(-20)+15\times9.8\times(50)=1470N\cdot mm$

②Calculating Load Applied to the Guide Block

〈acceleration〉

Block 1

vertical direction $Fra_1=\frac{m\cdot g}{4}-\frac{Ma_1}{2\cdot L_{unit}}+\frac{Ma_3}{2\cdot L_{rail}}$

$Fra_1=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}-\frac{13620}{2\times100}+\frac{1470}{2\times100}=49.5N$

horizontal direction $Fsa_1=\frac{Ma_2}{2\cdot L_{unit}}$

$Fsa_1=\frac{300}{2\times100}=1.5N$

Block 2

vertical direction $Fra_2=\frac{m\cdot g}{4}+\frac{Ma_1}{2\cdot L_{unit}}+\frac{Ma_3}{2\cdot L_{rail}}$

$Fra_2=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}+\frac{13620}{2\times100}+\frac{1470}{2\times100}=185.7N$

horizontal direction $Fsa_2=-\frac{Ma_2}{2\cdot L_{unit}}$

$Fsa_2=-\frac{300}{2\times100}=-1.5N$

Block 3

vertical direction $Fra_3=\frac{m\cdot g}{4}-\frac{Ma_1}{2\cdot L_{unit}}-\frac{Ma_3}{2\cdot L_{rail}}$

$Fra_3=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}-\frac{13620}{2\times100}-\frac{1470}{2\times100}=34.8N$

horizontal direction $Fsa_3=\frac{Ma_2}{2\cdot L_{unit}}$

$Fsa_3=\frac{300}{2\times100}=1.5N$

Block 4

vertical direction $Fra_4=\frac{m\cdot g}{4}+\frac{Ma_1}{2\cdot L_{unit}}-\frac{Ma_3}{2\cdot L_{rail}}$

$Fra_4=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}+\frac{13620}{2\times100}-\frac{1470}{2\times100}=171.0N$

horizontal direction $Fsa_4=-\frac{Ma_2}{2\cdot L_{unit}}$

$Fsa_4=-\frac{300}{2\times100}=-1.5N$

〈constant〉

Block 1

vertical direction $Fr_1=\frac{m\cdot g}{4}-\frac{M_1}{2\cdot L_{unit}}+\frac{M_3}{2\cdot L_{rail}}$

$Fr_1=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}-\frac{16170}{2\times100}+\frac{1470}{2\times100}=36.8N$

horizontal direction $Fs_1=\frac{M_2}{2\cdot L_{unit}}$

Block 2

vertical direction $Fr_2=\frac{m\cdot g}{4}+\frac{M_1}{2\cdot L_{unit}}+\frac{M_3}{2\cdot L_{rail}}$

$Fr_2=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}+\frac{16170}{2\times100}+\frac{1470}{2\times100}=198.5N$

horizontal direction $Fs_2=-\frac{M_2}{2\cdot L_{unit}}$

Block 3

vertical direction $Fr_3=\frac{m\cdot g}{4}-\frac{M_1}{2\cdot L_{unit}}-\frac{M_3}{2\cdot L_{rail}}$

$Fr_3=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}-\frac{16170}{2\times100}-\frac{1470}{2\times100}=22.1N$

horizontal direction $Fs_3=\frac{M_2}{2\cdot L_{unit}}$

Block 4

vertical direction $Fr_4=\frac{m\cdot g}{4}+\frac{M_1}{2\cdot L_{unit}}-\frac{M_3}{2\cdot L_{rail}}$

$Fr_4=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}+\frac{16170}{2\times100}-\frac{1470}{2\times100}=183.8N$

horizontal direction $Fs_4=-\frac{M_2}{2\cdot L_{unit}}$

〈deceleration〉

Block 1

vertical direction $Frd_1=\frac{m\cdot g}{4}-\frac{Md_1}{2\cdot L_{unit}}+\frac{Md_3}{2\cdot L_{rail}}$

$Frd_1=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}-\frac{18720}{2\times100}+\frac{1470}{2\times100}=24.0N$

horizontal direction $Fsd_1=\frac{Md_2}{2\cdot L_{unit}}$

$Fsd_1=\frac{-300}{2\times100}=-1.5N$

Block 2

vertical direction $Frd_2=\frac{m\cdot g}{4}+\frac{Md_1}{2\cdot L_{unit}}+\frac{Md_3}{2\cdot L_{rail}}$

$Frd_2=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}+\frac{18720}{2\times100}+\frac{1470}{2\times100}=211.2N$

horizontal direction $Fsd_2=-\frac{Md_2}{2\cdot L_{unit}}$

$Fsd_2=-\frac{-300}{2\times100}=1.5N$

Block 3

vertical direction $Frd_3=\frac{m\cdot g}{4}-\frac{Md_1}{2\cdot L_{unit}}-\frac{Md_3}{2\cdot L_{rail}}$

$Frd_3=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}-\frac{18720}{2\times100}-\frac{1470}{2\times100}=9.3N$

horizontal direction $Fsd_3=\frac{Md_2}{2\cdot L_{unit}}$

$Fsd_3=\frac{-300}{2\times100}=-1.5N$

Block 4

vertical direction $Frd_4=\frac{m\cdot g}{4}+\frac{Md_1}{2\cdot L_{unit}}-\frac{Md_3}{2\cdot L_{rail}}$

$Frd_4=\frac{30\times9.8}{4}+\frac{15\times9.8}{4}+\frac{18720}{2\times100}-\frac{1470}{2\times100}=196.5N$

horizontal direction $Fsd_4=-\frac{Md_2}{2\cdot L_{unit}}$

$Fsd_4=-\frac{-300}{2\times100}=1.5N$

③Calculating Equivalent Load

◎Pr in the vertical direction and Ps in the horizontal direction are calculated by the following equations.

$Pr=|Fr|$

$Ps=|k\cdot Fs|$

k=1 for SGL guide

Table 1-26

	acceleration	constant	deceleration
block 1	$Pra_1=49.5$	$Pr_1=36.8$	$Prd_1=24.0$
	$Psa_1=1.5$	$Ps_1=0$	$Psd_1=1.5$
block 2	$Pra_2=185.7$	$Pr_2=198.5$	$Prd_2=211.2$
	$Psa_2=1.5$	$Ps_2=0$	$Psd_2=1.5$
block 3	$Pra_3=34.8$	$Pr_3=22.1$	$Prd_3=9.3$
	$Psa_3=1.5$	$Ps_3=0$	$Psd_3=1.5$
block 4	$Pra_4=171.0$	$Pr_4=183.8$	$Prd_4=196.5$
	$Psa_4=1.5$	$Ps_4=0$	$Psd_4=1.5$

◎Equation for Dynamic Equivalent Load

$$P = Pr + Ps$$

$Pa_1 = Pra_1 + Psa_1 = 49.5 + 1.5 = 51.0$ (N)
calculating in the same manner

Table 1-27

	acceleration	constant	deceleration
block 1	$Pa_1=51.0$	$P_1=36.8$	$Pd_1=25.5$
block 2	$Pa_2=187.2$	$P_2=198.5$	$Pd_2=212.7$
block 3	$Pa_3=36.3$	$P_3=22.1$	$Pd_3=10.8$
block 4	$Pa_4=172.5$	$P_4=183.8$	$Pd_4=198.0$

◎Calculating Average Equivalent Load

$$Pm = \sqrt[3]{\frac{1}{\ell s} \times \left\{ \left(Pa^3 \times \frac{V_{max} \times t1}{2}\right) + \left(P^3 \times V_{max} \times t2\right) + \left(Pd^3 \times \frac{V_{max} \times t3}{2}\right) \right\}}$$

$$Pm_1 = \sqrt[3]{\frac{1}{700} \times \left\{ \left(51.0^3 \times \frac{200 \times 0.2}{2}\right) + \left(36.8^3 \times 200 \times 3.3\right) + \left(25.5^3 \times \frac{200 \times 0.2}{2}\right) \right\}} = 37.1(N)$$

$$Pm_2 = \sqrt[3]{\frac{1}{700} \times \left\{ \left(187.2^3 \times \frac{200 \times 0.2}{2}\right) + \left(198.5^3 \times 200 \times 3.3\right) + \left(212.7^3 \times \frac{200 \times 0.2}{2}\right) \right\}} = 198.6(N)$$

$$Pm_3 = \sqrt[3]{\frac{1}{700} \times \left\{ \left(36.3^3 \times \frac{200 \times 0.2}{2}\right) + \left(22.1^3 \times 200 \times 3.3\right) + \left(10.8^3 \times \frac{200 \times 0.2}{2}\right) \right\}} = 22.6(N)$$

$$Pm_4 = \sqrt[3]{\frac{1}{700} \times \left\{ \left(172.5^3 \times \frac{200 \times 0.2}{2}\right) + \left(183.8^3 \times 200 \times 3.3\right) + \left(198.0^3 \times \frac{200 \times 0.2}{2}\right) \right\}} = 183.9(N)$$

④Calculating Rated Life

Decide each coefficient

f_H : **hardness coefficient** $f_H=1$ for hardness of guide is 58HRC or more
f_T : **temperature coefficient** $f_T=1$ operating temperature is below 100℃ (80℃ is maximum for SGL guide)
f_C : **contact coefficient** $f_C=1$ for blocks are not in close contact
f_W : **applied load coefficient** $f_W=1.5$ for Vmax=200mm/s

◎Calculating Rated Life
Selecting Block 2 that carries the maximum dynamic equivalent load

$$L = \left(\frac{f_H \times f_T \times f_C}{f_W} \times \frac{C}{Pm}\right)^3 \times 50$$

$$L = \left(\frac{1 \times 1 \times 1}{1.5} \times \frac{7290}{198.6}\right)^3 \times 50 = 732725(km)$$

◎Calculating Life Time

$$L_h = \frac{L \times 10^3}{2 \times \ell s \times n_1 \times 60}$$

$$L_h = \frac{732725 \times 10^3}{2 \times 0.7 \times 8 \times 60} = 1090364(hour)$$

⑤Calculating Static Safety Factor

◎Equation for Static Equivalent Load

$$Po = Pr + Ps$$

$Poa_1 = Pra_1 + Psa_1 = 49.5 + 1.5 = 51.0$ (N)
calculating in the same manner

Table 1-28

	acceleration	constant	deceleration
block 1	$Poa_1=51.0$	$Po_1=36.8$	$Pod_1=25.5$
block 2	$Poa_2=187.2$	$Po_2=198.5$	$Pod_2=212.7$
block 3	$Poa_3=36.3$	$Po_3=22.1$	$Pod_3=10.8$
block 4	$Poa_4=172.5$	$Po_4=183.8$	$Pod_4=198.0$

Selecting Block 2 that carries the maximum static equivalent load

$$f_S = \frac{Co}{Po}$$

$$f_S = \frac{Co}{Pod_2} = \frac{9450}{212.7} = 44$$

RATED LIFE CALCULATION EXAMPLE 2

1 Horizontal Axis, 2 Blocks, Considering Acceleration/Deceleration

Operating Conditions

part number: SEB9A
basic dynamic load rating $C=1.92kN$
basic static load rating $C_0=2.53kN$
guide block span: $L_{unit}=70mm$
drive: $Y_d=30mm$
$Z_d=-10mm$
mass: $m_1=5kg$ $X_1=0mm$
$Y_1=0mm$
$Z_1=10mm$
$m_2=20kg$ $X_2=-20mm$
$Y_2=-10mm$
$Z_2=20mm$
velocity: $V_{max}=150mm/s$
time: $t_1=0.1s$
$t_2=1.9s$
$t_3=0.1s$
acceleration: $a_1=1.5m/s^2$
$a_3=1.5m/s^2$
stroke: $\ell_s=300mm$
number of cycles per minute: $n_1=14cpm$

Figure 1-12

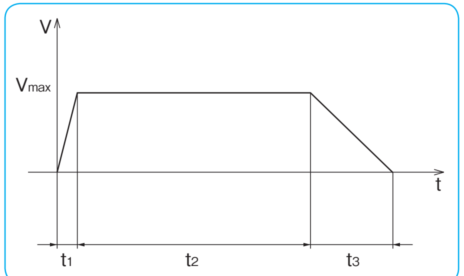
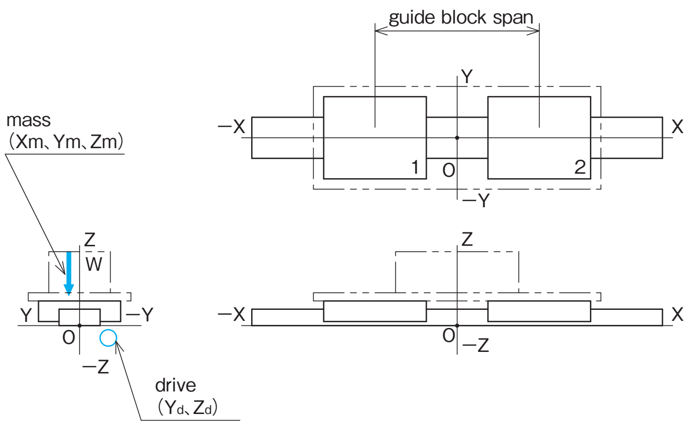


Figure 1-13



①Calculating Moment Applied to the Unit

〈acceleration〉

pitching $Ma_1=m \cdot g \cdot Xm-m \cdot a_1 \cdot (Zm-Zd)$

$Ma_1=5\times9.8\times(0)-5\times1.5\times\{(10)-(-10)\}+20\times9.8\times(-20)-20\times1.5\times\{(20)-(-10)\}=-4970N \cdot mm$

yawing $Ma_2=-m \cdot a_1 \cdot (Ym-Yd)$

$Ma_2=-5\times1.5\times\{(0)-(-30)\}-20\times1.5\times\{(-10)-(-30)\}=-825N \cdot mm$

rolling $Ma_3=m \cdot g \cdot Ym$

$Ma_3=5\times9.8\times(0)+20\times9.8\times(-10)=-1960N \cdot mm$

〈constant〉

pitching $M_1=m \cdot g \cdot Xm$

$M_1=5\times9.8\times(0)+20\times9.8\times(-20)=-3920N \cdot mm$

yawing $M_2=0$

$M_2=0\ N \cdot mm$

rolling $M_3=m \cdot g \cdot Ym$

$M_3=5\times9.8\times(0)+20\times9.8\times(-10)=-1960N \cdot mm$

〈deceleration〉

pitching $Md_1=m \cdot g \cdot Xm+m \cdot a_3 \cdot (Zm-Zd)$

$Md_1=5\times9.8\times(0)+5\times1.5\times\{(10)-(-10)\}+20\times9.8\times(-20)+20\times1.5\times\{(20)-(-10)\}=-2870N \cdot mm$

yawing $Md_2=m \cdot a_3 \cdot (Ym-Yd)$

$Md_2=5\times1.5\times\{(0)-(-30)\}+20\times1.5\times\{(-10)-(-30)\}=825N \cdot mm$

rolling $Md_3=m \cdot g \cdot Ym$

$Md_3=5\times9.8\times(0)+20\times9.8\times(-10)=-1960N \cdot mm$

②Calculating Load Applied to the Guide Block

〈acceleration〉

Block 1

vertical direction $Fra_1=\frac{m\cdot g}{2}-\frac{Ma_1}{L_{unit}}$

$Fra_1=\frac{5\times 9.8}{2}+\frac{20\times 9.8}{2}-\frac{-4970}{70}=193.5N$

horizontal direction $Fsa_1=\frac{Ma_2}{L_{unit}}$

$Fsa_1=\frac{-825}{70}=-11.8N$

rolling moment $Mra_1=\frac{Ma_3}{2}$

$Mra_1=\frac{-1960}{2}=-980N\cdot mm$

Block 2

vertical direction $Fra_2=\frac{m\cdot g}{2}+\frac{Ma_1}{L_{unit}}$

$Fra_2=\frac{5\times 9.8}{2}+\frac{20\times 9.8}{2}+\frac{-4970}{70}=51.5N$

horizontal direction $Fsa_2=\frac{Ma_2}{L_{unit}}$

$Fsa_2=\frac{-825}{70}=-11.8N$

rolling moment $Mra_2=\frac{Ma_3}{2}$

$Mra_2=\frac{-1960}{2}=-980N\cdot mm$

〈constant〉

Block 1

vertical direction $Fr_1=\frac{m\cdot g}{2}-\frac{M_1}{L_{unit}}$

$Fr_1=\frac{5\times 9.8}{2}+\frac{20\times 9.8}{2}-\frac{-3920}{70}=178.5N$

horizontal direction $Fs_1=\frac{M_2}{L_{unit}}$

rolling moment $Mr_1=\frac{M_3}{2}$

$Mr_1=\frac{-1960}{2}=-980N\cdot mm$

Block 2

vertical direction $Fr_2=\frac{m\cdot g}{2}+\frac{M_1}{L_{unit}}$

$Fr_2=\frac{5\times 9.8}{2}+\frac{20\times 9.8}{2}+\frac{-3920}{70}=66.5N$

horizontal direction $Fs_2=-\frac{M_2}{L_{unit}}$

rolling moment $Mr_2=\frac{M_3}{2}$

$Mr_2=\frac{-1960}{2}=-980N\cdot mm$

〈deceleration〉

Block 1

vertical direction $Frd_1=\frac{m\cdot g}{2}-\frac{Md_1}{L_{unit}}$

$Frd_1=\frac{5\times 9.8}{2}+\frac{20\times 9.8}{2}-\frac{-2870}{70}=163.5N$

horizontal direction $Fsd_1=\frac{Md_2}{L_{unit}}$

$Fsd_1=\frac{825}{70}=11.8N$

rolling moment $Mrd_1=\frac{Md_3}{2}$

$Mrd_1=\frac{-1960}{2}=-980N\cdot mm$

Block 2

vertical direction $Frd_2=\frac{m\cdot g}{2}+\frac{Md_1}{L_{unit}}$

$Frd_2=\frac{5\times 9.8}{2}+\frac{20\times 9.8}{2}+\frac{-2870}{70}=81.5N$

horizontal direction $Fsd_2=-\frac{Md_2}{L_{unit}}$

$Fsd_2=-\frac{825}{70}=-11.8N$

rolling moment $Mrd_2=\frac{Md_3}{2}$

$Mrd_2=\frac{-1960}{2}=-980N\cdot mm$

③Calculating Equivalent Load

◎Pr in the vertical direction and Ps in the horizontal direction are calculated by the following equations.

$$Pr = |Fr| + |Er \cdot Mr|$$
$$Ps = |k \cdot Fs|$$

Er=0.220 for SEB9A
k=0.84 for SEB-A guide

$Pra_1 = |Fra_1| + |Er \cdot Mra_1| = |193.5| + |0.220 \times (-980)| = 409.1$ (N)
calculating in the same manner

Table 1-29

	acceleration	constant	deceleration
block 1	$Pra_1=409.1$	$Pr_1=394.1$	$Prd_1=379.1$
	$Psa_1=9.9$	$Ps_1=0$	$Psd_1=9.9$
block 2	$Pra_2=267.1$	$Pr_2=282.1$	$Prd_2=297.1$
	$Psa_2=9.9$	$Ps_2=0$	$Psd_2=9.9$

◎Equation for Dynamic Equivalent Load

$$P = Pr + Ps$$

$Pa_1=Pra_1+Psa_1=409.1+9.9=419.0$(N)
calculating in the same manner

Table 1-30

	acceleration	constant	deceleration
block 1	$Pa_1=419.0$	$P_1=394.1$	$Pd_1=389.0$
block 2	$Pa_2=277.0$	$P_2=282.1$	$Pd_2=307.0$

◎Calculating Average Equivalent Load

$$Pm = \sqrt[3]{\frac{1}{\ell s} \times \left\{ \left(Pa^3 \times \frac{V_{max} \times t_1}{2}\right) + \left(P^3 \times V_{max} \times t_2\right) + \left(Pd^3 \times \frac{V_{max} \times t_3}{2}\right) \right\}}$$

$$Pm_1 = \sqrt[3]{\frac{1}{300} \times \left\{ \left(419.0^3 \times \frac{150 \times 0.1}{2}\right) + \left(394.1^3 \times 150 \times 1.9\right) + \left(389.0^3 \times \frac{150 \times 0.1}{2}\right) \right\}} = 394.6\text{(N)}$$

$$Pm_2 = \sqrt[3]{\frac{1}{300} \times \left\{ \left(277.0^3 \times \frac{150 \times 0.1}{2}\right) + \left(282.1^3 \times 150 \times 1.9\right) + \left(307.0^3 \times \frac{150 \times 0.1}{2}\right) \right\}} = 282.7\text{(N)}$$

④Calculating Rated Life

Decide each coefficient

f_H : **hardness coefficient** $f_H=1$ for hardness of guide is 58HRC or more
f_T : **temperature coefficient** $f_T=1$ operating temperature is below 100℃ (80℃ is maximum for SEB-A guide)
f_C : **contact coefficient** $f_C=1$ for blocks are not in close contact
f_W : **applied load coefficient** $f_W=1.5$ for Vmax=150mm/s

◎Calculating Rated Life
Selecting Block 1 that carries the maximum dynamic equivalent load

$$L = \left(\frac{f_H \times f_T \times f_C}{f_W} \times \frac{C}{Pm}\right)^3 \times 50$$

$$L = \left(\frac{1 \times 1 \times 1}{1.5} \times \frac{1920}{394.6}\right)^3 \times 50 = 1706\text{(km)}$$

◎Calculating Life Time

$$L_h = \frac{L \times 10^3}{2 \times \ell s \times n_1 \times 60}$$

$$L_h = \frac{1706 \times 10^3}{2 \times 0.3 \times 14 \times 60} = 3384\text{(hour)}$$

⑤Calculating Static Safety Factor

◎Equation for Static Equivalent Load

$$Po = Pr + Ps$$

$Poa_1=Pra_1+Psa_1=409.1+9.9=419.0$ (N)
calculating in the same manner

Table 1-31

	acceleration	constant	deceleration
block 1	$Poa_1=419.0$	$Po_1=394.1$	$Pod_1=389.0$
block 2	$Poa_2=277.0$	$Po_2=282.1$	$Pod_2=307.0$

Selecting Block 1 that carries the maximum static equivalent load

$$f_S = \frac{Co}{Po}$$

$$f_S = \frac{Co}{Poa_1} = \frac{2530}{419.0} = 6.0$$

RATED LIFE CALCULATION EXAMPLE 3

2 Vertical Axes, 1 Bush each, Considering Acceleration/Deceleration

Operating Conditions

part number: SM30W
basic dynamic load rating $C=2.49kN$
basic static load rating $C_0=5.49kN$
shaft span: $L_{rail}=80mm$
drive: $Y_d=20mm$
$Z_d=-20mm$
mass: $m_1=5kg$ $X_1=0mm$
$Y_1=0mm$
$Z_1=30mm$
$m_2=20kg$ $X_2=40mm$
$Y_2=50mm$
$Z_2=20mm$
velocity: $V_{max}=150mm/s$
time: $t_1=0.1s$
$t_2=0.7s$
$t_3=0.1s$
acceleration: $a_1=1.5m/s^2$
$a_3=1.5m/s^2$
stroke: $\ell_s=120mm$
number of cycles per minute: $n_1=33cpm$

Figure 1-14

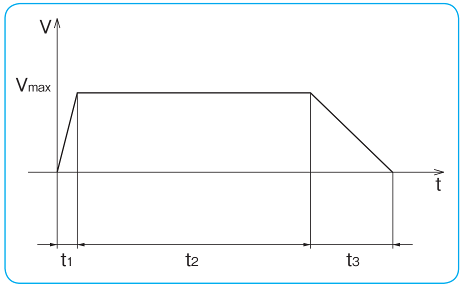
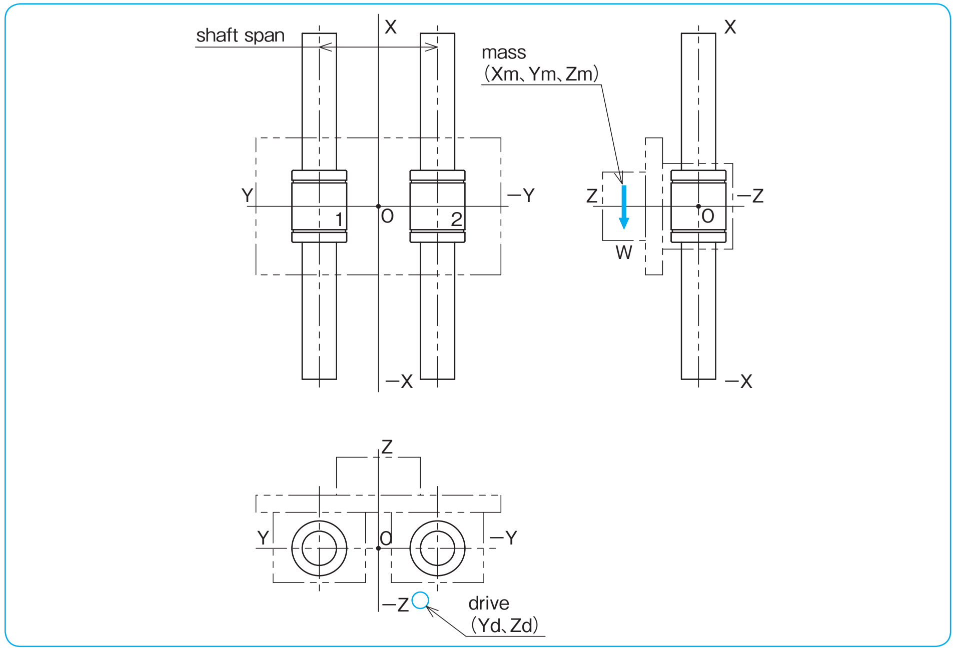


Figure 1-15



①Calculating Moment Applied to the Unit

⟨acceleration⟩

pitching $Ma_1=m\cdot g\cdot(Zm-Zd)+m\cdot a_1\cdot(Zm-Zd)$

$Ma_1=5\times9.8\times\{(30)-(-20)\}+5\times1.5\times\{(30)-(-20)\}+20\times9.8\times\{(20)-(-20)\}+20\times1.5\times\{(20)-(-20)\}=11865N\cdot mm$

yawing $Ma_2=m\cdot g\cdot(Ym-Yd)+m\cdot a_1\cdot(Ym-Yd)$

$Ma_2=5\times9.8\times\{(0)-(20)\}+5\times1.5\times\{(0)-(20)\}+20\times9.8\times\{(50)-(20)\}+20\times1.5\times\{(50)-(20)\}=5650N\cdot mm$

rolling $Ma_3=0$

⟨constant⟩

pitching $M_1=m\cdot g\cdot(Zm-Zd)$

$M_1=5\times9.8\times\{(30)-(-20)\}+20\times9.8\times\{(20)-(-20)\}=10290N\cdot mm$

yawing $M_2=m\cdot g\cdot(Ym-Yd)$

$M_2=5\times9.8\times\{(0)-(20)\}+20\times9.8\times\{(50)-(20)\}=4900N\cdot mm$

rolling $M_3=0$

⟨deceleration⟩

pitching $Md_1=m\cdot g\cdot(Zm-Zd)-m\cdot a_3\cdot(Zm-Zd)$

$Md_1=5\times9.8\times\{(30)-(-20)\}-5\times1.5\times\{(30)-(-20)\}+20\times9.8\times\{(20)-(-20)\}-20\times1.5\times\{(20)-(-20)\}=8715N\cdot mm$

yawing $Md_2=m\cdot g\cdot(Ym-Yd)-m\cdot a_3\cdot(Ym-Yd)$

$Md_2=5\times9.8\times\{(0)-(20)\}-5\times1.5\times\{(0)-(20)\}+20\times9.8\times\{(50)-(20)\}-20\times1.5\times\{(50)-(20)\}=4150N\cdot mm$

rolling $Md_3=0$

②Calculating Load Applied to the Slide Bush

⟨acceleration⟩

Bush 1

vertical direction $Fra_1=\frac{Ma_3}{L_{rail}}=0$

horizontal direction $Fsa_1=0$

pitching $Mpa_1=\frac{Ma_1}{2}$

$Mpa1=\frac{11865}{2}=5932.5N\cdot mm$

yawing $Mya_1=\frac{Ma_2}{2}$

$Mya1=\frac{5650}{2}=2825N\cdot mm$

Bush 2

vertical direction	$Fra_2=\frac{Ma_3}{L_{rail}}=0$
horizontal direction	$Fsa_2=0$
pitching	$Mpa_2=\frac{Ma_1}{2}$

$Mpa_2=\frac{11865}{2}=5932.5N\cdot mm$

yawing	$Mya_2=\frac{Ma_2}{2}$

$Mya_2=\frac{5650}{2}=2825N\cdot mm$

〈constant〉

Bush 1

vertical direction	$Fr_1=\frac{M_3}{L_{rail}}=0$
horizontal direction	$Fs_1=0$
pitching	$Mp_1=\frac{M_1}{2}$

$Mp_1=\frac{10290}{2}=5145N\cdot mm$

yawing	$My_1=\frac{M_2}{2}$

$My_1=\frac{4900}{2}=2450N\cdot mm$

Bush 2

vertical direction	$Fr_2=\frac{M_3}{L_{rail}}=0$
horizontal direction	$Fs_2=0$
pitching	$Mp_2=\frac{M_1}{2}$

$Mp_2=\frac{10290}{2}=5145N\cdot mm$

yawing	$My_2=\frac{M_2}{2}$

$My_2=\frac{4900}{2}=2450N\cdot mm$

〈deceleration〉

Bush 1

vertical direction	$Frd_1=\frac{Md_3}{L_{rail}}=0$
horizontal direction	$Fsd_1=0$
pitching	$Mpd_1=\frac{Md_1}{2}$

$Mpd_1=\frac{8715}{2}=4357.5N\cdot mm$

yawing	$Myd_1=\frac{Md_2}{2}$

$Myd_1=\frac{4150}{2}=2075N\cdot mm$

Bush 2

vertical direction	$Frd_2=\frac{Md_3}{L_{rail}}=0$
horizontal direction	$Fsd_2=0$
pitching	$Mpd_2=\frac{Md_1}{2}$

$Mpd_2=\frac{8715}{2}=4357.5N\cdot mm$

yawing	$Myd_2=\frac{Md_2}{2}$

$Myd_2=\frac{4150}{2}=2075N\cdot mm$

③Calculating Equivalent Load

◎Pr in the vertical direction and Ps in the horizontal direction are calculated by the following equations.

$$Pr = |Fr| + |E_1 \cdot Mp|$$
$$Ps = |k \cdot Fs| + |E_1 \cdot My|$$

$E_1 = 6.63 \times 10^{-2}$ for SM30W
k=1 for Slide Bush

Table 1-32

		acceleration	constant	deceleration
bush 1		$Pra_1=393.3$	$Pr_1=341.1$	$Prd_1=288.9$
		$Psa_1=187.3$	$Ps_1=162.4$	$Psd_1=137.6$
bush 2		$Pra_2=393.3$	$Pr_2=341.1$	$Prd_2=288.9$
		$Psa_2=187.3$	$Ps_2=162.4$	$Psd_2=137.6$

◎Equation for Dynamic Equivalent Load

$$P = Pr + Ps$$

$Pa_1 = Pra_1 + Psa_1 = 393.3 + 187.3 = 580.6$(N)
calculating in the same manner

Table 1-33

	acceleration	constant	deceleration
bush 1	$Pa_1=580.6$	$P_1=503.5$	$Pd_1=426.5$
bush 2	$Pa_2=580.6$	$P_2=503.5$	$Pd_2=426.5$

◎Calculating Average Equivalent Load

$$Pm = \sqrt[3]{\frac{1}{\ell s} \times \left\{ \left(Pa^3 \times \frac{V_{max} \times t_1}{2}\right) + \left(P^3 \times V_{max} \times t_2\right) + \left(Pd^3 \times \frac{V_{max} \times t_3}{2}\right) \right\}}$$

$$Pm_1 = \sqrt[3]{\frac{1}{120} \times \left\{ \left(580.6^3 \times \frac{150 \times 0.1}{2}\right) + \left(503.5^3 \times 150 \times 0.7\right) + \left(426.5^3 \times \frac{150 \times 0.1}{2}\right) \right\}} = 505.0(N)$$

$$Pm_2 = \sqrt[3]{\frac{1}{120} \times \left\{ \left(580.6^3 \times \frac{150 \times 0.1}{2}\right) + \left(503.5^3 \times 150 \times 0.7\right) + \left(426.5^3 \times \frac{150 \times 0.1}{2}\right) \right\}} = 505.0(N)$$

④Calculating Rated Life

Decide each coefficient

f_H : **hardness coefficient** $f_H=1$ for hardness of bush is 58HRC or more
f_T : **temperature coefficient** $f_T=1$ operating temperature is below 100℃ (80℃ is maximum for Bush with resin retainer)
f_C : **contact coefficient** $f_C=1$ for bushes are not in close contact
f_W : **applied load coefficient** $f_W=1.5$ for Vmax=150mm/s

◎Calculating Rated Life
Selecting Bush 1 that carries the maximum equivalent load

$$L = \left(\frac{f_H \times f_T \times f_C}{f_W} \times \frac{C}{Pm}\right)^3 \times 50$$

$$L = \left(\frac{1 \times 1 \times 1}{1.5} \times \frac{2490}{505.0}\right)^3 \times 50 = 1775(km)$$

◎Calculating Life Time

$$L_h = \frac{L \times 10^3}{2 \times \ell s \times n_1 \times 60}$$

$$L_h = \frac{1775 \times 10^3}{2 \times 0.120 \times 33 \times 60} = 3735(hour)$$

⑤Calculating Static Safety Factor

◎Equation for Static Equivalent Load

$$Po = Pr + Ps$$

$Poa_1 = Pra_1 + Psa_1 = 393.3 + 187.3 = 580.6$(N)
calculating in the same manner

Table 1-34

	acceleration	constant	deceleration
bush 1	$Poa_1=580.6$	$Po_1=503.5$	$Pod_1=426.5$
bush 2	$Poa_2=580.6$	$Po_2=503.5$	$Pod_2=426.5$

Selecting Bush 1 that carries the maximum static equivalent load

$$f_S = \frac{Co}{Po}$$

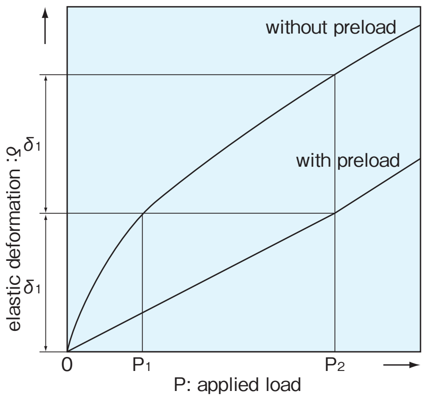
$$f_S = \frac{Co}{Poa_1} = \frac{5490}{580.6} = 9.4$$

RIGIDITY AND PRELOAD

Effect of Preload and Rigidity

The rigidity of a linear systems must be taken into consideration when it is to be used in high-precision positioning devices or high-precision machinery. Preloaded slide guides and ball splines, which use balls as the rolling elements, are available upon request to meet the need for greater rigidity.
If a force is applied to the ball elements without preload, an elastic deformation proportional to the applied force to the 2/3 power will result. Therefore, the elastic deformation is relatively large during the initial loading stage, however then becomes smaller as the load increases.
Preloading on the rolling elements absorbs the deformation of the block under the same loading.
Please contact NB for available data in regard to rigidity.

Figure 1-16 Applied Load versus Block Deformation



Types of Preload and its Specification

Preload is categorized into three ranges: standard, light, and medium for option. In the NB linear systems, preload is applied by installing rolling elements that are slightly larger than standard. Therefore, the specification of the preload is expressed by a negative value.

FRICTIONAL RESISTANCE AND REQUIRED THRUST

The static friction of a linear systems is extremely low. Since the difference between the static and dynamic friction is marginal, stable motion can be achieved from low to high speed. The frictional resistance (required thrust) can be obtained from the load and the seal resistance unique to each type of system using the following equation:

$$F=\mu \cdot W+f \quad (14)$$

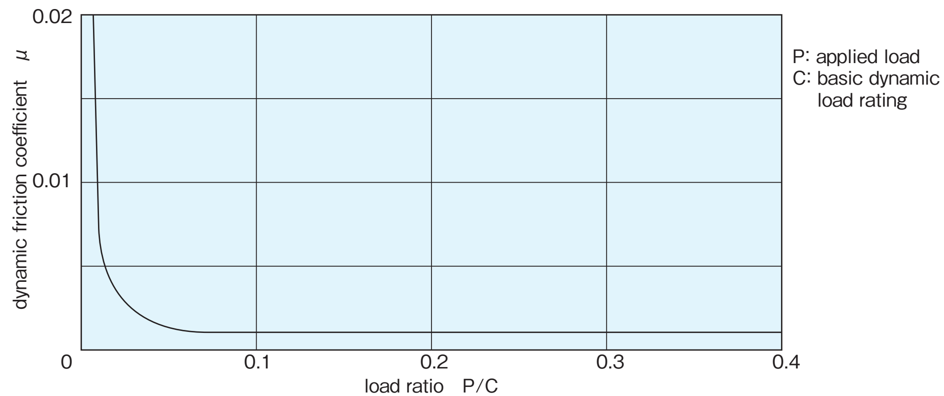
F: frictional resistance (N)　μ: dynamic friction coefficient
W: applied load (N)　f: seal resistance (N)

The dynamic friction coefficient varies with the applied load, preload, viscosity of the lubricant, and other factors. However, the values given in Table 1-35 are used for the normal loading condition (20% of basic dynamic load rating) without any preload.
The seal resistance depends on the seal-lip condition as well as on the condition of the lubricant, however, it does not change proportionally with the applied load, which commonly is expressed by a constant value of 2 to 5 N.

Table 1-35 Dynamic Friction Coefficient

product	type	dynamic friction coefficient (μ)
Slide Guide	SGL・SGW	0.002～0.003
	SEB	0.004～0.006
	SER	0.004～0.006
Ball Spline	SSP	0.004～0.006
Rotary Ball Spline	SPR・SPB SPBR	0.004～0.006
Stroke Ball Spline	SPLFS	0.001～0.003
Slide Bush	SM・KB SW・GM SMA・SME	0.002～0.003
Top Ball	TK・TKA TKE・TKD TW・TWA TWJ・TWD	0.002～0.003
Stroke Bush	SR	0.0006～0.0012
Slide Rotary Bush	SRE	0.002～0.003
	RK	0.002～0.003
Slide Way	NV・SV・RV	0.001～0.003
Slide Table	NVT・NYT・SVT・SYT	0.001～0.003
Miniature Slide	SYBS	0.001～0.003

Figure 1-17 Applied Load versus Dynamic Friction Coefficient



OPERATING ENVIRONMENT

Temperature Range

The NB linear systems are heat-treated in order to harden the surface. Therefore, if the temperature of the linear systems exceeds 100℃, the hardness and load rating will be reduced (refer to page Eng-5, hardness coefficient). If resin is used in any one of the components, the systems cannot be used in a high-temperature environment. The recommended operating temperature ranges for each type of linear systems are listed in Table 1-36.

Table 1-36 Major Types and Recommended Temperature Range

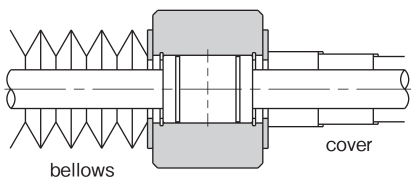
component material	includes resin	steel	stainless	other
operating temperature range	−20℃～80℃	−20℃～110℃	−20℃～140℃*	
Slide Guide	SEB-A/SEBS-B SGL/SGW	SER	SEBS-BM SERS	
Ball Spline	SSP/SSPF		SPLFS	
Rotary Ball Spline	SPR/SPB			
Ball Screw Spline	SPBR/SPBF			
Slide Bush	SM G/SMS G/ KB G/KBS G/ SW G/SWS G/ GM	SM/KB/SW	SMS/KBS/SWS	
Top Ball	TK			
Stroke Bush		SR/SRB		
Slide Rotary Bush	RK	SRE		
Slide Way	NV/NVS	SV/RV	SVS/NVS-RNS	
Slide Table	NVT/NYT	SVT/SYT	SYTS	NVTS/SVTS**
Miniature Slide			SYBS	
Slide Screw		SS		

* If the system is made of stainless steel and has a seal, the temperature range is up to 120℃
** Please contact NB if the system is to be used out of room temperatures.

Operating Environment

Foreign particles or dust in the linear systems affects the motion accuracy and shortens the life time. Standard seals will perform well for dust prevention under normal operating conditions, however, in a harsh environment it is necessary to attach bellows or protective covers as Figure 1-18 shows.

Figure 1-18 Example of Dust Prevention



LUBRICATION

Lubrication

The objective of lubrication includes the reduction of friction among the rolling elements as well as between the rolling elements and the raceway, preventing of sintering, reduction of wear, and prevention of rust by forming a film over the surface.
To maximize the performance of a linear systems, the lubricant type and a lubrication methodl appropriate for the operating environment should be selected.
In addition, the steel part of the product is applied with rust-preventing oil that has little effect on the lubrication.

Table 1-37 (1) Lubrication

lubrication	type
grease lubrication	lithium soap based grease urea grease
oil lubrication	Turbine Oil ISO Standard VG32 ～ 68

Both oil and grease lubrication are applicable. Please select proper lubricant and its method in confomity to operating conditions.

Table 1-37 (2) Pre-applied Lubricant

product	lubrication
Slide Guide	lithium soap based grease pre-applied
Ball Spline	lithium soap based grease pre-applied
Rotary Ball Spline	lithium soap based grease pre-applied
Stroke Ball Spline	lithium soap based grease pre-applied
Ball Screw Spline	lithium soap based grease pre-applied
Slide Bush	anti-rust oil only
Top Ball	anti-rust oil only
Stroke Bush	anti-rust oil only
Slide Rotary Bush	anti-rust oil only
Slide Shaft	anti-rust oil only
Slide Way・Slide Table	lithium soap based grease pre-applied
Miniature Slide	lithium soap based grease pre-applied
Gonio Way	lithium soap based grease pre-applied
Actuator	lithium soap based grease pre-applied
Slide Screw	radial ball bearings part lithium based grease pre-applied

For products applied with "anti-rust oil only", remove the anti-rust oil from the factory and enclose the lubricant before use.
The product with "Lithium Soap Grease pre-applied " is filled with grease and can be used as is. When installing the product, it is recommended to remove the rust preventive oil from the mounting surface before assembling.

Lubrication Interval

Please relubricate with a similar type of grease periodically depending on the operating condition. The recommended relubrication period is about 6 months or 1,000 km of travel distance under normal condition.
It is possible to extend the lubrication interval. Fiber sheet (P.A-16) is available for slide guide, and felt seal (P.C-11) is available for slide bush.
By installing a reverse seal (P.A-17) for slide guide and a double lip seal (P.C-11) for slide bush, it is possible to prevent grease leakage and extend the lubrication interval.

NB provides the following optional greases. Please select one in accordance with the use conditions of your linear system.

●KGLA Grease (Low Dust Generation Grease)

KGLA Grease has an excellent property of low dust generation with a lithium-type thickening agent used. It is ideal for use in a clean room.

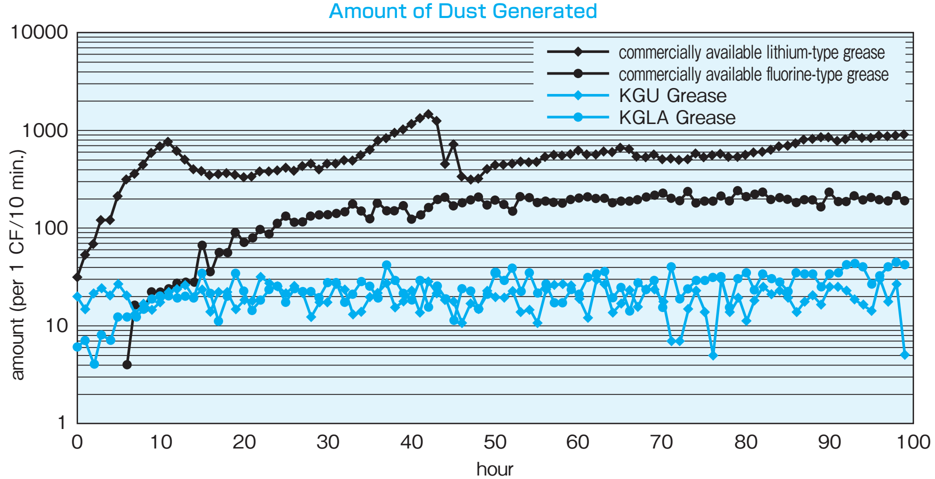
●KGU Grease (Low Dust Generation Grease)

With urea-type thickening agent used, KGU Grease has features including a superior low dust generation property and the reduced dynamic frictional resistance during low-speed operation.

Table 1-38 Main Property

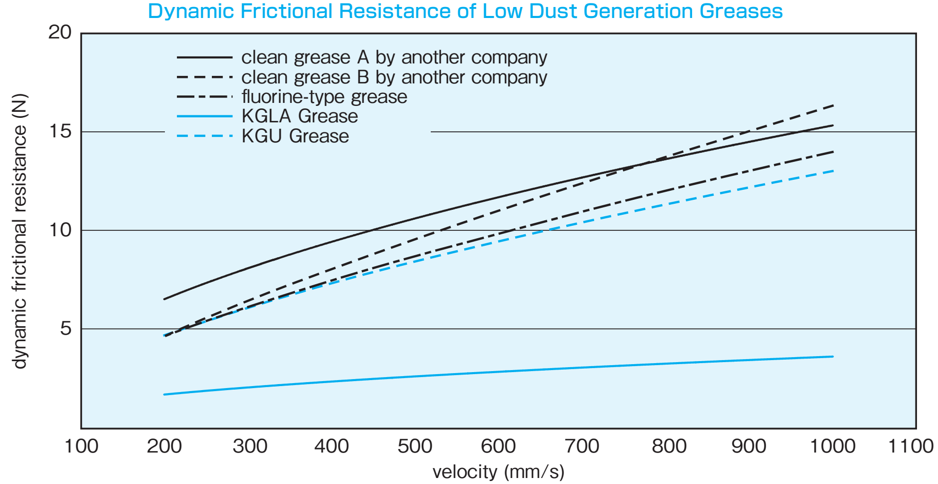
item	grease name	
	KGLA Grease	KGU Grease
appearance	whitish-yellow	light brown
base oil	synthetic oil and refined oil mixed	synthetic oil and refined oil mixed
kinematic viscosity of base oil (mm^2/s, 40℃)	25	100
thickening agent	lithium soap	urea
mixture viscosity	260	248
drop point (℃)	195	280 or higher
copper plate corrosion (100℃, 24hrs)	passed	passed
evaporation (mass%)	0.3 (99℃ 22h)	0.09 (99℃ 22h)
oil separation (mass%100℃, 24hrs)	4.6	0.5
oxidation stability (MPa99℃, 100hrs)	0.025	0.015
bearing corrosion prevention (52℃, 48hrs)	passed	passed
operating temperature range (℃)	−40～120	−30～160

Figure 1-19 Dust Level Measurement Data



measurement conditions / work: SEBS9B; stroke: 200 mm; velocity: 700 mm/s
airflow: $3m^3/min$; particle diameter: 0.3μm or larger

Figure 1-20 Dynamic Frictional Resistance Measurement Data



SGL15TE without seals, normal preload, no load, grease volume: 1cc

●KGF Grease (Anti-fretting/Anti-corrosion Grease)

With urea-type thickening agent used, KGF Grease is very effective to prevent fretting and corrosion.

Table 1-39 Main Property

item	grease name KGF Grease
appearance	brown
base oil	synthetic oil
kinematic viscosity of base oil (mm^2/s, 40℃)	approx. 25
thickening agent	urea
mixture viscosity	292
drop point (℃)	250 or higher
copper plate corrosion (100℃ , 24 hrs)	passed
evaporation (mass%)	0.27 (99℃ 22h)
oil separation (mass%100℃ , 24 hrs)	1.1
oxidation stability (MPa99℃ , 100 hrs)	0.085
bearing corrosion prevention (52℃ , 48 hrs)	passed
rinsing water resistance (38℃ , 1 hr)	1.7
operating temperature range (℃)	−20〜150

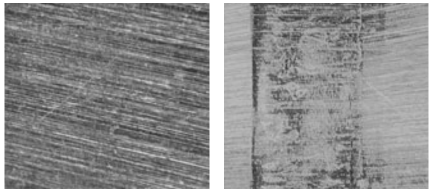
Anti-fretting/Anti-corrosion Test Data

Table 1-40 Test Conditions

item	content
tested item	NVT4165
stroke	2 mm
acceleration	2.4G
average acceleration	0.1 m/s
cycle per minute	1,450 cpm
grease injection volume	0.5 cc
total travel distance	184 km
total cycles	46 million cycles

Figure 1-21 Raceway Condition after Testing

KGF Grease (fretting not generated) general grease (fretting generated)



●Grease for the food processing industry (NSF H1 certified) is available.

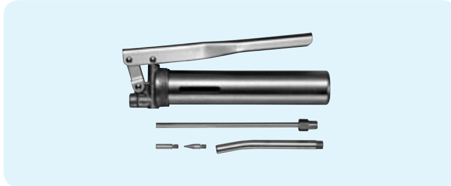
It is the most suitable combination for the food processing applications to use this type of grease with stainless steel products. Please contact NB for details.

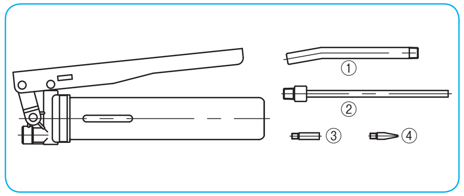
NB MAINTENANCE KIT

There are two types of maintenance kit available at NB.

1. Grease Gun Set: GG1

Different types of nozzles are adaptable to a variety of products including Actuators and products with grease-fitting.



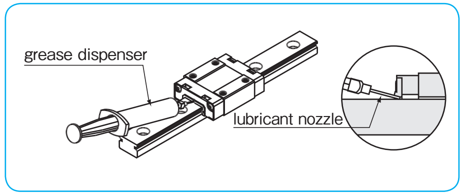


product	EXRAIL Slide Guide	Slide Bush	Slide Rotary Bush	Actuator	Others
①lubricant nozzle (φ10)	X all size SGL all size SGW（21,27,35）	TR□-Q TQ□（30,35,40） SMA-W SME-W	SMA-RW	BG（46,55）	–
③ and ② lubricant nozzle（φ 5）	SGW（17）	TQ□（16,20,25）	–	BG（20,26,33） BH（23,30）	–
④ and ② lubricant nozzle	–	–	–	–	Applied with ball screw or lubrication hole

In the case of difficulty in pumping, due to internal grease adhesion or shape of the bearing, please use nozzle ④ to apply grease directly onto running grooves.

2. Grease Dispenser: TU1

Syringe dispenser is recommended for miniature guide （SEBS-B type） and for limited space applications.



① Lubricant Nozzle (19G)
Needle Diameter：φ1.00
Needle Inner Diameter：φ0.67 (for KGF Grease)

② Lubricant Nozzle （17G）
Needle Diameter：φ1.50
Needle Inner Diameter：φ1.03 (for KGLA・KGU Grease)

PRECAUTIONS FOR HANDLING AND USE

Please follow the instructions below to maintain the accuracy of NB linear systems as a precision part and for a safety use.

⚠ (1) Notes on Handling

①Any shock load caused by rough handling (such as dropping or hitting with hammer) may cause a scar or dent on the raceway which will hinder smooth movement and shorten expected travel life. Also be aware that such impact may damage the resin parts.

②Never try to disassemble the product. Doing so may cause an entry of contamination or deterioration of assembly accuracy.

③The blocks or the outer cylinders may move just by tilting the rail or the shaft. Be careful not to let them fall off from the rail or the shaft by mistake.

④The accuracy on the mounting surface and parallelism of the rails or the shafts after assembly are important factors to optimize the performance of the linear systems. Exercise adequate care for mounting accuracy.

⚠ (2) Notes on Use

①Be careful not to let dust or foreign particles enter the linear systems during use.

②When using the linear systems under an environment where dust or coolant may scatter, protect the system with a cover or bellows.

③When the NB linear systems is used in a manner that its rail is fixed to the ceiling and downward load is applied to the block (s) or the outer cylinder (s), if the block or the outer cylinder breaks, it may fall off from the rail and drop to the floor. Provide additional measures for preventing dropping of the block or the outer cylinder, such as a safety catch.

⚠ (3) Instructions in considering the "Life Time" of a Linear System

①When the load applied to a block or an outer cylinder exceeds 0.5 time of the basic dynamic load rating ($P > 0.5C$), the actual life of the systems may become shorter than a calculated life time. Therefore, it is recommended to use the systems with 0.5C or lower.

②In the repetition of very minute stroke, where the rolling element, a steel ball or a cylindrical roller, makes only less than a half turn, early wear called fretting occurs at the contact points between the rolling elements and the raceway. There is no perfect measure to avoid this, but the life of the system can be extended by using anti-fretting grease and moving the blocks or the outer cylinders for the full stroke length once in a few thousand times of use.

Anti-fretting grease is available as an option. Please select it for applications with very minute stroke length.