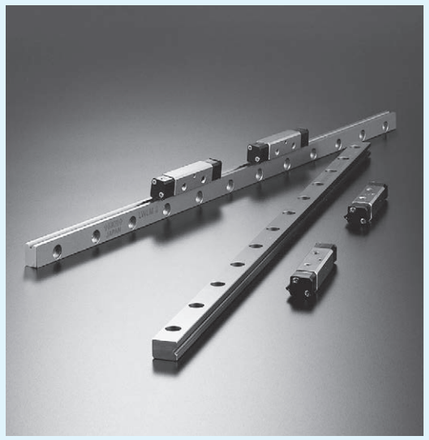
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General Explanation



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Friction

Friction of linear motion rolling guide

The static friction (start-up friction) of linear motion rolling guides is much lower than that of conventional plain guides. Also, the difference between static friction and dynamic friction is small, and frictional resistance varies little when velocity changes. These are excellent features of linear motion rolling guides, and account for their ability to reduce power consumption, suppress operating temperature rise, and increase traveling speed.
Since frictional resistance and variation are small, high-speed response characteristics to motion commands and high accuracy positioning can be achieved.

Friction coefficient

The frictional resistance of linear motion rolling guides varies with their model, applied load, velocity and characteristics of lubricant. Generally, lubricant or seals are major factors in determining the frictional resistance in light load or high-speed operation, while the amount of load is the major factor in heavy load or low speed operation. The frictional resistance of linear motion rolling guides depends on various factors, but generally the following formula is used.

$$F = \mu P \quad \cdots\cdots (13)$$

where, F : Frictional resistance, N
μ : Dynamic friction coefficient
P : Applied load, N

For sealed guides, seal resistance is added to the above value, but this resistance varies greatly depending on the interference amount of seal lip and lubrication conditions.
Where the lubrication and mounting condition are correct and the load is moderate, the friction coefficients of Linear Way and Linear Roller Way in operation are within the range shown in Table 10. Generally, friction coefficient is large under small load.

Table 10 Friction coefficient

Series name	Dynamic friction coefficient μ (1)
Linear Way	0.0040～0.0060
Linear Roller Way	0.0020～0.0040

Note (1) These friction coefficients do not include seal.

Lubrication

Objectives of lubrication

The objectives of applying lubricant for linear motion rolling guides is to keep raceways, rolling elements, etc. in a linear motion rolling guide from metal contact, and thereby reduce friction and wear preventing heat generation and seizure. When an adequate oil film is formed at the rolling contact area between the raceways and rolling elements, the contact stress due to load can be reduced. To manage the formation of adequate oil film is important for ensuring the reliability of linear motion rolling mechanism.

Selection of lubricant

To obtain the full performance of linear motion rolling guides, it is necessary to select an appropriate lubricant and lubrication method by considering the model, load and velocity of each linear motion rolling guide. However, as compared with plain guides, lubrication of linear motion rolling guides is much simpler. Only a small amount of lubrication oil is needed and replenishment interval is longer, so maintenance can be greatly reduced. Grease and oil are the two most commonly used lubricants for linear motion rolling guides.

Grease lubrication

For linear motion rolling guides, lithium-soap base grease (Consistency No.2 of JIS) is commonly used. For rolling guides operating under heavy load conditions, grease containing extreme pressure additives is recommended.
In clean and high-vacuum environments, where low dust generating performance and low vaporization characteristics are required, greases containing a synthetic-base oil or a soap other than the lithium-soap base are used. For applications in these environments, due consideration is necessary to select a grease that is suitable for the operating conditions of linear motion rolling guide and achieves satisfactory lubrication performance at the same time.

Table 11 Pre-packed grease list

Series name	Pre-packed grease
C-Lube Linear Way ML Linear Way L	MULTEMP PS No.2 [KYODO YUSHI CO., LTD.]
C-Lube Linear Way MLV	
C-Lube Linear Way MV	Alvania EP Grease 2 [Shell Lubricants Japan K.K.]
C-Lube Linear Way ME Linear Way E	
C-Lube Linear Way MH(1) Linear Way H(1)	
Linear Way F	
C-Lube Linear Way MUL Linear Way U(2)	MULTEMP PS No.2 [KYODO YUSHI CO., LTD.]
C-Lube Linear Roller Way Super MX Linear Roller Way Super X	Alvania EP Grease 2 [Shell Lubricants Japan K.K.]
Linear Roller Way X	
Linear Way Module	

Notes (1) MULTEMP PS No.2 is pre-packed in size 8 to 12 series.
(2) Alvania EP Grease 2 is pre-packed in size 40 to 86 series.

Grease replenishment interval

The quality of any grease will gradually deteriorate as operating time passes. Therefore, periodic replenishment is necessary. Grease replenishment interval varies depending on the operating conditions. A six month interval is generally recommended, and if the machine operation consists of reciprocating motions with many cycles and long strokes, replenishment every three month is recommended.
In addition, linear motion rolling guides in which the lubrication part "C-Lube" is built deliver long-term maintenance free performance. This eliminates the need for lubrication mechanism and workload which used to be necessary for linear motion rolling guides and significantly reduces maintenance cost.

Grease replenishment method

New grease must be supplied through a grease feed device such as a grease nipple until old grease is discharged. After grease is replenished, running-in is performed and excess grease will be discharged to outside of the linear motion rolling guide. Discharged grease must then be removed before starting the operation.
The amount of grease required for standard replenishment is about 1/3 to 1/2 of the free space inside the linear motion rolling guide. When grease is supplied from a grease nipple for the first time, there will be grease lost in the replenishment path. The amount lost should be taken into consideration.
Generally, immediately after grease is replenished, frictional resistance tends to increase. If additional running-in is performed for 10 to 20 reciprocating cycles after excess grease is discharged, frictional resistance becomes small and stable.
For applications where low frictional resistance is required, the replenishment amount of grease may be reduced, but it must be kept to an appropriate level so as not to give a bad influence on the lubrication performance.

Mixing of different type of grease

Mixing different types of grease may result in changing the properties of base oil, soap base, or additives used, and, in some cases, severely deteriorate the lubrication performance or cause trouble due to chemical changes of additives. Old grease should therefore be removed thoroughly before filling with new grease.

Lubrication part "C-Lube"

C-Lube is a porous resin with molding formed fine resin powder. It is a lubrication part impregnated with a large amount of lubrication oil in its open pores by capillary inside.
Lubrication oil is supplied directly to balls (steel balls) or rollers (cylindrical rollers), not to the track rail. When the balls or rollers have contact with C-Lube built in the slide unit, lubrication oil is supplied to the surface of the balls or rollers. As the balls or rollers circulate, the lubricant is distributed to the loading area along the track rail. This results in adequate lubrication oil being properly maintained in the loading area and lubrication performance will last for a long time.
The surface of C-Lube is always covered with the lubrication oil. Lubrication oil is continuously supplied to the surface of balls or rollers by surface tension in the contact of C-Lube surface and balls or rollers.

Oil lubrication

For oil lubrication, heavy load requires high oil viscosity and high velocity requires low oil viscosity. Generally, for linear motion rolling guides operating under heavy load, lubrication oil with a viscosity of about 68 mm^2/s is used. For linear motion rolling guides under light load at high-speed operation, lubrication oil with a viscosity of about 13 mm^2/s is used.

Table 12 Grease brands used in linear motion rolling guide

Brand		Base oil	Thickener	Consistency	Range of operating temperature (2) ℃	Usage
Alvania EP Grease 2	[Shell Lubricants Japan K.K.]	Mineral oil	Lithium	284	-20～110	General application with extreme-pressure additive
Alvania Grease S2	[Shell Lubricants Japan K.K.]	Mineral oil	Lithium	283	-25～120	General application
MULTEMP PS No.2	[KYODO YUSHI CO., LTD.]	Synthetic oil, Mineral oil	Lithium	275	-50～130	General application
IKO Low Dust-Generation Grease for Clean Environment CG2	[NIPPON THOMPSON CO., LTD.]	Synthetic oil	Urea	280	-40～200	For clean environment Long life
IKO Low Dust-Generation Grease for Clean Environment CGL	[NIPPON THOMPSON CO., LTD.]	Synthetic oil, Mineral oil	Lithium / Calcium	225	-30～120	For clean environment Low sliding
Klüberalfa GR Y-VAC3(1)	[NOK KLUEBER]	Synthetic oil	Ethylene tetra-fluoride	No.3	-20～250	For vacuum
IKO Anti-Fretting Corrosion Grease AF2	[NIPPON THOMPSON CO., LTD.]	Synthetic oil	Urea	285	-50～170	Fretting-proof
6459 Grease N	[Shell Lubricants Japan K.K.]	Mineral oil	Poly-urea	305	–	Fretting-proof

Notes (1) Set replenishment intervals to short.
(2) The ranges of operating temperature are quoted from the grease manufacturer's cataloged values, but do not guarantee regular use under high temperature environment.
Remarks Check with the chosen grease manufacturer's catalog before use.
For grease for applications other than those listed, please contact IKO.

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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

Selection Procedure

Selection of Linear Way and Linear Roller Way should be considered from the most important required matter to details in order.
Typical procedure is shown below.

Example of Linear Way and Linear Roller Way selection procedure

Check for use condition
- Machines and locations in use
- Confirm requirements, performance, and special environments of Linear Way and Linear Roller Way.

↓

Selection of Linear Way and Linear Roller Way model
- Select a suitable Linear Way and Linear Roller Way model for usage conditions in consideration of an applied load, a load direction, rigidity, friction, ease of mounting, etc.

See pages Ⅰ−7 to Ⅰ−8 and descriptions of each series.

↓

Selection of interchangeable or non-interchangeable specification
- Take maintainability and ease of assembly into account.

See pages Ⅰ−15 to Ⅰ−18 and descriptions of each series.

↓

Selection of accuracy class
- Select based on required traveling accuracy. Select a higher accuracy class especially when traveling accuracy is important.

See descriptions of each series.

↓

Temporary specification of size and numbers of sets and slide units
- Take a balance of machines / equipment and past experience into account.

↓

Calculation of applied load
- Calculate an applied load on each slide unit of Linear Way and Linear Roller Way.
- Consider loads and fluctuating loads by acceleration and deceleration.

See pages Ⅲ−9 to Ⅲ−18.

↓

Calculation of static safety factor
- Calculate a static safety factor to confirm suitability for usage conditions.

See page Ⅲ−6.

↓

Calculation of life
- Calculate rating life to confirm suitability for use conditions.

See page Ⅲ−6.

↓

Consideration of preload amount or clearance
- Select a suitable preload amount or clearance for use conditions.

See page Ⅲ−20 and descriptions of each series.

↓

Determination of size, numbers of sets and slide units, and preload

↓

Selection of lubrication and dust protection
- Select oil lubrication or grease lubrication.
- Select dust protection such as seals and bellows according to environmental conditions.

See pages Ⅲ−21 to Ⅲ−27 and descriptions of each series.

↓

Consideration of surroundings
- Consider a mounting method and related dimensions.

See page Ⅲ−36 and descriptions of each series.

↓

Final specification determination of Linear Way, Linear Roller Way and their surroundings

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Load Rating and Life

Life of linear motion rolling guides

Even in normal operational status, a linear motion rolling guide will reach the end of its life after a certain period of operations. As repeated load is constantly applied onto a raceway and rolling elements of the linear motion rolling guide, this leads to leprous damage (scale-like wear fragments) called fatigue flaking due to rolling contact fatigue of materials, it will be unusable at the end. Total traveling distance before occurrence of this fatigue flaking on a raceway or rolling elements is called the life of linear motion rolling guide.
As the life of linear motion rolling guide may vary depending on material fatigue phenomenon, rating life based on statistic calculation is used.

Rating life

Rating life of linear motion rolling guide refers to the total traveling distance 90% of a group of the same linear motion rolling guide can operate without linear motion rolling guide material damages due to rolling contact fatigue when they are operated individually under the same conditions.

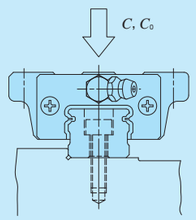


Fig. 1 Direction of load rating

Basic dynamic load rating C

Complying with ISO 14728-1

Basic dynamic load rating refers to load with certain direction and size that is logically endurable for rating life of 50×10^3 m when a group of the same linear motion rolling guides is operated individually under the same conditions.

Basic static load rating C_0

Complying with ISO 14728-2

Basic static load rating refers to static load generating a certain contact stress at the center of contact part of the rolling elements and a raceway under maximum load, which is the load at the allowable limit for normal rolling motion. Generally, it is used considering static safety factor.

Static moment rating T_0, T_X, T_Y

Static moment rating refers to static moment load generating a certain contact stress at the center of contact parts of rolling elements and a raceway under the maximum load when the moment load shown in Fig. 2 is loaded, which is the moment load at the allowable limit for normal rolling motion. Generally, it is used considering static safety factor.

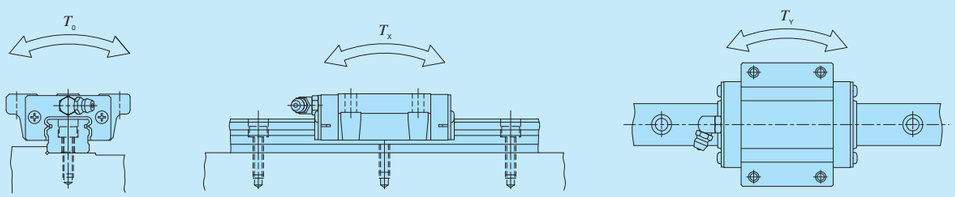


Fig. 2 Direction of static moment rating

Calculating formula of life

The rating life calculation formulas are shown below.

Linear Way

$$L=50\left(\frac{C}{P}\right)^3 \quad \cdots\cdots(1)$$

Linear Roller Way

$$L=50\left(\frac{C}{P}\right)^{10/3} \quad \cdots\cdots(2)$$

where, L: Rating life, 10^3 m
C: Basic dynamic load rating, N
P: Dynamic equivalent load, N

Life time can be calculated by applying a stroke length and a number of strokes per minute to the formula below.

$$L_h=\frac{10^6 L}{2Sn_1\times60} \quad \cdots\cdots(3)$$

where, L_h : Rating life in hours, h
S : Stroke length, mm
n_1 : Number of strokes per minute, min^{-1}

Load factor

Load applied to a linear motion rolling guide can be larger than theoretical load due to machine vibration or shock. Generally, the applied load is obtained by multiplying it by the load factor indicated in Table 1.

Table 1 Load factor

Operating conditions	f_W
Smooth operation free from shock	1 ～ 1.2
Normal operation	1.2 ～ 1.5
Operation with shock load	1.5 ～ 3

Static safety factor

Generally, basic static load rating and static moment rating is considered as load at the allowable limit for normal rolling motion. However, static safety factor must be considered according to operating conditions and required performance of the linear motion rolling guide.
Static safety factor can be obtained by the following equation and typical values are indicated in Tables 2.1 and 2.2.
Equation (5) is a representative equation for a moment load. Moment load and static moment rating in each direction is applied for the calculation.

$$f_S=\frac{C_0}{P_0} \quad \cdots\cdots(4)$$

$$f_S=\frac{T_0}{M_0} \quad \cdots\cdots(5)$$

where, f_S : Static safety factor
C_0 : Basic static load rating, N
P_0 : Static equivalent load, N
T_0 : Static moment rating, N · m
M_0 : Moment load in each direction, N · m
(maximum moment load)

Table 2.1 Static safety factor for Linear Way

Operational conditions	f_s
Operation with vibration and / or shock	3 ～ 5
High operating performance	2 ～ 4
Normal operating conditions	1 ～ 3

Table 2.2 Static safety factor for Linear Roller Way

Operational conditions	f_s
Operation with vibration and / or shock	4 ～ 6
High operating performance	3 ～ 5
Normal operating conditions	2.5 ～ 3

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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

Dynamic equivalent load

When a load is applied in a direction other than that of the basic dynamic load rating or a complex load is applied, the dynamic equivalent load must be calculated to obtain the basic rating life.

Obtain the downward and lateral conversion loads from the loads and moments in various directions.

$$F_{re}=k_r|F_r|+\frac{C_0}{T_0}|M_0|+\frac{C_0}{T_X}|M_X| \cdots\cdots(6)$$

$$F_{ae}=k_a|F_a|+\frac{C_0}{T_Y}|M_Y| \cdots\cdots(7)$$

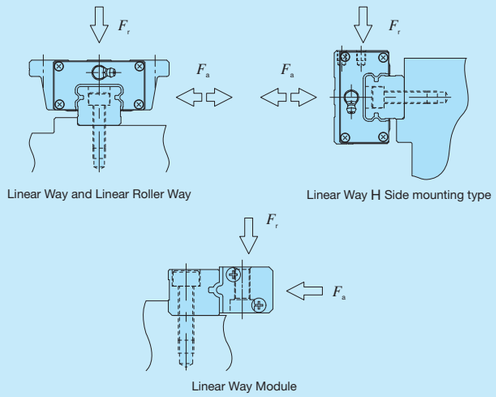
[For Linear Way H Side mounting type (LWHY)]

$$F_{ae}=k_a|F_a|+\frac{C_0}{T_0}|M_0|+\frac{C_0}{T_X}|M_x| \cdots\cdots(8)$$

$$F_{re}=k_r|F_r|+\frac{C_0}{T_Y}|M_Y| \cdots\cdots(9)$$

where, F_{re} : Downward conversion load, N
F_{ae} : Lateral conversion load, N
F_r : Downward load, N
F_a : Lateral load, N
M_0 : Moment load in the T_0 direction, N · m
M_X : Moment load in the T_X direction, N · m
M_Y : Moment load in the T_Y direction, N · m
k_r, k_a : Conversion factors for load direction (See Table 3)
C_0 : Basic static load rating, N
T_0 : Static moment rating in the T_0 direction, N · m
T_X : Static moment rating in the T_X direction, N · m
T_Y : Static moment rating in the T_Y direction, N · m

Table 3 Conversion factor for load direction



Series name and size		Conversion factor k_r $F_r \geqq 0$	Conversion factor k_r $F_r < 0$	Conversion factor k_a
C-Lube Linear Way ML Linear Way L	Ball retained type	1	1	1.19
	Ball non-retained type	1	1	0.84
C-Lube Linear Way MLV		1	1	1.19
C-Lube Linear Way MV		1	1.23	1.35
C-Lube Linear Way ME Linear Way E	15～30	1	1	1
	35～45	1	1.19	1.28
Low Decibel Linear Way E		1	1	1
C-Lube Linear Way MH Linear Way H	8～12	1	1	1.19
	15～30	1	1	1
	35～65	1	1.19	1.28
Linear Way H	15～30	1	1	1
Linear Way H Horizontal mounting type	35～45 (1)	1	1	0.84 0.95
Linear Way F	33～42	1	1	1
	69	1	1	1.19
	LWFH	1	1.19	1.28
C-Lube Linear Way MUL Linear Way U	25, 30	1	1	1.19
	40～86	1	1	1
C-Lube Linear Roller Way Super MX Linear Roller Way Super X		1	1	1
Linear Roller Way X		1	1	1
Linear Way Module	LWLM	1	1	0.73
	LRWM	1	1	0.58

Note (1) The upper value of k_a columns represents the right direction and the lower value represents the left direction.

Obtain the dynamic equivalent load from the downward and lateral conversion loads.

$$P=XF_{re}+YF_{ae} \cdots\cdots(10)$$

where, P : Dynamic equivalent load, N
X, Y : Dynamic equivalent load factor (See Table 4)
F_{re} : Downward conversion load, N
F_{ae} : Lateral conversion load, N

Table 4 Dynamic equivalent load factor

Class	X	Y
$\|F_{re}\| \geqq \|F_{ae}\|$	1	0.6
$\|F_{re}\| < \|F_{ae}\|$	0.6	1

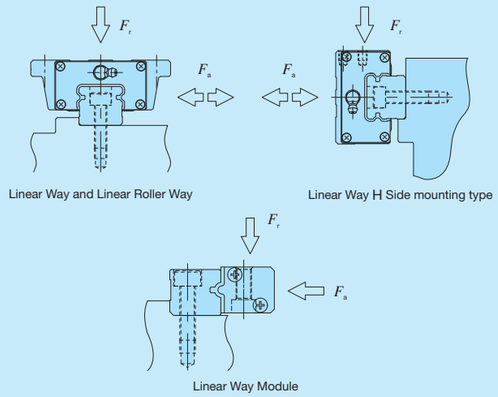
Static equivalent load

When a load is applied in a direction other than that of the basic static load rating or a complex load is applied, the static equivalent load must be calculated to obtain the static safety factor.

$$P_0=k_{0r}|F_r|+k_{0a}|F_a|+\frac{C_0}{T_0}|M_0|+\frac{C_0}{T_X}|M_X|+\frac{C_0}{T_Y}|M_Y| \cdots\cdots(11)$$

where, P_0 : Static equivalent load, N
F_r : Downward load, N
F_a : Lateral load, N
M_0 : Moment load in the T_0 direction, N · m
M_X : Moment load in the T_X direction, N · m
M_Y : Moment load in the T_Y direction, N · m
k_{0r}, k_{0a} : Conversion factors for load direction (See Table 5)
C_0 : Basic static load rating, N
T_0 : Static moment rating in the T_0 direction, N · m
T_X : Static moment rating in the T_X direction, N · m
T_Y : Static moment rating in the T_Y direction, N · m

Table 5 Conversion factor for load direction



Series name and size		Conversion factor k_{0r} $F_r \geqq 0$	Conversion factor k_{0r} $F_r < 0$	Conversion factor k_{0a}
C-Lube Linear Way ML Linear Way L	Ball retained type	1	1	1.19
	Ball non-retained type	1	1	0.84
C-Lube Linear Way MLV		1	1	1.19
C-Lube Linear Way MV		1	1.88	2.08
C-Lube Linear Way ME Linear Way E	15～30	1	1	1
	35～45	1	1.19	1.28
Low Decibel Linear Way E		1	1	1
C-Lube Linear Way MH Linear Way H	8～12	1	1	1.19
	15～30	1	1	1
	35～65	1	1.19	1.28
Linear Way H	15～30	1	1	1
Linear Way H Horizontal mounting type	35～45 (1)	1	1	0.78 0.93
Linear Way F	33～42	1	1	1
	69	1	1	1.19
	LWFH	1	1.19	1.28
C-Lube Linear Way MUL Linear Way U	25, 30	1	1	1.19
	40～86	1	1	1
C-Lube Linear Roller Way Super MX Linear Roller Way Super X		1	1	1
Linear Roller Way X		1	1	1
Linear Way Module	LWLM	1	1	0.60
	LRWM	1	1	0.50

Note (1) The upper value of k_{0a} columns represents the right direction and the lower value represents the left direction.

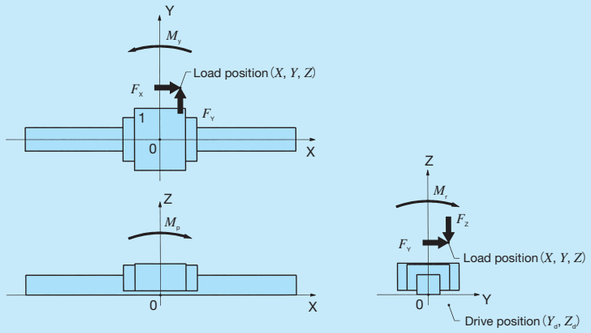
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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

Calculated Load

Examples of calculation for the loads applied to Linear Way and Linear Roller Way that is incorporated in machine / equipment is shown in Table 6.1 to Table 6.6.

Table 6.1 One track rail and one slide unit

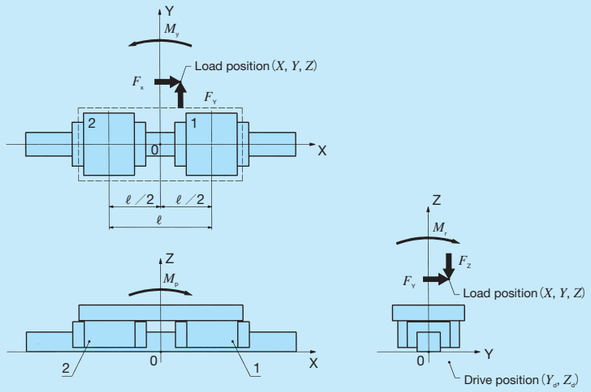


Slide unit No.	Load applied on the slide unit				
	Downward load F_r	Lateral load F_a	Moment load in the T_0 direction M_0	Moment load in the T_X direction M_X	Moment load in the T_Y direction M_Y
1	F_z	F_Y	M_r	M_p	M_y

Remark: The moment loads in each direction M_r, M_p, M_y can be obtained by the following equation.

$$M_r = F_Y Z + F_Z Y$$
$$M_p = F_X (Z - Z_d) + F_Z X$$
$$M_y = -F_X (Y - Y_d) + F_Y X$$

Table 6.2 One track rail and two slide units

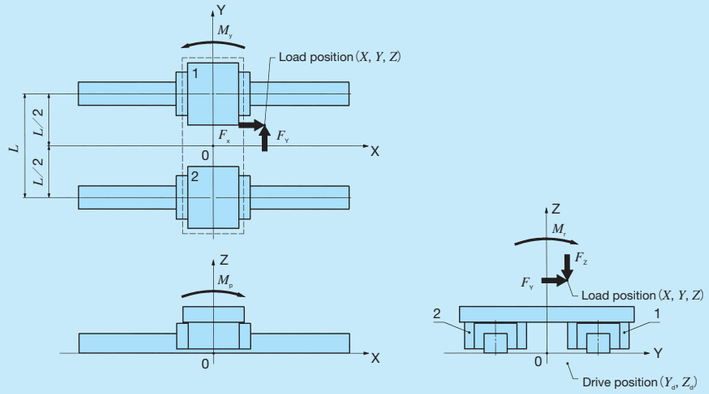


Slide unit No.	Load applied on the slide unit		
	Downward load F_r	Lateral load F_a	Moment load in the T_0 direction M_0
1	$\frac{F_z}{2} + \frac{M_p}{\ell}$	$\frac{F_Y}{2} + \frac{M_y}{\ell}$	$\frac{M_r}{2}$
2	$\frac{F_z}{2} - \frac{M_p}{\ell}$	$\frac{F_Y}{2} - \frac{M_y}{\ell}$	$\frac{M_r}{2}$

Remark: The moment loads in each direction M_r, M_p, M_y can be obtained by the following equation.

$$M_r = F_Y Z + F_Z Y$$
$$M_p = F_X (Z - Z_d) + F_Z X$$
$$M_y = -F_X (Y - Y_d) + F_Y X$$

Table 6.3 Two track rails and one slide unit



Slide unit No.	Load applied on the slide unit			
	Downward load F_r	Lateral load F_a	Moment load in the T_X direction M_X	Moment load in the T_Y direction M_Y
1	$\frac{F_z}{2} + \frac{M_r}{L}$	$\frac{F_Y}{2}$	$\frac{M_p}{2}$	$\frac{M_y}{2}$
2	$\frac{F_z}{2} - \frac{M_r}{L}$	$\frac{F_Y}{2}$	$\frac{M_p}{2}$	$\frac{M_y}{2}$

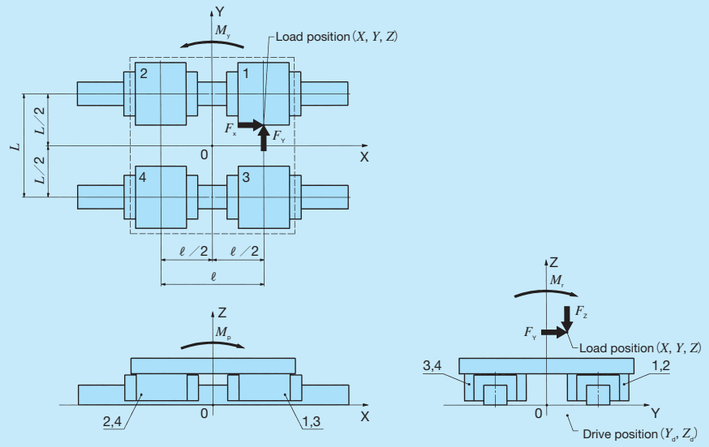
Remark: The moment loads in each direction M_r, M_p, M_y can be obtained by the following equation.

$$M_r = F_Y Z + F_Z Y$$
$$M_p = F_X (Z - Z_d) + F_Z X$$
$$M_y = -F_X (Y - Y_d) + F_Y X$$

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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

Table 6.4 Two track rails and two slide units



Slide unit No.	Load applied on the slide unit	
	Downward load F_r	Lateral load F_a
1	$\frac{F_z}{4}+\frac{M_r}{2L}+\frac{M_p}{2\ell}$	$\frac{F_Y}{4}+\frac{M_y}{2\ell}$
2	$\frac{F_z}{4}+\frac{M_r}{2L}-\frac{M_p}{2\ell}$	$\frac{F_Y}{4}-\frac{M_y}{2\ell}$
3	$\frac{F_z}{4}-\frac{M_r}{2L}+\frac{M_p}{2\ell}$	$\frac{F_Y}{4}+\frac{M_y}{2\ell}$
4	$\frac{F_z}{4}-\frac{M_r}{2L}-\frac{M_p}{2\ell}$	$\frac{F_Y}{4}-\frac{M_y}{2\ell}$

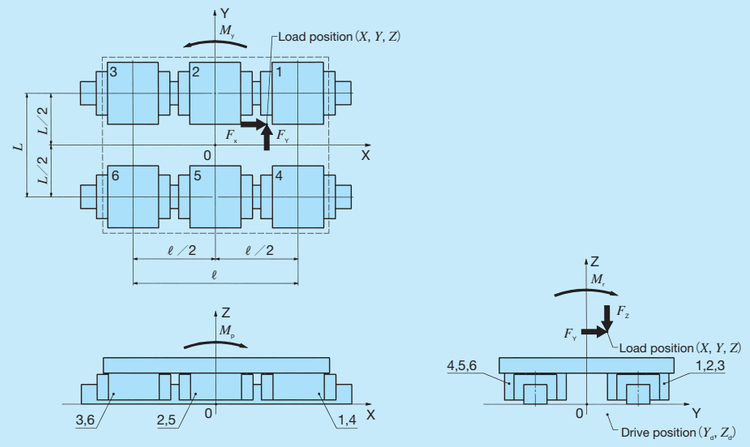
Remark: The moment loads in each direction M_r, M_p, M_y can be obtained by the following equation.

$M_r=F_Y Z+F_Z Y$

$M_p=F_X\ (Z-Z_d)+F_Z X$

$M_y=-F_X\ (Y-Y_d)+F_Y X$

Table 6.5 Two track rails and three slide units



Slide unit No.	Load applied on the slide unit	
	Downward load F_r	Lateral load F_a
1	$\frac{F_z}{6}+\frac{M_r}{3L}+\frac{M_p}{2\ell}$	$\frac{F_Y}{6}+\frac{M_y}{2\ell}$
2	$\frac{F_z}{6}+\frac{M_r}{3L}$	$\frac{F_Y}{6}$
3	$\frac{F_z}{6}+\frac{M_r}{3L}-\frac{M_p}{2\ell}$	$\frac{F_Y}{6}-\frac{M_y}{2\ell}$
4	$\frac{F_z}{6}-\frac{M_r}{3L}+\frac{M_p}{2\ell}$	$\frac{F_Y}{6}+\frac{M_y}{2\ell}$
5	$\frac{F_z}{6}-\frac{M_r}{3L}$	$\frac{F_Y}{6}$
6	$\frac{F_z}{6}-\frac{M_r}{3L}-\frac{M_p}{2\ell}$	$\frac{F_Y}{6}-\frac{M_y}{2\ell}$

Remark: The moment loads in each direction M_r, M_p, M_y can be obtained by the following equation.

$M_r=F_Y Z+F_Z Y$

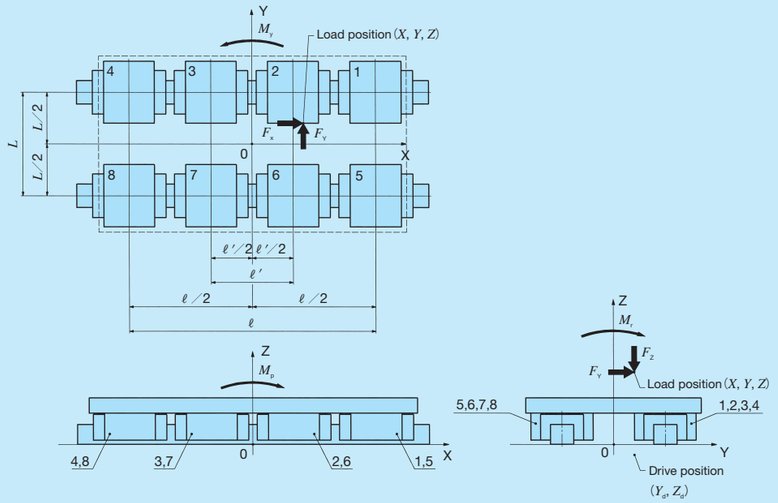
$M_p=F_X\ (Z-Z_d)+F_Z X$

$M_y=-F_X\ (Y-Y_d)+F_Y X$

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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

Table 6.6 Two track rails and four slide units



Slide unit No.	Load applied on the slide unit	
	Downward load F_r	Lateral load F_a
1	$\frac{F_z}{8}+\frac{M_r}{4L}+\frac{M_p}{2}\frac{\ell}{\ell^2+\ell'^2}$	$\frac{F_Y}{8}+\frac{M_y}{2}\frac{\ell}{\ell^2+\ell'^2}$
2	$\frac{F_z}{8}+\frac{M_r}{4L}+\frac{M_p}{2}\frac{\ell'}{\ell^2+\ell'^2}$	$\frac{F_Y}{8}+\frac{M_y}{2}\frac{\ell'}{\ell^2+\ell'^2}$
3	$\frac{F_z}{8}+\frac{M_r}{4L}-\frac{M_p}{2}\frac{\ell'}{\ell^2+\ell'^2}$	$\frac{F_Y}{8}-\frac{M_y}{2}\frac{\ell'}{\ell^2+\ell'^2}$
4	$\frac{F_z}{8}+\frac{M_r}{4L}-\frac{M_p}{2}\frac{\ell}{\ell^2+\ell'^2}$	$\frac{F_Y}{8}-\frac{M_y}{2}\frac{\ell}{\ell^2+\ell'^2}$
5	$\frac{F_z}{8}-\frac{M_r}{4L}+\frac{M_p}{2}\frac{\ell}{\ell^2+\ell'^2}$	$\frac{F_Y}{8}+\frac{M_y}{2}\frac{\ell}{\ell^2+\ell'^2}$
6	$\frac{F_z}{8}-\frac{M_r}{4L}+\frac{M_p}{2}\frac{\ell'}{\ell^2+\ell'^2}$	$\frac{F_Y}{8}+\frac{M_y}{2}\frac{\ell'}{\ell^2+\ell'^2}$
7	$\frac{F_z}{8}-\frac{M_r}{4L}-\frac{M_p}{2}\frac{\ell'}{\ell^2+\ell'^2}$	$\frac{F_Y}{8}-\frac{M_y}{2}\frac{\ell'}{\ell^2+\ell'^2}$
8	$\frac{F_z}{8}-\frac{M_r}{4L}-\frac{M_p}{2}\frac{\ell}{\ell^2+\ell'^2}$	$\frac{F_Y}{8}-\frac{M_y}{2}\frac{\ell}{\ell^2+\ell'^2}$

Remark: The moment loads in each direction M_r, M_p, M_y can be obtained by the following equation.

$M_r=F_Y Z+F_Z Y$

$M_p=F_X\ (Z-Z_d)+F_Z X$

$M_y=-F_X\ (Y-Y_d)+F_Y X$

Mean Equivalent Load for Fluctuating Load

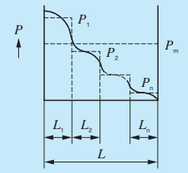
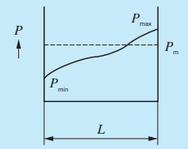
When the load on the Linear Way and Linear Roller Way varies, instead of dynamic equivalent load P, the mean equivalent load P_m is used for calculating formula of life.
The mean equivalent load is a load converted to give life equal to that for fluctuating load. It is obtained by the following formula:

$$P_m=\sqrt[p]{\frac{1}{L}\int_0^L P_n^{\,p}\,dL} \quad \cdots\cdots (12)$$

where, P_m : Mean equivalent load, N
L : Total traveling distance, m
P_n : Fluctuating load, N
p : Exponent (ball type: 3, roller type: 10/3)

Table 7 gives calculation examples of the mean equivalent load for typical fluctuating loads.

Table 7 Mean equivalent load for fluctuating load

Example		Mean equivalent load
① Stepwise changing load		$P_m=\sqrt[p]{\frac{1}{L}(P_1^{\,p}L_1+P_2^{\,p}L_2+\ldots+P_n^{\,p}L_n)}$ where, L_1 : Total traveling distance receiving the load P_1, m L_2 : Total traveling distance receiving the load P_2, m L_n : Total traveling distance receiving the load P_n, m
② Monotonously changing load		$P_m\fallingdotseq\frac{1}{3}(2P_{max}+P_{min})$ where, P_{max} : Maximum value of fluctuating load, N P_{min} : Minimum value of fluctuating load, N

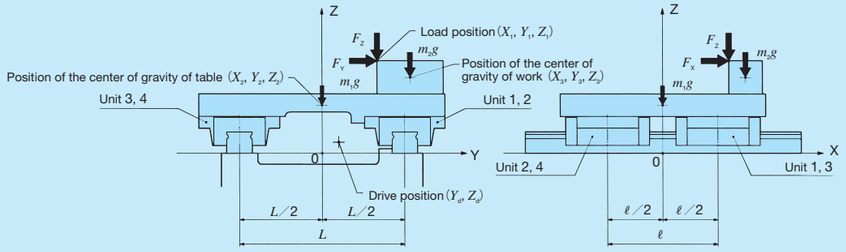
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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

Examples of Load and Life Calculation

Example 1

Linear Way Model·····ME 25 C2 R640 H
Basic dynamic load rating····· C = 18100 N
Basic static load rating····· C_0 = 21100 N
Applied load····· F_{X1} = 1000 N
····· F_{Y1} = 2000 N
····· F_{Z1} = 1000 N
Load position····· X_1 = 60 mm
····· Y_1 = 50 mm
····· Z_1 = 83 mm
Table mass····· m_1 = 10 kg
Position of the center of gravity of table····· X_2 = 0 mm
····· Y_2 = 0 mm
····· Z_2 = 43 mm
Work mass····· m_2 = 10 kg
Position of center of gravity of work····· X_3 = 75 mm
····· Y_3 = 80 mm
····· Z_3 = 68 mm
Number of strokes per minute····· n_1 = 5 min^{-1}
Stroke length····· S = 100 mm
Distance between slide units····· ℓ = 100 mm
Distance between the track rails····· L = 150 mm
Drive position····· Y_d = 150 mm
····· Z_d = 10 mm



The life and static safety factor in the case of Example 1 is calculated. Load factor f_W is assumed to be 1.5.

❶Calculation of load on the slide unit

Due to the applied load and the table weight, moment load occurs around each coordinate axis of the Linear Way as shown below.

$$M_r = \Sigma (F_Y Z) + \Sigma (F_Z Y) = F_{Y1} Z_1 + F_{Z1} Y_1 + m_1 g Y_2 + m_2 g Y_3$$
$$= 2000 \times 83 + 1000 \times 50 + 10 \times 9.8 \times 0 + 10 \times 9.8 \times 80 \fallingdotseq 224000$$

$$M_p = \Sigma \{F_X (Z - Z_d)\} + \Sigma (F_Z X) = F_{X1} (Z_1 - Z_d) + F_{Z1} X_1 + m_1 g X_2 + m_2 g X_3$$
$$= 1000 \times (83 - 10) + 1000 \times 60 + 10 \times 9.8 \times 0 + 10 \times 9.8 \times 75 \fallingdotseq 140000$$

$$M_y = -\Sigma \{F_X (Y - Y_d)\} + \Sigma (F_Y X) = -F_{X1} (Y_1 - Y_d) + F_{Y1} X_1$$
$$= -1000 \times (50 - 150) + 2000 \times 60 = 220000$$

where, M_r: Moment load in the rolling direction, N · mm
M_p: Moment load in the pitching direction, N · mm
M_y: Moment load in the yawing direction, N · mm

The loads applied on each slide unit are calculated according to Table 6.4 on page Ⅲ−11.

$$F_{r1} = \frac{\Sigma F_z}{4} + \frac{M_r}{2L} + \frac{M_p}{2\ell} = \frac{F_{Z1} + m_1 g + m_2 g}{4} + \frac{M_r}{2L} + \frac{M_p}{2\ell}$$
$$= \frac{1000 + 10 \times 9.8 + 10 \times 9.8}{4} + \frac{224000}{2 \times 150} + \frac{140000}{2 \times 100}$$
$$\fallingdotseq 1750$$

$$F_{r2} = \frac{\Sigma F_z}{4} + \frac{M_r}{2L} - \frac{M_p}{2\ell} = \frac{F_{Z1} + m_1 g + m_2 g}{4} + \frac{M_r}{2L} - \frac{M_p}{2\ell} \fallingdotseq 346$$

$$F_{r3} = \frac{\Sigma F_z}{4} - \frac{M_r}{2L} + \frac{M_p}{2\ell} = \frac{F_{Z1} + m_1 g + m_2 g}{4} - \frac{M_r}{2L} + \frac{M_p}{2\ell} \fallingdotseq 252$$

$$F_{r4} = \frac{\Sigma F_z}{4} - \frac{M_r}{2L} - \frac{M_p}{2\ell} = \frac{F_{Z1} + m_1 g + m_2 g}{4} - \frac{M_r}{2L} - \frac{M_p}{2\ell}$$
$$\fallingdotseq -1150$$

$$F_{a1} = F_{a3} = \frac{\Sigma F_Y}{4} + \frac{M_y}{2\ell} = \frac{F_{Y1}}{4} + \frac{M_y}{2\ell}$$
$$= \frac{2000}{4} + \frac{220000}{2 \times 100} = 1600$$

$$F_{a2} = F_{a4} = \frac{\Sigma F_Y}{4} - \frac{M_y}{2\ell} = \frac{F_{Y1}}{4} - \frac{M_y}{2\ell} = -600$$

❷Calculating of rating life

The upward / downward load and lateral load are converted by formula (6) and (7) on page Ⅲ−7.

$$F_{re1} = k_r |F_{r1}| = 1 \times 1750 = 1750$$
$$F_{re2} = k_r |F_{r2}| = 1 \times 346 = 346$$
$$F_{re3} = k_r |F_{r3}| = 1 \times 252 = 252$$
$$F_{re4} = k_r |F_{r4}| = 1 \times 1150 = 1150$$
$$F_{ae1} = k_a |F_{a1}| = 1 \times 1600 = 1600$$
$$F_{ae2} = k_a |F_{a2}| = 1 \times 600 = 600$$
$$F_{ae3} = k_a |F_{a3}| = 1 \times 1600 = 1600$$
$$F_{ae4} = k_a |F_{a4}| = 1 \times 600 = 600$$

where, k_r, k_a: Conversion factors for load direction (See Table 3 on page Ⅲ−7.)

The dynamic equivalent load is calculated by formula (10) on page Ⅲ−7.

$$P_1 = X |F_{re1}| + Y |F_{ae1}| = 1 \times 1750 + 0.6 \times 1600 = 2710$$
$$P_2 = X |F_{re2}| + Y |F_{ae2}| = 0.6 \times 346 + 1 \times 600 \fallingdotseq 808$$
$$P_3 = X |F_{re3}| + Y |F_{ae3}| = 0.6 \times 252 + 1 \times 1600 \fallingdotseq 1750$$
$$P_4 = X |F_{re4}| + Y |F_{ae4}| = 1 \times 1150 + 0.6 \times 600 = 1510$$

The basic rating life of slide unit 1 receiving the largest dynamic equivalent load is calculated. The basic rating life is obtained by the formula (1) given on the page Ⅲ−6 considering the load factor f_w (see Table 1 on page Ⅲ−6).

$$L_1 = 50 \left(\frac{C}{f_W P_1}\right)^3 = 50 \times \left(\frac{18100}{1.5 \times 2710}\right)^3 \fallingdotseq 4410$$

$$L_{h1} = \frac{10^6 L_1}{2 S n_1 \times 60} = \frac{10^6 \times 4410}{2 \times 100 \times 5 \times 60} \fallingdotseq 73500$$

As the result of calculation above, the basic rating life is about 73,500 hours.

❸Calculating of static safety factor

The static equivalent load is calculated from the upward / downward load and lateral load by formula (11) on page Ⅲ−8.

$$P_{01} = k_{0r} |F_{r1}| + k_{0a} |F_{a1}| = 1 \times 1750 + 1 \times 1600 = 3350$$
$$P_{02} = k_{0r} |F_{r2}| + k_{0a} |F_{a2}| = 1 \times 346 + 1 \times 600 = 946$$
$$P_{03} = k_{0r} |F_{r3}| + k_{0a} |F_{a3}| = 1 \times 252 + 1 \times 1600 = 1852$$
$$P_{04} = k_{0r} |F_{r4}| + k_{0a} |F_{a4}| = 1 \times 1150 + 1 \times 600 = 1750$$

where, k_{0r}, k_{0a}: Conversion factors for load direction (See Table 5 on page Ⅲ−8.)

The static safety factor of slide unit 1 receiving the largest static equivalent load is calculated. The static safety factor is calculated by formula (4) on page Ⅲ−6.

$$f_{s1} = \frac{C_0}{P_{01}} = \frac{21100}{3350} \fallingdotseq 6.3$$

As the result of calculation above, the static safety factor is about 6.3.

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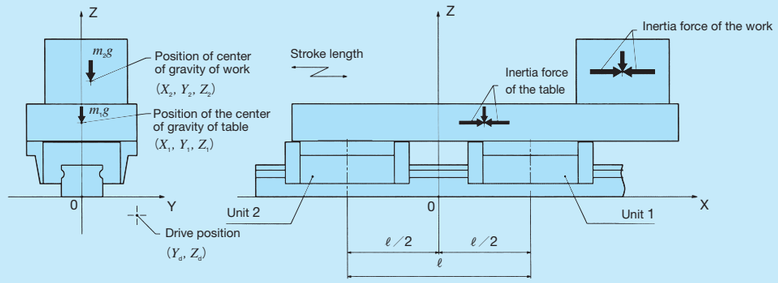
1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

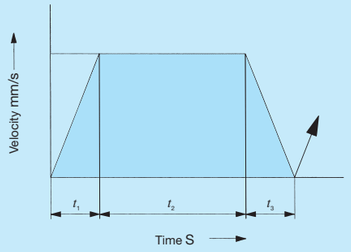
Examples of Load and Life Calculation

Example 2

Linear Way Model·····MH 45 C2 R1050 H
Basic dynamic load rating····· C = 74600 N
Basic static load rating····· C_0 = 80200 N
Static moment rating in the T_0 direction···· T_0 = 1610 N · m
Table mass····· m_1 = 100 kg
Position of the center of gravity of table··· X_1 = 50 mm
··· Y_1 = 0 mm
··· Z_1 = 80 mm
Work mass····· m_2 = 1000 kg
Position of center of gravity of work···· X_2 = 200 mm
···· Y_2 = 10 mm
···· Z_2 = 130 mm

Distance between slide units··· ℓ = 200 mm
Stroke length····· S = 500 mm
Number of strokes per minute··· n_1 = 6 min^{-1}
Maximum traveling velocity···· V = 100 mm/s
Time spent for acceleration ··· t_1 = 0.1 s
Time spent during constant speed motion··· t_2 = 4.9 s
Time spent for deceleration···· t_3 = 0.1 s
Drive position····· Y_d = 60 mm
····· Z_d = −20 mm





The life and static safety factor in the case of Example 2 is calculated. Load factor f_w is assumed to be 1.5.

❶Calculation of load on the slide unit

Due to the applied load and the table mass and inertia force, moment load occurs around each coordinate axis of the Linear Way as shown below.

〔During acceleration at the start of motion〕

$$M_r = \Sigma\ (F_Y Z) + \Sigma\ (F_Z Y) = m_1 g Y_1 + m_2 g Y_2 = 100\times 9.8\times 0 + 1000\times 9.8\times 10 \fallingdotseq 98000$$

$$M_p = \Sigma\ \{F_X\ (Z - Z_d)\} + \Sigma\ (F_Z X) = m_1 \frac{V_{max}}{1000\times t_1}\ (Z_1 - Z_d) + m_2 \frac{V_{max}}{1000\times t_1}\ (Z_2 - Z_d) + m_1 g X_1 + m_2 g X_2$$
$$= 100\times \frac{100}{1000\times 0.1}\times\ (80+20) + 1000\times \frac{100}{1000\times 0.1} \times\ (130+20) + 100\times 9.8\times 50 + 1000\times 9.8\times 200 \fallingdotseq 2169000$$

$$M_y = -\Sigma\ \{F_X\ (Y - Y_d)\} + \Sigma\ (F_Y X) = -m_1 \frac{V_{max}}{1000\times t_1}\ (Y_1 - Y_d) - m_2 \frac{V_{max}}{1000\times t_1}\ (Y_2 - Y_d)$$
$$= -100\times \frac{100}{1000\times 0.1}\times\ (0-60) - 1000\times \frac{100}{1000\times 0.1} \times\ (10-60) \fallingdotseq 56000$$

〔During constant speed motion〕

$$M_r = m_1 g Y_1 + m_2 g Y_2 \fallingdotseq 98000$$
$$M_p = m_1 g X_1 + m_2 g X_2 \fallingdotseq 2010000$$
$$M_y = 0$$

〔During deceleration at the end of motion〕

$$M_r = m_1 g Y_1 + m_2 g Y_2 \fallingdotseq 98000$$
$$M_p = -m_1 \frac{V_{max}}{1000\times t_3}(Z_1 - Z_d) - m_2 \frac{V_{max}}{1000\times t_3}(Z_2 - Z_d) + m_1 g X_1 + m_2 g X_2 \fallingdotseq 1850000$$
$$M_y = m_1 \frac{V_{max}}{1000\times t_3}(Y_1 - Y_d) + m_2 \frac{V_{max}}{1000\times t_3}(Y_2 - Y_d) \fallingdotseq -56000$$

where, M_r: Moment load in the rolling direction, N · mm
M_p: Moment load in the pitching direction, N · mm
M_y: Moment load in the yawing direction, N · mm

The loads applied on each slide unit are calculated according to Table 6.2 on page Ⅲ−9.

〔During acceleration at the start of motion〕

$$F_{r1} = \frac{\Sigma F_Z}{2} + \frac{M_p}{\ell} = \frac{m_1 g + m_2 g}{2} + \frac{M_p}{\ell} = \frac{100\times 9.8 + 1000\times 9.8}{2} + \frac{2169000}{200} \fallingdotseq 16200$$
$$F_{r2} = \frac{\Sigma F_Z}{2} + \frac{M_p}{\ell} = \frac{m_1 g + m_2 g}{2} - \frac{M_p}{\ell} \fallingdotseq -5460$$
$$F_{a1} = \frac{\Sigma F_Y}{2} + \frac{M_y}{\ell} = 280$$
$$F_{a2} = \frac{\Sigma F_Y}{2} - \frac{M_y}{\ell} = -280$$
$$M_{01} = M_{02} = \frac{M_r}{2} = 49000$$

〔During constant speed motion〕

$$F_{r1} = \frac{100\times 9.8 + 1000\times 9.8}{2} + \frac{2010000}{200} \fallingdotseq 15400$$
$$F_{r2} \fallingdotseq -4660$$
$$F_{a1} = F_{a2} = 0$$
$$M_{01} = M_{02} = 49000$$

〔During deceleration at the end of motion〕

$$F_{r1} = \frac{100\times 9.8 + 1000\times 9.8}{2} + \frac{1850000}{200} \fallingdotseq 14600$$
$$F_{r2} \fallingdotseq -3860$$
$$F_{a1} \fallingdotseq -280$$
$$F_{a2} \fallingdotseq 280$$
$$M_{01} = M_{02} = 49000$$

❷Calculating of rating life

The upward / downward load, lateral load and the moment load along T_0 direction are calculated by the formula (6) and (7) on page Ⅲ−7, and the dynamic equivalent load is calculated by formula (10).

〔During acceleration at the start of motion〕

$$F_{re1} = k_r\,|\,F_{r1}\,| + \frac{C_0}{T_0}|M_{01}\,| = 1\times 16200 + \frac{80200}{1610}\times \frac{49000}{1000} \fallingdotseq 18600$$
$$F_{re2} = 1\times 5460 + \frac{80200}{1610}\times \frac{49000}{1000} \fallingdotseq 7900$$
$$F_{ae1} = k_a\,|\,F_{a1}\,| = 1.28\times 280 \fallingdotseq 358$$
$$F_{ae2} = 1.28\times 280 \fallingdotseq 358$$
$$P_{1a} = X F_{re1} + Y F_{ae1} = 1\times 18600 + 0.6\times 358 \fallingdotseq 18800$$
$$P_{2a} = X F_{re2} + Y F_{ae2} = 1\times 7900 + 0.6\times 358 \fallingdotseq 8110$$

〔During constant speed motion〕

$$F_{re1} = 1\times 15400 + \frac{80200}{1610}\times \frac{49000}{1000} \fallingdotseq 17800$$
$$F_{re2} = 1\times 4660 + \frac{80200}{1610}\times \frac{49000}{1000} \fallingdotseq 7100$$
$$F_{ae1} = 0$$
$$F_{ae2} = 0$$
$$P_{1b} = 17800$$
$$P_{2b} = 7100$$

〔During deceleration at the end of motion〕

$$F_{re1} = 1\times 14600 + \frac{80200}{1610}\times \frac{49000}{1000} \fallingdotseq 17000$$
$$F_{re2} = 1\times 3860 + \frac{80200}{1610}\times \frac{49000}{1000} \fallingdotseq 6300$$
$$F_{ae1} = 1.28\times 280 \fallingdotseq 358$$
$$F_{ae2} = 1.28\times 280 \fallingdotseq 358$$
$$P_{1c} = 1\times 17000 + 0.6\times 358 \fallingdotseq 17200$$
$$P_{2c} = 1\times 6300 + 0.6\times 358 \fallingdotseq 6510$$

Because the dynamic equivalent load changes stepwise along the traveling distance, the mean equivalent load is calculated from ① in Table 7 on page Ⅲ−14.

$$P_{m1} = \sqrt[3]{\frac{1}{S}\left(P_{1a}{}^3\frac{V_{max}\,t_1}{2} + P_{1b}{}^3 V_{max} t_2 + P_{1c}{}^3\frac{V_{max}\,t_3}{2}\right)}$$
$$= \left\{\frac{1}{500}\times\left(18800^3\times\frac{100\times 0.1}{2} + 17800^3\times 100\times 4.9 + 17200^3\times\frac{100\times 0.1}{2}\right)\right\}^{1/3} \fallingdotseq 17800$$

$$P_{m2} = \left\{\frac{1}{500}\times\left(8110^3\times\frac{100\times 0.1}{2} + 7100^3\times 100\times 4.9 + 6510^3\times\frac{100\times 0.1}{2}\right)\right\}^{1/3} \fallingdotseq 7110$$

The basic rating life of slide unit 1 receiving the largest dynamic equivalent load is calculated. The basic rating life is obtained by the formula (1) given on the page Ⅲ−6 considering the load factor f_w (see Table 1 on page Ⅲ−6).

$$L_1 = 50\left(\frac{C}{f_W P_{m1}}\right)^3 = 50\left(\frac{74600}{1.5\times 17800}\right)^3 \fallingdotseq 1090$$
$$L_{h1} = \frac{10^6 L_1}{2 S n_1\times 60} = \frac{10^6\times 1090}{2\times 500\times 6\times 60} \fallingdotseq 3030$$

As the result of calculation above, the basic rating life is about 3,030 hours.

❸Calculating of static safety factor

The static equivalent load is calculated from the upward / downward load and lateral load by formula (11) on page Ⅲ−8.

〔During acceleration at the start of motion〕

$$P_{01a} = k_{0r}\,|\,F_{r1}\,| + k_{0a}\,|\,F_{a1}\,| + \frac{C_0}{T_0}|M_{01}\,| = 1\times 16200 + 1.28\times 280 + \frac{80200}{1610}\times\frac{49000}{1000} \fallingdotseq 19000$$

$$P_{02a} = k_{0r}\,|\,F_{r2}\,| + k_{0a}\,|\,F_{a2}\,| + \frac{C_0}{T_0}|M_{02}\,| = 1.19\times 5460 + 1.28\times 280 + \frac{80200}{1610}\times\frac{49000}{1000} \fallingdotseq 9300$$

〔During constant speed motion〕

$$P_{01b} = 1\times 15400 + 1.28\times 0 + \frac{80200}{1610}\times\frac{49000}{1000} \fallingdotseq 19000$$
$$P_{02b} = 1.19\times 4660 + 1.28\times 0 + \frac{80200}{1610}\times\frac{49000}{1000} \fallingdotseq 7990$$

〔During deceleration at the end of motion〕

$$P_{01c} = 1\times 14600 + 1.28\times 280 + \frac{80200}{1610}\times\frac{49000}{1000} \fallingdotseq 17400$$
$$P_{02c} = 1.19\times 3860 + 1.28\times 280 + \frac{80200}{1610}\times\frac{49000}{1000} \fallingdotseq 7390$$

The static safety factor of slide unit 1 during acceleration at the start of motion receiving the largest static equivalent load is calculated. The static safety factor is calculated by formula (4) on page Ⅲ−6.

$$f_s = \frac{C_0}{P_{01a}} = \frac{80200}{19000} \fallingdotseq 4.2$$

As the result of calculation above, the static safety factor is about 4.2.

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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

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Accuracy

Five classes of accuracy, ordinary, high, precision, super precision, and ultra precision are specified for Linear Way and Linear Roller Way.

The outline of applicable accuracy classes is shown in Table 8. For details, see an explanation of each series.

Table 8 Accuracy classes and series

Class (classification symbol) / Series name	Ordinary (No symbol)	High (H)	Precision (P)	Super precision (SP)	Ultra precision (UP)
C-Lube Linear Way ML Linear Way L	–	○	○	–	–
C-Lube Linear Way MLV	–	○	–	–	–
C-Lube Linear Way MV	○	○	○	○	–
C-Lube Linear Way ME Linear Way E	○	○	○	○	–
C-Lube Linear Way MH Linear Way H	–	○	○	○	–
Linear Way F	–	○	○	○	–
C-Lube Linear Way MUL Linear Way U	○	○	–	–	–
C-Lube Linear Roller Way Super MX Linear Roller Way Super X	–	○	○	○	○
Linear Roller Way X	–	○	○	○	○
Linear Way Module	–	○	○	○	–

Preload

Objectives of preload

In some cases, the linear motion rolling guide is used with clearance given to the linear motion rolling guide when light motion with small load is required. However, for some applications, it may be used with play in the guiding mechanism removed or with preload to increase rigidity.

Preload is applied to the contact parts of a raceway and rolling elements with internal stress generated in advance. When a external load is applied on the preloaded linear motion rolling guide, shock absorbing with this internal stress makes elastic deformation smaller, and its rigidity is increased. (See Fig. 3)

Preload setting

Preload amount is determined by considering the characteristics of the machines or equipments on which the linear motion rolling guide is mounted and the nature of load acting on the linear motion rolling guide. The standard amount of preload for linear motion rolling guides is, in general, approx. 1/3 of load when the rolling elements are balls (steel balls) and approx. 1/2 of load when they are rollers (cylindrical rollers). If the linear motion rolling guides are required to have very high rigidity to withstand vibration or fluctuating load, a larger preload may be applied.

For applicable preload amount, see Table 9. For details, see an explanation of each series.

Precaution for preload selection

Even when high rigidity must be required, excessive preload should be avoided, because it will produce an excessive stress between rolling elements and raceways, and eventually result in short life of linear motion rolling guides. It is important to apply a proper amount of preload, considering the operational conditions. When using with a large preload, contact IKO.

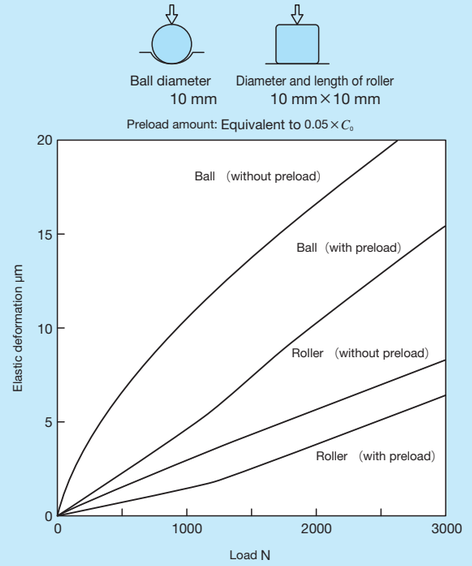


Fig. 3 Preload and elastic deformation behavior

Table 9 Series and preload amount

Preload (preload symbol) / Series name	Clearance (T_C)	Clearance (T_0)	Standard (No symbol)	Light preload (T_1)	Medium preload (T_2)	Heavy preload (T_3)
C-Lube Linear Way ML Linear Way L	–	○	○	○	–	–
C-Lube Linear Way MLV(1)	–	–	–	–	–	–
C-Lube Linear Way MV	○	–	○	○	–	–
C-Lube Linear Way ME Linear Way E	○	–	○	○	○	–
C-Lube Linear Way MH Linear Way H	–	○	○	○	○	○
Linear Way F	–	–	○	○	○	–
C-Lube Linear Way MUL Linear Way U	–	–	○	○	–	–
C-Lube Linear Roller Way Super MX Linear Roller Way Super X	–	–	○	○	○	○
Linear Roller Way X	–	–	○	○	○	○

Note (1) Preload is adjusted to have subtle clearance or minimal amount of preload.

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Reference tables

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Statements

● Unit Conversion Rate Table

SI, CGS series and gravity system unit cross-reference table

Amount / Unit system	Length	Mass	Time	Acceleration	Force	Stress and pressure	Energy	Power	Temperature	Viscosity	Kinetic viscosity	Flux	Flux density	Magnetic field intensity
SI	m	kg	s	m/s^2	N	Pa	J	W	K	Pa·s	m^2/s	Wb	T	A/m
CGS series	cm	g	s	Gal	dyn	dyn/cm^2	erg	erg/s	℃	P	St	Mx	Gs	Oe
Gravity system	m	$kgf·s^2/m$	s	m/s^2	kgf	kgf/m^2	kgf·m	kgf·m/s	℃	$kgf·s/m^2$	m^2/s	—	—	—

SI unit conversion

Amount	Unit name	Code	SI conversion rate	SI unit name	Code
Angle	D	°	$\pi/180$	Radian	rad
	Min	′	$\pi/10\ 800$		
	Sec	″	$\pi/648\ 000$		
Length	Meter	m	1	Meter	m
	Micron	μ	10^{-6}		
	Angstrom	Å	10^{-10}		
	X ray unit		$\approx 1.002\ 08\times10^{-13}$		
	Nautical mile	n mile	1852		
Area	Square meter	m^2	1	Square meter	m^2
	Are	a	10^2		
	Hectare	ha	10^4		
Volume	Cubic meter	m^3	1	Cubic meter	m^3
	Liter	l, L	10^{-3}		
Mass	Kilogram	kg	1	Kilogram	kg
	Ton	t	10^3		
	Atomic mass unit	u	$\approx 1.660\ 57\times10^{-27}$		
Time	Sec	s	1	Sec	s
	Min	min	60		
	Hr	h	3 600		
	Day	d	86 400		
Velocity	Meter per second	m/s	1	Meter per second	m/s
	Knot	kn	1 852/3 600		
Frequency and vibration	Number of cycle	s^{-1}	1	Hertz	Hz
Number of rotations	Rotation per minute	min^{-1}	1/60	Per second	s^{-1}
Angular velocity	Radian per second	rad/s	1	Radian per second	rad/s
Acceleration	Meter per second	m/s^2	1	Meter per second	m/s^2
	G	G	9.806 65		
Force	Weight in kg	kgf	9.806 65	Newton	N
	Weight in ton	tf	9 806.65		
	Dyne	dyn	10^{-5}		
Force moment load	Weight in kg meter	kgf·m	9.806 65	Newton meter	N · m
Stress and pressure	Weight in kg per square meter	kgf/m^2	9.806 65	Pascal	Pa
	Weight in kg per square cm	kgf/cm^2	$9.806\ 65\times10^4$		
	Weight in kg per square mm	kgf/mm^2	$9.806\ 65\times10^6$		
Pressure	Meter water column	mH_2O	9 806.65	Pascal	Pa
	millimeter of mercury column	mmHg	101 325/760		
	Torr	Torr	101 325/760		
	Air pressure	atm	101 325		
	Bar	bar	10^5		
Energy	Erg	erg	10^{-7}	Joule	J
	IT calorie	cal_{IT}	4.186 8		
	Weight in kg meter	kgf·m	9.806 65		
	Kilowatt per hour	kW·h	3.600×10^6		
	French horse-power per hour	PS·h	$\approx 2.647\ 79\times10^6$		
	Electron volt	eV	$\approx 1.602\ 19\times10^{-19}$		
Power and motivity	Watt	W	1	Watt	W
	French horse-power	PS	≈735.5		
	Weight in kg meter per second	kgf·m/s	9.806 65		
Viscosity	Poise	P	10^{-1}	Pascal second	Pa·s
	Centipoise	cP	10^{-3}		
	Weight in kg second per square meter	$kgf·s/m^2$	9.806 65		
Kinetic viscosity	Stokes	St	10^{-4}	Square meter per second	m^2/s
	Centistokes	cSt	10^{-6}		
Temperature	D	℃	+273.15	Kelvin	K
Radioactivity	Curie	Ci	3.7×10^{10}	Becquerel	Bq
Exposure radiation dose	Roentgen	R	2.58×10^{-4}	Coulomb per kg	C/kg
Absorbed dose	Rad	rad	10^{-2}	Gray	Gy
Dose equivalent	Rem	rem	10^{-2}	Sievert	Sv
Flux	Maxwell	Mx	10^{-8}	Weber	Wb
Flux density	Gamma	γ	10^{-9}	Tesla	T
	Gauss	Gs	10^{-4}		
Magnetic field intensity	Oersted	Oe	$10^3/4\pi$	Ampere per meter	A/m
Electric charge	Coulomb	C	1	Coulomb	C
Electric potential difference	Volt	V	1	Volt	V
Capacitance	Farad	F	1	Farad	F
(Electric) Resistance	Ohm	Ω	1	Ohm	Ω
(Electric) Conductance	Siemens	S	1	Siemens	S
Inductance	Henry	H	1	Henry	H
Current	Ampere	A	1	Ampere	A

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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

● Inch-mm Conversion Table

1 inch=25.4mm

inch		0″	1″	2″	3″	4″	5″	6″	7″	8″
Fractional number	Decimal number									
	0		25.400	50.800	76.200	101.600	127.000	152.400	177.800	203.200
1 / 64″	0.015625	0.397	25.797	51.197	76.597	101.997	127.397	152.797	178.197	203.597
1 / 32″	0.031250	0.794	26.194	51.594	76.994	102.394	127.794	153.194	178.594	203.994
3 / 64″	0.046875	1.191	26.591	51.991	77.391	102.791	128.191	153.591	178.991	204.391
1 / 16″	0.062500	1.588	26.988	52.388	77.788	103.188	128.588	153.988	179.388	204.788
5 / 64″	0.078125	1.984	27.384	52.784	78.184	103.584	128.984	154.384	179.784	205.184
3 / 32″	0.093750	2.381	27.781	53.181	78.581	103.981	129.381	154.781	180.181	205.581
7 / 64″	0.109375	2.778	28.178	53.578	78.978	104.378	129.778	155.178	180.578	205.978
1 / 8″	0.125000	3.175	28.575	53.975	79.375	104.775	130.175	155.575	180.975	206.375
9 / 64″	0.140625	3.572	28.972	54.372	79.772	105.172	130.572	155.972	181.372	206.772
5 / 32″	0.156250	3.969	29.369	54.769	80.169	105.569	130.969	156.369	181.769	207.169
11 / 64″	0.171875	4.366	29.766	55.166	80.566	105.966	131.366	156.766	182.166	207.566
3 / 16″	0.187500	4.762	30.162	55.562	80.962	106.362	131.762	157.162	182.562	207.962
13 / 64″	0.203125	5.159	30.559	55.959	81.359	106.759	132.159	157.559	182.959	208.359
7 / 32″	0.218750	5.556	30.956	56.356	81.756	107.156	132.556	157.956	183.356	208.756
15 / 64″	0.234375	5.953	31.353	56.753	82.153	107.553	132.953	158.353	183.753	209.153
1 / 4″	0.250000	6.350	31.750	57.150	82.550	107.950	133.350	158.750	184.150	209.550
17 / 64″	0.265625	6.747	32.147	57.547	82.947	108.347	133.747	159.147	184.547	209.947
9 / 32″	0.281250	7.144	32.544	57.944	83.344	108.744	134.144	159.544	184.944	210.344
19 / 64″	0.296875	7.541	32.941	58.341	83.741	109.141	134.541	159.941	185.341	210.741
5 / 16″	0.312500	7.938	33.338	58.738	84.138	109.538	134.938	160.338	185.738	211.138
21 / 64″	0.328125	8.334	33.734	59.134	84.534	109.934	135.334	160.734	186.134	211.534
11 / 32″	0.343750	8.731	34.131	59.531	84.931	110.331	135.731	161.131	186.531	211.931
23 / 64″	0.359375	9.128	34.528	59.928	85.328	110.728	136.128	161.528	186.928	212.328
3 / 8″	0.375000	9.525	34.925	60.325	85.725	111.125	136.525	161.925	187.325	212.725
25 / 64″	0.390625	9.922	35.322	60.722	86.122	111.522	136.922	162.322	187.722	213.122
13 / 32″	0.406250	10.319	35.719	61.119	86.519	111.919	137.319	162.719	188.119	213.519
27 / 64″	0.421875	10.716	36.116	61.516	86.916	112.316	137.716	163.116	188.516	213.916
7 / 16″	0.437500	11.112	36.512	61.912	87.312	112.712	138.112	163.512	188.912	214.312
29 / 64″	0.453125	11.509	36.909	62.309	87.709	113.109	138.509	163.909	189.309	214.709
15 / 32″	0.468750	11.906	37.306	62.706	88.106	113.506	138.906	164.306	189.706	215.106
31 / 64″	0.484375	12.303	37.703	63.103	88.503	113.903	139.303	164.703	190.103	215.503
1 / 2″	0.500000	12.700	38.100	63.500	88.900	114.300	139.700	165.100	190.500	215.900

1 inch=25.4mm

inch		0″	1″	2″	3″	4″	5″	6″	7″	8″
Fractional number	Decimal number									
33 / 64″	0.515625	13.097	38.497	63.897	89.297	114.697	140.097	165.497	190.897	216.297
17 / 32″	0.531250	13.494	38.894	64.294	89.694	115.094	140.494	165.894	191.294	216.694
35 / 64″	0.546875	13.891	39.291	64.691	90.091	115.491	140.891	166.291	191.691	217.091
9 / 16″	0.562500	14.288	39.688	65.088	90.488	115.888	141.288	166.688	192.088	217.488
37 / 64″	0.578125	14.684	40.084	65.484	90.884	116.284	141.684	167.084	192.484	217.884
19 / 32″	0.593750	15.081	40.481	65.881	91.281	116.681	142.081	167.481	192.881	218.281
39 / 64″	0.609375	15.478	40.878	66.278	91.678	117.078	142.478	167.878	193.278	218.678
5 / 8″	0.625000	15.875	41.275	66.675	92.075	117.475	142.875	168.275	193.675	219.075
41 / 64″	0.640625	16.272	41.672	67.072	92.472	117.872	143.272	168.672	194.072	219.472
21 / 32″	0.656250	16.669	42.069	67.469	92.869	118.269	143.669	169.069	194.469	219.869
43 / 64″	0.671875	17.066	42.466	67.866	93.266	118.666	144.066	169.466	194.866	220.266
11 / 16″	0.687500	17.462	42.862	68.262	93.662	119.062	144.462	169.862	195.262	220.662
45 / 64″	0.703125	17.859	43.259	68.659	94.059	119.459	144.859	170.259	195.659	221.059
23 / 32″	0.718750	18.256	43.656	69.056	94.456	119.856	145.256	170.656	196.056	221.456
47 / 64″	0.734375	18.653	44.053	69.453	94.853	120.253	145.653	171.053	196.453	221.853
3 / 4″	0.750000	19.050	44.450	69.850	95.250	120.650	146.050	171.450	196.850	222.250
49 / 64″	0.765625	19.447	44.847	70.247	95.647	121.047	146.447	171.847	197.247	222.647
25 / 32″	0.781250	19.844	45.244	70.644	96.044	121.444	146.844	172.244	197.644	223.044
51 / 64″	0.796875	20.241	45.641	71.041	96.441	121.841	147.241	172.641	198.041	223.441
13 / 16″	0.812500	20.638	46.038	71.438	96.838	122.238	147.638	173.038	198.438	223.838
53 / 64″	0.828125	21.034	46.434	71.834	97.234	122.634	148.034	173.434	198.834	224.234
27 / 32″	0.843750	21.431	46.831	72.231	97.631	123.031	148.431	173.831	199.231	224.631
55 / 64″	0.859375	21.828	47.228	72.628	98.028	123.428	148.828	174.228	199.628	225.028
7 / 8″	0.875000	22.225	47.625	73.025	98.425	123.825	149.225	174.625	200.025	225.425
57 / 64″	0.890625	22.622	48.022	73.422	98.822	124.222	149.622	175.022	200.422	225.822
29 / 32″	0.906250	23.019	48.419	73.819	99.219	124.619	150.019	175.419	200.819	226.219
59 / 64″	0.921875	23.416	48.816	74.216	99.616	125.016	150.416	175.816	201.216	226.616
15 / 16″	0.937500	23.812	49.212	74.612	100.012	125.412	150.812	176.212	201.612	227.012
61 / 64″	0.953125	24.209	49.609	75.009	100.409	125.809	151.209	176.609	202.009	227.409
31 / 32″	0.968750	24.606	50.006	75.406	100.806	126.206	151.606	177.006	202.406	227.806
63 / 64″	0.984375	25.003	50.403	75.803	101.203	126.603	152.003	177.403	202.803	228.203

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1mm=0.03937inch

● Hardness Conversion Table (Reference)

Rockwell C scale hardness Load 1471N HRC	Vickers hardness HV	Brinell hardness Standard ball	Brinell hardness Tungsten Carbide ball	Rockwell hardness A scale Load 588.4N Diamond circular cone	Rockwell hardness B scale Load 980.7N Diameter 1/16in ball	Shore hardness HS
68	940	—	—	85.6	—	97
67	900	—	—	85.0	—	95
66	865	—	—	84.5	—	92
65	832	—	(739)	83.9	—	91
64	800	—	(722)	83.4	—	88
63	772	—	(705)	82.8	—	87
62	746	—	(688)	82.3	—	85
61	720	—	(670)	81.8	—	83
60	697	—	(654)	81.2	—	81
59	674	—	(634)	80.7	—	80
58	653	—	615	80.1	—	78
57	633	—	595	79.6	—	76
56	613	—	577	79.0	—	75
55	595	—	560	78.5	—	74
54	577	—	543	78.0	—	72
53	560	—	525	77.4	—	71
52	544	(500)	512	76.8	—	69
51	528	(487)	496	76.3	—	68
50	513	(475)	481	75.9	—	67
49	498	(464)	469	75.2	—	66
48	484	451	455	74.7	—	64
47	471	442	443	74.1	—	63
46	458	432	432	73.6	—	62
45	446	421	421	73.1	—	60
44	434	409	409	72.5	—	58
43	423	400	400	72.0	—	57
42	412	390	390	71.5	—	56
41	402	381	381	70.9	—	55
40	392	371	371	70.4	—	54
39	382	362	362	69.9	—	52

Rockwell C scale hardness Load 1471N HRC	Vickers hardness HV	Brinell hardness Standard ball	Brinell hardness Tungsten Carbide ball	Rockwell hardness A scale Load 588.4N Diamond circular cone	Rockwell hardness B scale Load 980.7N Diameter 1/16in ball	Shore hardness HS
38	372	353	353	69.4	—	51
37	363	344	344	68.9	—	50
36	354	336	336	68.4	(109.0)	49
35	345	327	327	67.9	(108.5)	48
34	336	319	319	67.4	(108.0)	47
33	327	311	311	66.8	(107.5)	46
32	318	301	301	66.3	(107.0)	44
31	310	294	294	65.8	(106.0)	43
30	302	286	286	65.3	(105.5)	42
29	294	279	279	64.7	(104.5)	41
28	286	271	271	64.3	(104.0)	41
27	279	264	264	63.8	(103.0)	40
26	272	258	258	63.3	(102.5)	38
25	266	253	253	62.8	(101.5)	38
24	260	247	247	62.4	(101.0)	37
23	254	243	243	62.0	100.0	36
22	248	237	237	61.5	99.0	35
21	243	231	231	61.0	98.5	35
20	238	226	226	60.5	97.8	34
(18)	230	219	219	—	96.7	33
(16)	222	212	212	—	95.5	32
(14)	213	203	203	—	93.9	31
(12)	204	194	194	—	92.3	29
(10)	196	187	187	—	90.7	28
(8)	188	179	179	—	89.5	27
(6)	180	171	171	—	87.1	26
(4)	173	165	165	—	85.5	25
(2)	166	158	158	—	83.5	24
(0)	160	152	152	—	81.7	24

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1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

● Tolerances of Shaft Dimensions

unit: μm

Classification of diameter mm		b12		c12		d6		e6		e12		f5		f6		g5	
Above	Below	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
—	3	−140	− 240	− 60	− 160	− 20	− 26	− 14	− 20	− 14	−114	− 6	−10	− 6	− 12	− 2	− 6
3	6	−140	− 260	− 70	− 190	− 30	− 38	− 20	− 28	− 20	−140	−10	−15	−10	− 18	− 4	− 9
6	10	−150	− 300	− 80	− 230	− 40	− 49	− 25	− 34	− 25	−175	−13	−19	−13	− 22	− 5	−11
10	18	−150	− 330	− 95	− 275	− 50	− 61	− 32	− 43	− 32	−212	−16	−24	−16	− 27	− 6	−14
18	30	−160	− 370	−110	− 320	− 65	− 78	− 40	− 53	− 40	−250	−20	−29	−20	− 33	− 7	−16
30	40	−170	− 420	−120	− 370	− 80	− 96	− 50	− 66	− 50	−300	−25	−36	−25	− 41	− 9	−20
40	50	−180	− 430	−130	− 380												
50	65	−190	− 490	−140	− 440	−100	−119	− 60	− 79	− 60	−360	−30	−43	−30	− 49	−10	−23
65	80	−200	− 500	−150	− 450												
80	100	−220	− 570	−170	− 520	−120	−142	− 72	− 94	− 72	−422	−36	−51	−36	− 58	−12	−27
100	120	−240	− 590	−180	− 530												
120	140	−260	− 660	−200	− 600	−145	−170	− 85	−110	− 85	−485	−43	−61	−43	− 68	−14	−32
140	160	−280	− 680	−210	− 610												
160	180	−310	− 710	−230	− 630												
180	200	−340	− 800	−240	− 700	−170	−199	−100	−129	−100	−560	−50	−70	−50	− 79	−15	−35
200	225	−380	− 840	−260	− 720												
225	250	−420	− 880	−280	− 740												
250	280	−480	−1000	−300	− 820	−190	−222	−110	−142	−110	−630	−56	−79	−56	− 88	−17	−40
280	315	−540	−1060	−330	− 850												
315	355	−600	−1170	−360	− 930	−210	−246	−125	−161	−125	−695	−62	−87	−62	− 98	−18	−43
355	400	−680	−1250	−400	− 970												
400	450	−760	−1390	−440	−1070	−230	−270	−135	−175	−135	−765	−68	−95	−68	−108	−20	−47
450	500	−840	−1470	−480	−1110												

g6		h5		h6		h7		h8		h9		h10		h11		Classification of diameter mm	
H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	Above	Below
− 2	− 8	0	− 4	0	− 6	0	−10	0	−14	0	− 25	0	− 40	0	− 60	—	3
− 4	−12	0	− 5	0	− 8	0	−12	0	−18	0	− 30	0	− 48	0	− 75	3	6
− 5	−14	0	− 6	0	− 9	0	−15	0	−22	0	− 36	0	− 58	0	− 90	6	10
− 6	−17	0	− 8	0	−11	0	−18	0	−27	0	− 43	0	− 70	0	−110	10	18
− 7	−20	0	− 9	0	−13	0	−21	0	−33	0	− 52	0	− 84	0	−130	18	30
− 9	−25	0	−11	0	−16	0	−25	0	−39	0	− 62	0	−100	0	−160	30	40
																40	50
−10	−29	0	−13	0	−19	0	−30	0	−46	0	− 74	0	−120	0	−190	50	65
																65	80
−12	−34	0	−15	0	−22	0	−35	0	−54	0	− 87	0	−140	0	−220	80	100
																100	120
−14	−39	0	−18	0	−25	0	−40	0	−63	0	−100	0	−160	0	−250	120	140
																140	160
																160	180
−15	−44	0	−20	0	−29	0	−46	0	−72	0	−115	0	−185	0	−290	180	200
																200	225
																225	250
−17	−49	0	−23	0	−32	0	−52	0	−81	0	−130	0	−210	0	−320	250	280
																280	315
−18	−54	0	−25	0	−36	0	−57	0	−89	0	−140	0	−230	0	−360	315	355
																355	400
−20	−60	0	−27	0	−40	0	−63	0	−97	0	−155	0	−250	0	−400	400	450
																450	500

unit: μm

Classification of diameter mm		h12		js5		j5		js6		j6		j7		k5		k6	
Above	Below	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
—	3	0	−100	+ 2	− 2	+2	− 2	+ 3	− 3	+ 4	− 2	+ 6	− 4	+ 4	0	+ 6	0
3	6	0	−120	+ 2.5	− 2.5	+3	− 2	+ 4	− 4	+ 6	− 2	+ 8	− 4	+ 6	+1	+ 9	+1
6	10	0	−150	+ 3	− 3	+4	− 2	+ 4.5	− 4.5	+ 7	− 2	+10	− 5	+ 7	+1	+10	+1
10	18	0	−180	+ 4	− 4	+5	− 3	+ 5.5	− 5.5	+ 8	− 3	+12	− 6	+ 9	+1	+12	+1
18	30	0	−210	+ 4.5	− 4.5	+5	− 4	+ 6.5	− 6.5	+ 9	− 4	+13	− 8	+11	+2	+15	+2
30	40	0	−250	+ 5.5	− 5.5	+6	− 5	+ 8	− 8	+11	− 5	+15	−10	+13	+2	+18	+2
40	50																
50	65	0	−300	+ 6.5	− 6.5	+6	− 7	+ 9.5	− 9.5	+12	− 7	+18	−12	+15	+2	+21	+2
65	80																
80	100	0	−350	+ 7.5	− 7.5	+6	− 9	+11	−11	+13	− 9	+20	−15	+18	+3	+25	+3
100	120																
120	140	0	−400	+ 9	− 9	+7	−11	+12.5	−12.5	+14	−11	+22	−18	+21	+3	+28	+3
140	160																
160	180																
180	200	0	−460	+10	−10	+7	−13	+14.5	−14.5	+16	−13	+25	−21	+24	+4	+33	+4
200	225																
225	250																
250	280	0	−520	+11.5	−11.5	+7	−16	+16	−16	+16	−16	+26	−26	+27	+4	+36	+4
280	315																
315	355	0	−570	+12.5	−12.5	+7	−18	+18	−18	+18	−18	+29	−28	+29	+4	+40	+4
355	400																
400	450	0	−630	+13.5	−13.5	+7	−20	+20	−20	+20	−20	+31	−32	+32	+5	+45	+5
450	500																

m5		m6		n5		n6		p6		Classification of diameter mm	
H	L	H	L	H	L	H	L	H	L	Above	Below
+ 6	+ 2	+ 8	+ 2	+ 8	+ 4	+10	+ 4	+ 12	+ 6	—	3
+ 9	+ 4	+12	+ 4	+13	+ 8	+16	+ 8	+ 20	+12	3	6
+12	+ 6	+15	+ 6	+16	+10	+19	+10	+ 24	+15	6	10
+15	+ 7	+18	+ 7	+20	+12	+23	+12	+ 29	+18	10	18
+17	+ 8	+21	+ 8	+24	+15	+28	+15	+ 35	+22	18	30
+20	+ 9	+25	+ 9	+28	+17	+33	+17	+ 42	+26	30	40
										40	50
+24	+11	+30	+11	+33	+20	+39	+20	+ 51	+32	50	65
										65	80
+28	+13	+35	+13	+38	+23	+45	+23	+ 59	+37	80	100
										100	120
+33	+15	+40	+15	+45	+27	+52	+27	+ 68	+43	120	140
										140	160
										160	180
+37	+17	+46	+17	+51	+31	+60	+31	+ 79	+50	180	200
										200	225
										225	250
+43	+20	+52	+20	+57	+34	+66	+34	+ 88	+56	250	280
										280	315
+46	+21	+57	+21	+62	+37	+73	+37	+ 98	+62	315	355
										355	400
+50	+23	+63	+23	+67	+40	+80	+40	+108	+68	400	450
										450	500

1N=0.102kgf=0.2248lbs.
1mm=0.03937inch

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● Tolerances of Housing Hole Dimensions

unit: μm

Classification of diameter mm		B12		E7		E11		E12		F6		F7		G6		G7	
Above	Below	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
—	3	+ 240	+140	+ 24	+ 14	+ 74	+ 14	+114	+ 14	+ 12	+ 6	+ 16	+ 6	+ 8	+ 2	+12	+ 2
3	6	+ 260	+140	+ 32	+ 20	+ 95	+ 20	+140	+ 20	+ 18	+10	+ 22	+10	+12	+ 4	+16	+ 4
6	10	+ 300	+150	+ 40	+ 25	+115	+ 25	+175	+ 25	+ 22	+13	+ 28	+13	+14	+ 5	+20	+ 5
10	18	+ 330	+150	+ 50	+ 32	+142	+ 32	+212	+ 32	+ 27	+16	+ 34	+16	+17	+ 6	+24	+ 6
18	30	+ 370	+160	+ 61	+ 40	+170	+ 40	+250	+ 40	+ 33	+20	+ 41	+20	+20	+ 7	+28	+ 7
30	40	+ 420	+170	+ 75	+ 50	+210	+ 50	+300	+ 50	+ 41	+25	+ 50	+25	+25	+ 9	+34	+ 9
40	50	+ 430	+180														
50	65	+ 490	+190	+ 90	+ 60	+250	+ 60	+360	+ 60	+ 49	+30	+ 60	+30	+29	+10	+40	+10
65	80	+ 500	+200														
80	100	+ 570	+220	+107	+ 72	+292	+ 72	+422	+ 72	+ 58	+36	+ 71	+36	+34	+12	+47	+12
100	120	+ 590	+240														
120	140	+ 660	+260	+125	+ 85	+335	+ 85	+485	+ 85	+ 68	+43	+ 83	+43	+39	+14	+54	+14
140	160	+ 680	+280														
160	180	+ 710	+310														
180	200	+ 800	+340	+146	+100	+390	+100	+560	+100	+ 79	+50	+ 96	+50	+44	+15	+61	+15
200	225	+ 840	+380														
225	250	+ 880	+420														
250	280	+1000	+480	+162	+110	+430	+110	+630	+110	+ 88	+56	+108	+56	+49	+17	+69	+17
280	315	+1060	+540														
315	355	+1170	+600	+182	+125	+485	+125	+695	+125	+ 98	+62	+119	+62	+54	+18	+75	+18
355	400	+1250	+680														
400	450	+1390	+760	+198	+135	+535	+135	+765	+135	+108	+68	+131	+68	+60	+20	+83	+20
450	500	+1470	+840														

H6		H7		H8		H9		H10		H11		JS6		J6		Classification of diameter mm	
H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L	Above	Below
+ 6	0	+10	0	+14	0	+ 25	0	+ 40	0	+ 60	0	+ 3	− 3	+ 2	−4	—	3
+ 8	0	+12	0	+18	0	+ 30	0	+ 48	0	+ 75	0	+ 4	− 4	+ 5	−3	3	6
+ 9	0	+15	0	+22	0	+ 36	0	+ 58	0	+ 90	0	+ 4.5	− 4.5	+ 5	−4	6	10
+11	0	+18	0	+27	0	+ 43	0	+ 70	0	+110	0	+ 5.5	− 5.5	+ 6	−5	10	18
+13	0	+21	0	+33	0	+ 52	0	+ 84	0	+130	0	+ 6.5	− 6.5	+ 8	−5	18	30
+16	0	+25	0	+39	0	+ 62	0	+100	0	+160	0	+ 8	− 8	+10	−6	30	40
																40	50
+19	0	+30	0	+46	0	+ 74	0	+120	0	+190	0	+ 9.5	− 9.5	+13	−6	50	65
																65	80
+22	0	+35	0	+54	0	+ 87	0	+140	0	+220	0	+11	−11	+16	−6	80	100
																100	120
+25	0	+40	0	+63	0	+100	0	+160	0	+250	0	+12.5	−12.5	+18	−7	120	140
																140	160
																160	180
+29	0	+46	0	+72	0	+115	0	+185	0	+290	0	+14.5	−14.5	+22	−7	180	200
																200	225
																225	250
+32	0	+52	0	+81	0	+130	0	+210	0	+320	0	+16	−16	+25	−7	250	280
																280	315
+36	0	+57	0	+89	0	+140	0	+230	0	+360	0	+18	−18	+29	−7	315	355
																355	400
+40	0	+63	0	+97	0	+155	0	+250	0	+400	0	+20	−20	+33	−7	400	450
																450	500

unit: μm

Classification of diameter mm		JS7		J7		K5		K6		K7		M6		M7		N6	
Above	Below	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
—	3	+ 5	− 5	+ 4	− 6	0	− 4	0	− 6	0	−10	− 2	− 8	−2	−12	− 4	−10
3	6	+ 6	− 6	+ 6	− 6	0	− 5	+2	− 6	+ 3	− 9	− 1	− 9	0	−12	− 5	−13
6	10	+ 7	− 7	+ 8	− 7	+1	− 5	+2	− 7	+ 5	−10	− 3	−12	0	−15	− 7	−16
10	18	+ 9	− 9	+10	− 8	+2	− 6	+2	− 9	+ 6	−12	− 4	−15	0	−18	− 9	−20
18	30	+10	−10	+12	− 9	+1	− 8	+2	−11	+ 6	−15	− 4	−17	0	−21	−11	−24
30	40	+12	−12	+14	−11	+2	− 9	+3	−13	+ 7	−18	− 4	−20	0	−25	−12	−28
40	50																
50	65	+15	−15	+18	−12	+3	−10	+4	−15	+ 9	−21	− 5	−24	0	−30	−14	−33
65	80																
80	100	+17	−17	+22	−13	+2	−13	+4	−18	+10	−25	− 6	−28	0	−35	−16	−38
100	120																
120	140	+20	−20	+26	−14	+3	−15	+4	−21	+12	−28	− 8	−33	0	−40	−20	−45
140	160																
160	180																
180	200	+23	−23	+30	−16	+2	−18	+5	−24	+13	−33	− 8	−37	0	−46	−22	−51
200	225																
225	250																
250	280	+26	−26	+36	−16	+3	−20	+5	−27	+16	−36	− 9	−41	0	−52	−25	−57
280	315																
315	355	+28	−28	+39	−18	+3	−22	+7	−29	+17	−40	−10	−46	0	−57	−26	−62
355	400																
400	450	+31	−31	+43	−20	+2	−25	+8	−32	+18	−45	−10	−50	0	−63	−27	−67
450	500																

N7		P6		P7		R7		S7		Classification of diameter mm	
H	L	H	L	H	L	H	L	H	L	Above	Below
− 4	−14	− 6	−12	− 6	− 16	− 10	− 20	− 14	− 24	—	3
− 4	−16	− 9	−17	− 8	− 20	− 11	− 23	− 15	− 27	3	6
− 4	−19	−12	−21	− 9	− 24	− 13	− 28	− 17	− 32	6	10
− 5	−23	−15	−26	−11	− 29	− 16	− 34	− 21	− 39	10	18
− 7	−28	−18	−31	−14	− 35	− 20	− 41	− 27	− 48	18	30
− 8	−33	−21	−37	−17	− 42	− 25	− 50	− 34	− 59	30	40
										40	50
− 9	−39	−26	−45	−21	− 51	− 30	− 60	− 42	− 72	50	65
						− 32	− 62	− 48	− 78	65	80
−10	−45	−30	−52	−24	− 59	− 38	− 73	− 58	− 93	80	100
						− 41	− 76	− 66	− 101	100	120
−12	−52	−36	−61	−28	− 68	− 48	− 88	− 77	−117	120	140
						− 50	− 90	− 85	−125	140	160
						− 53	− 93	− 93	−133	160	180
−14	−60	−41	−70	−33	− 79	− 60	−106	−105	−151	180	200
						− 63	−109	−113	−159	200	225
						− 67	−113	−123	−169	225	250
−14	−66	−47	−79	−36	− 88	− 74	−126	−138	−190	250	280
						− 78	−130	−150	−202	280	315
−16	−73	−51	−87	−41	− 98	− 87	−144	−169	−226	315	355
						− 93	−150	−187	−244	355	400
−17	−80	−55	−95	−45	−108	−103	−166	−209	−272	400	450
						−109	−172	−229	−292	450	500

1N=0.102kgf=0.2248lbs.
1mm=0.03937inch