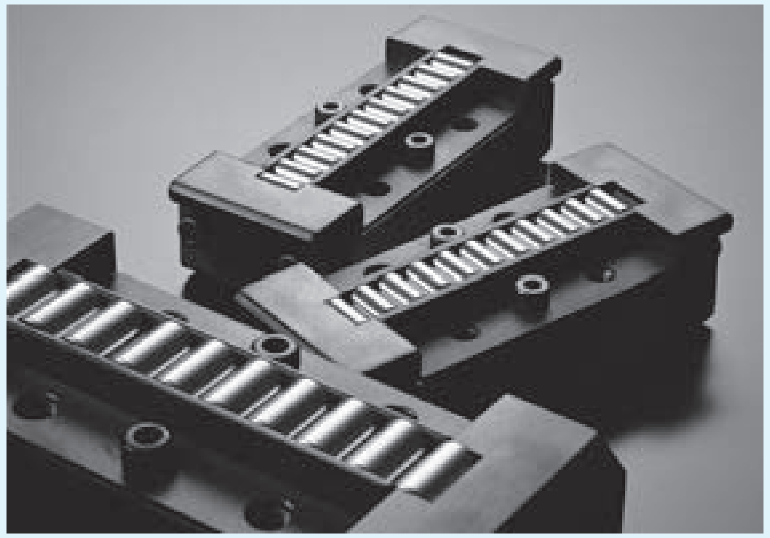

General Explanation

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 [1] 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.

Note [1] Stroke Rotary Bushing is represented as total number of rotations.

Basic dynamic load rating C

Basic dynamic load rating refers to load with certain direction and size that is logically endurable for rating life indicated in Table 1 when a group of the same linear motion rolling guides is operated individually under the same conditions.

Table 1 Load rating

Series	Rating life
Crossed Roller Way Roller Way & Flat Roller Cage	100×10^3m
Linear Slide Unit Linear Ball Spline Linear Bushing	50×10^3m
Stroke Rotary Bushing	10^6 rotations

Basic static load rating C_0

Basic static load rating refers to static load generating a certain contact stress at the center of contact parts 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.

Allowable load F

Allowable load refers to load of smooth rolling motion on contact surface to which maximum contact stress is applied and the sum of whose elastic deformation of rolling elements and raceway is small.
Therefore, use applied load within the allowable load range if very smooth rolling motion and high accuracy are required.

Dynamic torque rating T

Dynamic torque rating refers to a torque with a certain direction and size with which 90% of a group of the same linear ball splines can run 50 x 10^3m without material damages due to rolling contact fatigue when they are operated individually.

Static torque rating T_0
Static moment rating T_0, T_X, T_Y

Static torque rating and static moment rating refer to static torque or moment load generating a certain level of contact stress at the center of contact parts of rolling elements and a raceway under the maximum load, which is the torque or moment load (see Fig. 1) are loaded, which is the torque or moment load at the allowable limit for normal rolling motion. Generally, it is used considering static safety factor.

Load direction and load rating

Linear motion rolling guide is used with its load rating corrected in accordance to the load direction. Basic dynamic load rating and basic static load rating indicated in the dimension table should be corrected before use. As the values to be corrected vary depending on series, please see an explanation for each series.

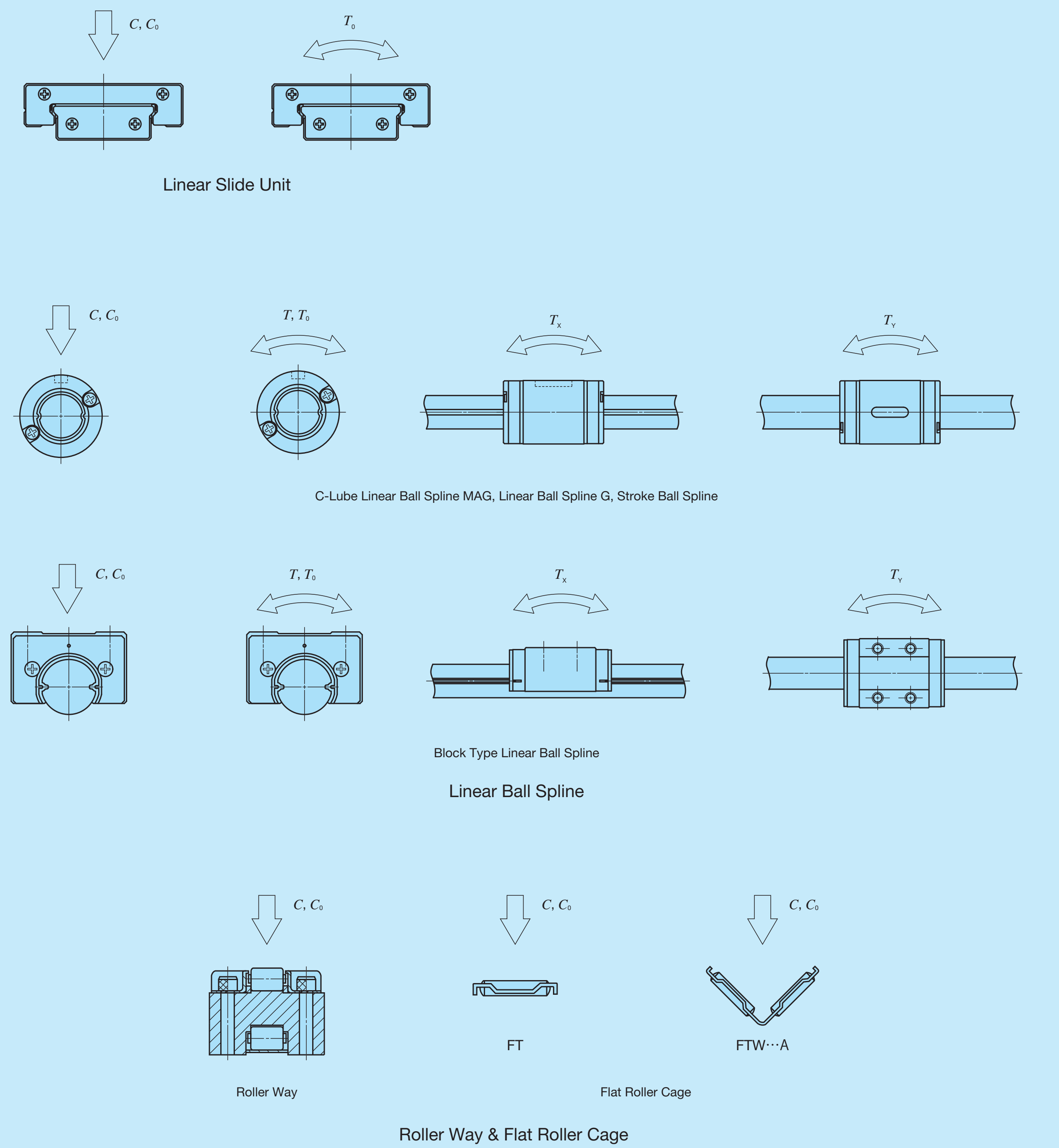

Fig. 1 Direction of load rating, torque rating, and moment load

Remark: For the cases of Crossed Roller Way and Linear Bushing, see an explanation of each series.

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

Calculating formula of life

Rating life and basic dynamic load rating of a linear motion rolling guide are correlated as indicated in Table 2.1 and Table 2.2.

Table 2.1 Calculating formula of life for each series

Series	Calculating formula of rating life: Total traveling distance 10^3 m	Calculating formula of rating life: Life length h	Code description
Crossed Roller Way Roller Way & Flat Roller Cage	$L=100\left(\frac{C}{P}\right)^{\frac{10}{3}}$	$L_h=\frac{10^6 L}{2Sn_1\times 60}$	L : Rating life, 10^3 m C : Basic dynamic load rating, N T : Dynamic torque rating, N·m P : Dynamic equivalent load (or applied load), N M : Applied torque N·m L_h : Rating life in hours h S : Stroke length mm n_1 : Number of strokes per minute cpm
Linear Slide Unit Linear Bushing	$L=50\left(\frac{C}{P}\right)^3$		
Linear Ball Spline	$L=50\left(\frac{C}{P}\right)^3$ $L=50\left(\frac{T}{M}\right)^3$		

Table 2.2 Calculating formula of life for Stroke Rotary Bushing

Series	Calculating formula of rating life: Total number of rotation 10^6 rotations	Calculating formula of rating life: Life length h	Code description
Rotational motion	$L=\left(\frac{C}{P}\right)^3$	$L_h=\frac{10^6 L}{60\sqrt{(D_{PW}\,n)^2+(10Sn_1)^2}/D_{PW}}$	L : Rating life, 10^6 rotations C : Basic dynamic load rating, N P : Applied load N L_h : Rating life in hours h n : Rotational speed rpm n_1 : Number of strokes per minute cpm S : Stroke length mm D_{PW} : Pitch circle diameter of balls mm ($D_{PW}\fallingdotseq 1.15F_w$) F_w : Inscribed circle diameter mm
Rotational and rotary compound motion			
Rotary and linear motion		$L_h=\frac{10^6 L}{600Sn_1/(\pi D_{PW})}$	

Temperature factor

As the allowable contact stress is decreased at operating temperature above 150°C, the basic dynamic load rating should be corrected by the following equation:

$$C_t=f_t\,C \quad\cdots\cdots(1)$$

where, C_t : Basic dynamic load rating taking into account temperature increase, N
f_t : Temperature factor (see Fig. 2)
C : Basic dynamic load rating, N

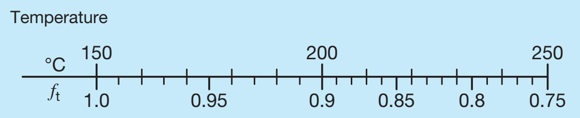

Fig. 2 Temperature factor

Hardness factor

Hardness of a raceway must be 58 to 64 HRC. When it is lower than 58 HRC, correct basic dynamic load rating by the following equation:

$$C_H=f_H\,C \quad\cdots\cdots(2)$$

where, C_H : Basic dynamic load rating taking into account the hardness, N
f_H : Hardness factor (see Fig. 3)
C : Basic dynamic load rating, N

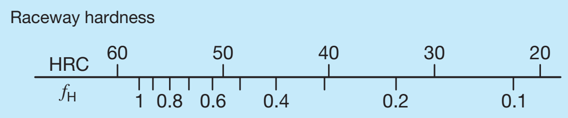

Fig. 3 Hardness factor

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 3.

Table 3 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 (or static torque 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 Table 4.

Equation (4) is a representative equation for moment load or torque. Static moment rating and maximum moment load in each direction is applied for the calculation.

$$f_S=\frac{C_0}{P_0} \quad\cdots\cdots(3)$$

$$f_S=\frac{T_0}{M_0} \quad\cdots\cdots(4)$$

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

Table 4 Static safety factor

Series	Operational condition and static safety factor: Operation with vibration and/or shock	Operational condition and static safety factor: High operating performance	Operational condition and static safety factor: Normal operating conditions
Crossed Roller Way	4 ～6	3～5	2.5～3
Linear Slide Unit	3 ～5	2～4	1 ～3
Linear Ball Spline	5 ～7	4～6	3 ～5
Linear Bushing	2.5	2	1.5
Stroke Rotary Bushing	2.5	2	1.5
Roller Way & Flat Roller Cage	4 ～6	3～5	2.5～3

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.4)

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.

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.

Linear Bushing and Stroke Rotary Bushing should never be given a large amount of preload.

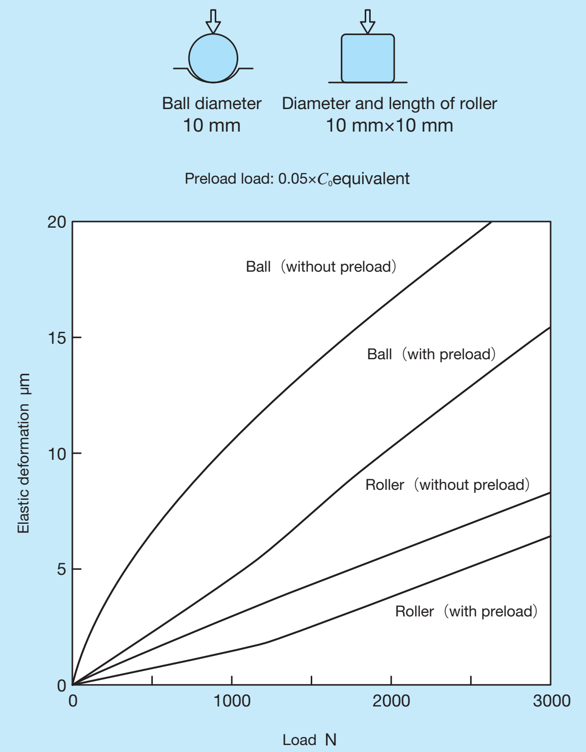

Figure 4 Preload and elastic deformation behavior

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

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.

$$F = \mu P \quad \cdots\cdots (3)$$

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 motion rolling guide in operation are within the range shown in Table 5. Generally, friction coefficient is large under small load.

Table 5 Friction coefficient

Series name	Dynamic friction coefficient μ (1)
Crossed Roller Way	0.0010~0.0030
Linear Slide Unit	0.0010~0.0020
Linear Ball Spline	0.0020~0.0040
Linear Bushing	0.0020~0.0030
Stroke Rotary Bushing	0.0006~0.0012
Roller Way	0.0020~0.0040
Flat Roller Cage	0.0010~0.0030

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 6 Pre-packed grease list

Series name	Pre-packed grease
C-Lube Linear Ball Spline MAG Linear Ball Spline G	Alvania EP Grease 2 [SHOWA SHELL SEKIYU K. K.]
Block Type Linear Ball Spline	MULTEMP PS No.2 [KYODO YUSHI CO., LTD.]

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 for10 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.

Table 7 Grease brands used in linear motion rolling guide

Brand		Base oil	Thickener	Range of operating temperature (2) ℃	Usage
Alvania EP Grease 2	[SHOWA SHELL SEKIYU K. K.]	Mineral oil	Lithium	−20~110	General application with extreme-pressure additive
Alvania Grease S2	[SHOWA SHELL SEKIYU K. K.]	Mineral oil	Lithium	−25~120	General application
Multemp PS No.2	[KYODO YUSHI CO., LTD.]	Synthetic oil, Mineral oil	Lithium	−50~130	General application
IKO Low Dust-Generation Grease for Clean Environment CG2	[NIPPON THOMPSON CO., LTD.]	Synthetic oil	Urea	−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	−30~120	For clean environment Low sliding
DEMNUM™ Grease L-200 (1)	[DAIKIN INDUSTRIES, LTD.]	Synthetic oil	Ethylene tetra-fluoride	−60~300	For clean environment
FOMBLIN® Y-VAC3 (1)	[SOLVAY SOLEXIS]	Synthetic oil	Ethylene tetra-fluoride	−20~250	For vacuum
IKO Anti-Fretting Grease AF2	[NIPPON THOMPSON CO., LTD.]	Synthetic oil	Urea	−50~170	Fretting-proof
6459 Grease N	[SHOWA SHELL SEKIYU K. K.]	Mineral oil	Poly-urea	−	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 1. FOMBLIN® is a registered trademark of SOLVAY SOLEXIS.
2. Check with the chosen grease manufacturer's catalog before use.
For grease for use other than listed, contact IKO.

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.

Lubrication part "C-Lube"

C-Lube Linear Ball Spline MAG has built-in 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), not to the spline shaft. When the balls have contact with C-Lube built in the external cylinder, lubrication oil is supplied to the surface of the balls. As the steel balls 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 steel balls by surface tension in the contact of C-Lube surface and steel balls.